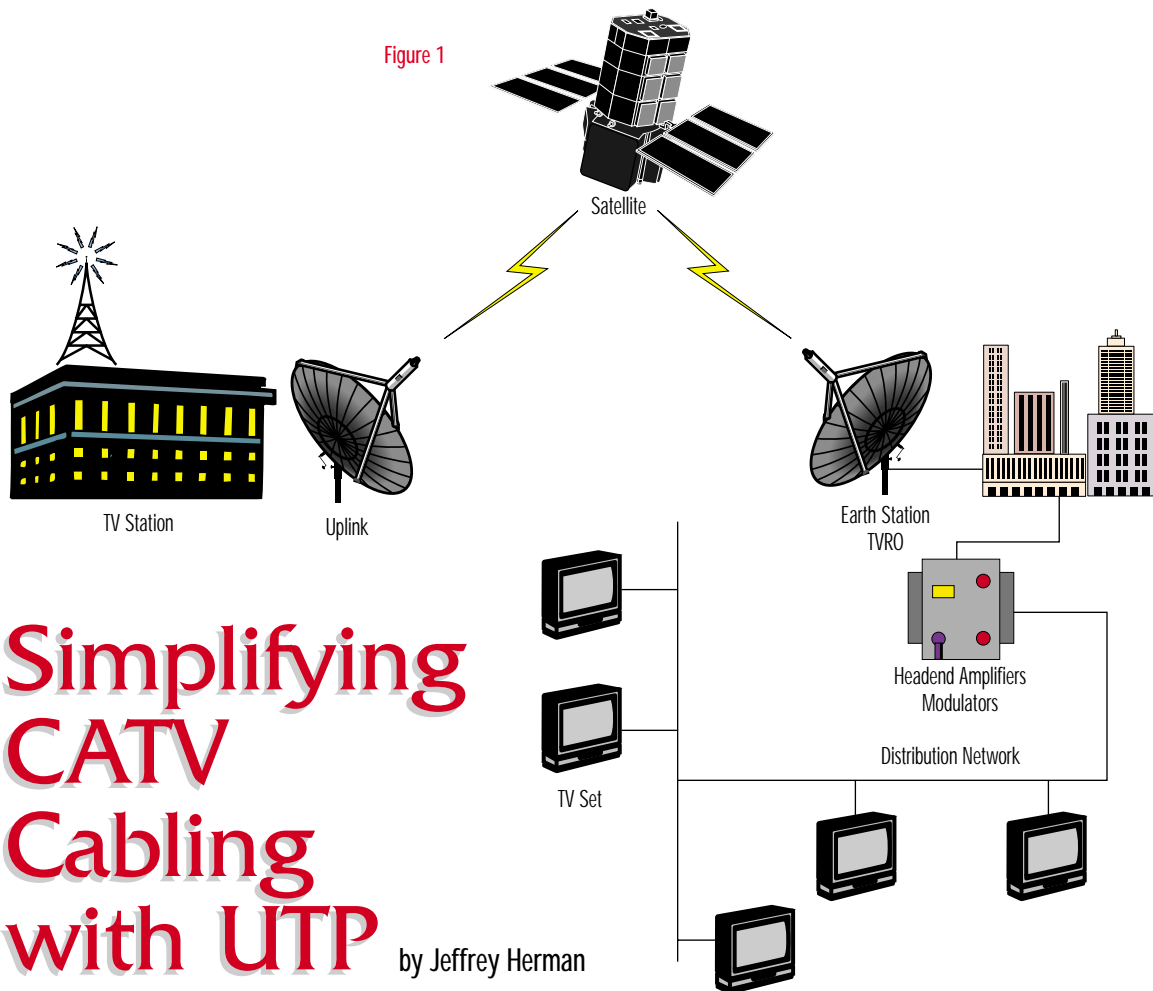


Figure 1



# Simplifying CATV Cabling with UTP

by Jeffrey Herman



STRUCTURED  
CABLING  
SYSTEMS

One of the largest untapped markets for structured cabling is community antenna television or cable television (CATV). It is estimated that there are over 60 million cable TV subscribers in the United States alone. CATV is comprised of multiple TV channels transmitted over a single cable, with each channel occupying a different frequency range. Several hundred video channels may be carried over a single cable. CATV originates at the television station and is distributed via land-based or satellite transmitters.

## Problem

Frequently, CATV connections must be distributed to multiple locations within a building. For example, a financial institution may want to provide access to business TV channels at several locations on the trading floor, or a school might want to distribute educational television to its classrooms. According to traditional CATV cabling techniques, a complex array of coax-

based equipment is needed. With recent developments in cabling and balun technology, it is possible to apply structured cabling techniques to CATV in certain applications for greater ease of management.

This article will explain the basic cabling topology of CATV and show how, in certain applications, CATV may be distributed via a structured cabling system based on unshielded twisted pair (UTP) cable, resulting in flexible moves, adds and changes (MACs), centralized management and better organized wiring.

## CATV Overview

In order to understand the CATV cabling problem, it is necessary to first have an overview of a CATV system. There are four main elements in a CATV system, as illustrated in Figure 1: an uplink, earth station, headend and distribution network.

The uplink sends TV programming signals to satellites for relay

back to earth.

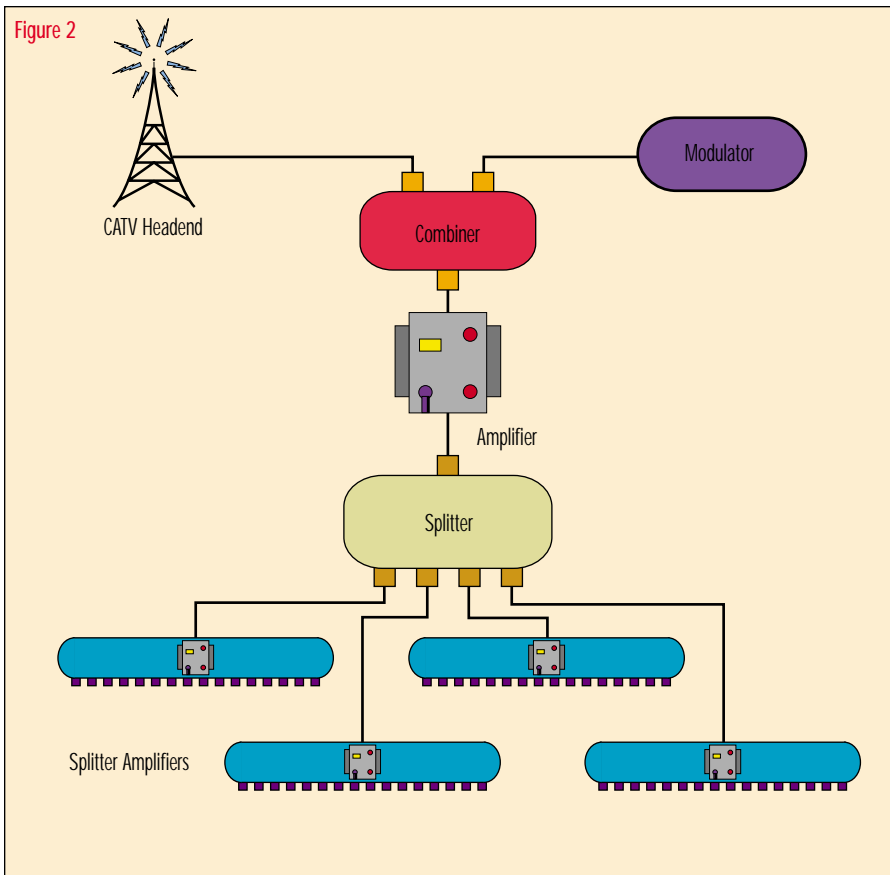
The earth station receives the satellite signals via an antenna known as a TVRO (television receive only). Earth stations are located throughout the cable system and receive programming from dozens of services like MTV, ESPN and HBO.

The control center of a cable television system is known as the headend. The headend receives incoming signals from satellites, television antennas and locally produced programs. It amplifies, converts, processes, combines and transmits these signals to its subscribers.

The distribution network is the system of copper and fiber optic cable used by the cable operator to deliver CATV to its subscribers. The first stage is the trunk line system, connecting the headend to the main amplifiers or fiber optic nodes. The next stage is the feeder system that carries the signals to individual neighborhoods.

The last stop in the CATV distrib-

Figure 2



Circle Reader Card #144

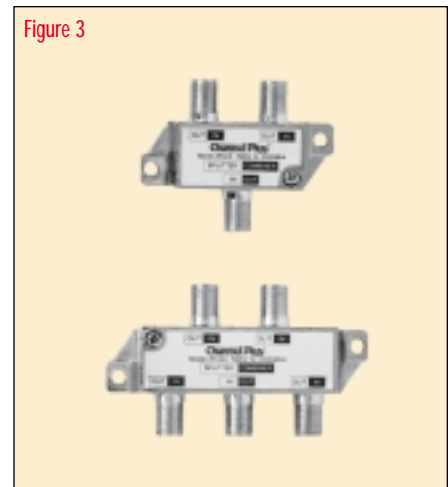
ution system is the drop line. The drop line is the network of coaxial cables that connects the feeder trunk to individual subscribers within a building or campus. This article focuses on this area.

### Traditional Cabling Approach to CATV

In order to understand how structured cabling techniques may be applied to CATV, it is necessary to understand how CATV is traditionally cabled in a building.

CATV enters the building either via

Figure 3



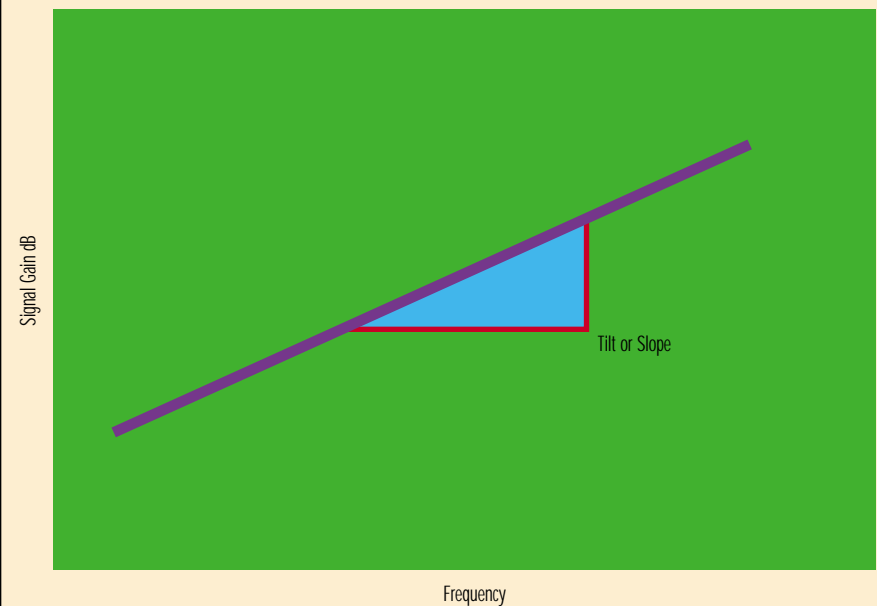
Circle Reader Card #145

cables managed by the CATV operator or via satellite and RF (radio frequency) antennas located on the premises. The type of cable used to distribute cable TV within a building is traditionally 75-ohm RG-6 or RG-11 coaxial cable that is terminated with F-connectors. The CATV feed is distributed to other parts of the building by RF splitters (Figure 2).

An RF splitter divides the signal into two or more outputs and, in the process, reduces the power of the original signal. If the signal is divided in two, the signal power at each output is half the original signal. If the signal is divided four ways, the signal strength is reduced to one-fourth the original signal. Figure 3 shows a typical two- and four-port splitter.

In order to compensate for signal loss due to splitters and lengthy cable runs, amplifiers are placed upstream from the splitters. Amplifiers increase signal power. The ratio by which the signal power is increased is known as gain and is measured in decibels (dBmV). Signal power loss is greater at higher frequencies than at lower frequencies. To compensate for this difference, the amount of amplification must be higher at the higher frequencies than at the lower frequencies.

Figure 4



The rate at which amplification is increased in relation to frequency is known as the tilt or slope (Figure 4).

Amplifiers with built-in tilt are known as tilt-gain amplifiers. Figure 5 shows a typical tilt-gain amplifier integrated with a

16-port RF splitter.

In certain applications, it is necessary to add baseband signals such as VCR or CCTV (closed circuit television) camera signal to a CATV network so they may be viewed from any TV set. An RF modulator

Figure 5



Figure 6



makes this possible. An RF modulator converts a baseband signal to an RF signal and transmits it over the CATV network. Figure 6 shows a typical RF modulator.

On short cable runs, an amplifier may overdrive a TV set at the lower frequency channels, necessitating the use of a signal attenuator. A signal attenuator is connected in-line with the CATV cable to reduce signal strength before it reaches the TV set.

### CATV Cabling: A Structured Cabling Approach

In certain applications, segments of coaxial cable may be replaced by UTP in a CATV network to allow equipment to be moved to any convenient modular outlet. Moves and changes are made on the fly and with the cabling already in place, substantial time and cost savings are realized.

In order to apply structured cabling techniques to CATV cabling, a reliable means of converting the video signal to UTP is needed. The CATV balun is the essential link. A CATV balun is a passive adapter that converts the CATV signal from RG-6 coax to UTP. Unlike baluns used in data networks, a CATV balun

must provide clear picture quality with-in specified distances. UTP cable attenuates the signal more than coax cable and, therefore, amplification is needed to compensate for the signal loss. Furthermore, higher frequency channels require more amplification because they attenuate faster than lower frequency channels.

Maximum Distance via UTP for a Home Run Connection

Proper cable planning requires that one knows how far the TV set can be located from the CATV feed and achieve acceptable audio/video picture quality. (See Figure 7.)

The maximum achievable distance between the CATV feed and the TV set via UTP is based on several factors:

- Input signal level (dBmV at the given channel frequency)
- CATV balun loss (dBmV per balun pair at the given channel frequency)
- Cable loss per meter (dBmV/m at the given channel frequency) for UTP. The grade of cable used is important. The minimum grade recommended is Category 5.
- Required signal level at the TV set

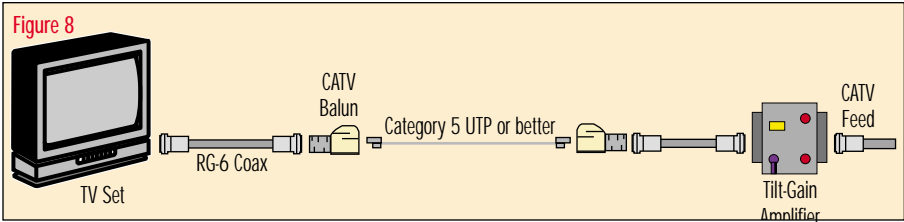
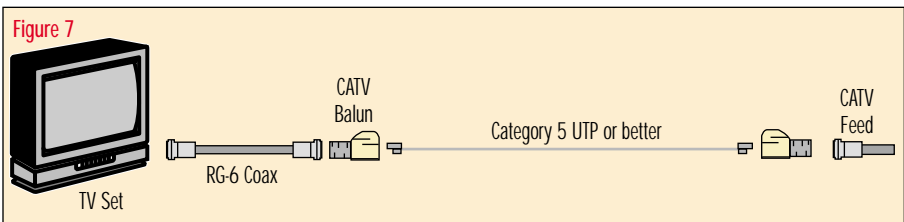


Table 1

Maximum Distance at Higher Frequency Channels (i.e.; Channel 61)	
Input Signal Level	30 dBmV
CATV Balun Loss Per Pair at Channel 61	3 dBmV
Required Signal at TV	10 dBmV
Cable Loss at Channel 61 (445.25 MHz)	0.45 dB/m
Max. UTP Cable Length	38 m
Maximum Distance at Lower Frequency Channels (i.e.; Channel 2)	
Input Signal Level	30 dBmV
CATV Balun Loss Per Pair at Channel 2	3 dBmV
Required Video Signal at TV	10 dBmV
Cable Loss at Channel 2 (55.25 MHz)	0.15 dB/m
Max. UTP Cable Length	113 m

Table 2

**Amplification at Higher Frequency Channels (i.e.; Channel 61)**

For example, to determine how much amplification is needed at Channel 61 (445 MHz):

Input Signal Level	10 dBmV
Required Signal Level at TV Set	10 dBmV
Channel Frequency at TV Set	445 MHz
Required Length of UTP	50 m
CATV Balun Loss Per Pair	3 dBmV
Cable Loss Per Meter	.45 dBmV/m
Amplification at 445 MHz = $10 + 3 + (.45 * 50) - 10$	25.5 dBmV

**Amplification at Lower Frequency Channels (i.e.; Channel 2)**

For example, to determine how much amplification is needed at Channel 2 (55.25 MHz):

Input Signal Level	10 dBmV
Required Signal Level at TV Set	10 dBmV
Channel Frequency at TV Set	55.25 MHz
Required Length of UTP	50 m
CATV Balun Loss Per Pair	3 dBmV
Cable Loss Per Meter	.15 dBmV/m
Amplification at 55.25 MHz = $10 + 3 + (.15 * 50) - 10$	10.5 dBmV

**In order to apply structured cabling techniques to CATV cabling, a reliable means of converting the video signal to UTP is needed. The CATV balun is the essential link.**

(dBmV at the given channel frequency)  
Without getting too technical, the basic formula to estimate the maximum achievable distance for a given signal level at a given channel frequency is as follows:

$$[\text{maximum distance}] =$$

$$\frac{[(\text{input signal level}) - [\text{CATV balun loss}] - [\text{required signal level at TV set}]]}{[\text{cable loss per meter}]}$$

$$[\text{cable loss per meter}]$$

Examples are shown in Table 1.

### Amplification Needed in a Home Run CATV Connection

Amplification may be needed to compensate for losses due to the UTP cable and other components. More amplification is needed at the higher frequency channels than at the lower ones. (See Figure 8.)

In order to determine how much amplification is needed at the higher and lower frequencies respectively, calculate the total signal loss between the CATV feed and the TV set. The values needed in order to make the calculation are as follows:

- Input signal level (dBmV at the given channel frequency)
- CATV balun loss (dBmV per balun pair at the given channel frequency)
- Cable loss per meter (dBmV/m at the

given channel frequency)

- Required length of UTP (meters)
- Required signal level at the TV set (dBmV at the given channel frequency)

$$[\text{amplification needed at given channel frequency}] =$$

$$[\text{required signal level at TV set}] + [\text{CATV balun loss}] + \{[\text{cable loss per meter}] \times [\text{required length of UTP}]\} - [\text{input signal level}]$$

Once the amplification at the high and low frequencies is known, the amount of amplifier tilt can be determined. Based on

the two calculations shown in Table 2, the amount of tilt needed is as follows:

$$\text{tilt} =$$

$$\text{amplification at high frequency} - \text{amplification at low frequency}$$

$$\text{Ex.: } = 28.5 \text{ dBmV} - 10.5 \text{ dBmV} = 18 \text{ dBmV}$$

Therefore, the amplifier in this case should provide 25.5 dBmV amplification at 445 MHz with a tilt of 18 dBmV over the frequency range. Some amplifiers have fixed tilt-gain. Others have

Table 3

RF Splitter	Loss
1-to-2 CATV Coax Splitter	3.5 dBmV
1-to-3 CATV Coax Splitter	5.5 dBmV
1-to-4 CATV Coax Splitter	7.0 dBmV
1-to-8 CATV Coax Splitter	11.0 dBmV

Figure 9

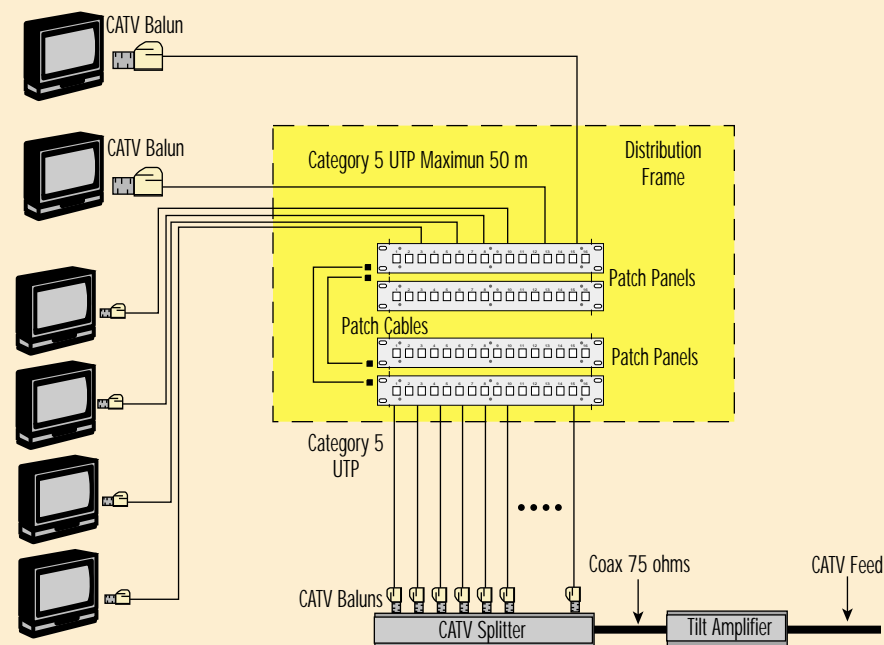
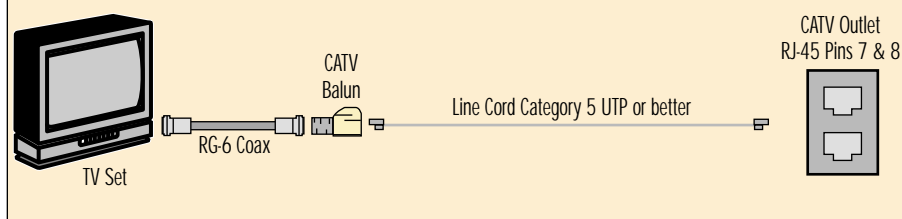
**Structured Cabling for CATV**

Figure 10



adjustable tilt-gain. In the example above, one could use an amplifier operating in the 40 MHz -1 GHz range, providing a gain of up to 35 dBmV with a tilt control of up to 20 dBmV.

Additional signal losses are introduced when RF splitters are used to distribute CATV to different parts of a building. These losses must be accounted for when planning a CATV cabling system. Table 3 shows typical signal losses for RF splitters.

### When To Add A Signal Attenuator On A CATV Home Run

Sometimes, the signal strength at the TV set is too high and may overdrive the TV. This may occur for TV sets operating on the lower frequency channels at short distances. If so, a signal attenuator may be needed to reduce the signal. Signal attenuators come in various sizes. For example, two 3 dBmV attenuators connected in series will provide 6 dBmV of attenuation. Consult the CATV equipment vendor to determine what the maximum allowable signal power is for the TV set.

### CATV Distribution Equipment in an SCS

One of the main benefits of applying structured cabling to CATV is for quicker moves, adds and changes. CATV distribution equipment should be placed in locations that will maximize distance performance of the CATV cabling system. RF splitters and amplifiers should be installed near the horizontal wiring closet with CATV baluns connected to the CATV feed or splitters. Patch panels or 110 blocks are used to manage the cross-connections between the RF splitters and modular TV outlets as shown in Figure 9.

It is advisable to place an amplifier at the headend and in front of each splitter. At the TV end, a CATV balun is connected to each TV. A UTP line cord with straight-through pinning makes the connection between the TV set and the outlet (Figure 10).

CATV baluns require one-pair UTP and typically pins 7 and 8 are active on an 8-pin modular jack (RJ-45). In order to determine what maximum distances will

Figure 11

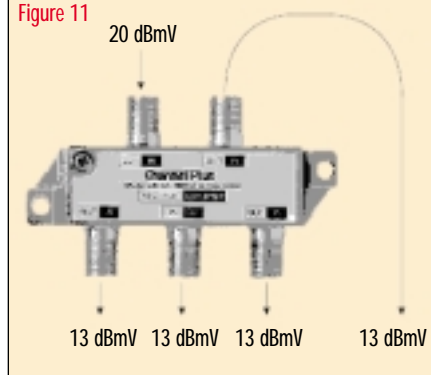


Figure 12



Table 4 UTP Loss vs. Frequency—Category 5e Typical

Frequency (MHz)	Max. Attenuation (dB/m)
31.25	.11
62.5	.15
100	.20
155	.25
200	.29
250	.33
300	.37
350	.40
400	.43
450	.46
500	.49
550	.52

be allowed, the planning of a CATV structured cabling system must include which TV channels are needed at each TV set.

### Support for Cable Modems

Cable modems allow Internet, telephony and CATV services to be offered via the existing CATV cabling infrastructure. The ability to support cable modem service via UTP depends on the performance of the CATV balun that converts the CATV

coax cable to UTP. A typical CATV balun has an operating frequency of 5 MHz to 550 MHz. Cable modem applications are supported via UTP providing the following conditions are met:

1. The downstream data channel lies within the operating frequency range of the CATV balun.
2. The upstream data channel lies within the operating frequency range of the CATV balun.
3. All data channels are able to tolerate the added signal loss introduced by the baluns and UTP.

### FCC Compliance

At high frequencies, EMI (electromagnetic interference) emissions are more significant due to the fact that when a CATV signal is amplified and sent through an RF splitter, the total EMI emission at the output of the splitter is approximately the sum of the EMI emissions at each output port. For example, if a 20 dBmV CATV signal enters a 1 to 4 RF splitter, the total EMI emission level at the output of the splitter will be based on the total output signal power from all four ports (Figure 11). In this case, assuming a 7 dBmV loss per port, the total signal output power for the four ports would be 52 dB. Contact the FCC for more information.

### UTP Losses

The main factor in determining the maximum achievable distance is signal attenuation of the UTP cable. The minimum grade of cable recommended for CATV applications is Category 5. Some vendors offer cable that surpasses Category 5 standards. Table 4 shows attenuation loss versus frequency for a typical vendor's enhanced Category 5 UTP.

### Elements of a CATV Balun

The CATV balun is the essential link in a structured CATV cabling system. A CATV balun contains miniature impedance-matching transformers that convert the unbalanced CATV signal to a balanced signal over a wide frequency spectrum. Due to the bandwidth limitation of the balun, a CATV balun supports only some of the available CATV channels. A typical CATV balun has a bandwidth of 550 MHz. Channel 61 is a typical upper limit in North America for cabling via UTP.

**CATV BALUNS DIFFER FROM DATA BALUNS.** If a data balun is inferior, the user may never be aware of it. However, if a CATV balun is inferior, the result will be seen immediately in the poor picture



quality on the TV screen. Before deciding which CATV balun to use, check the vendor specifications and do a pilot test at the maximum distance and highest channel.

**VIDEO QUALITY AT MAXIMUM DISTANCE.** The picture quality is the litmus test for the quality of the video balun. Look for a balun that gives the best video image at the maximum distance. The baluns should be able to support distances of at least 50 m at the higher channels and 100 m at the lower channels.

**INSERTION LOSS.** The typical insertion loss for a CATV balun should be no more than 3 dBmV per pair at the higher frequencies.

**BANDWIDTH.** The bandwidth of the CATV balun should be at least 550 MHz,

kinks in the cables.

2. Keep cabling away from sources of electromagnetic interference such as fluorescent lights, transformers, radio transmitters and power cables.
3. In order to minimize the effects of crosstalk, install home-run cables from the CATV distribution panel to each TV set.
4. Keep UTP cable distances within the CATV balun vendor's specifications.
5. In order to minimize electromagnetic interference, when terminating the twisted pairs, make sure the twisted pairs remain twisted right up to the point of termination. Do not use UTP splits or taps.
6. Before installing equipment, test the video image quality of the longest

**Table 5** CATV Channels Supported By CATV Baluns with 550 MHz Bandwidth

Region	Band	Channel	Frequency Range (MHz)
United States	VHF LOW	2-6	54-88
	FM	95-97	90-108
	VHF MID	98-99, 14-22	108-174
	VHF HIGH	7-13	174-216
	VHF SUPER	23-36	216-300
	VHF HYPER	37-61	300-450
France	I	2-4	49-65
	II	5-10	174.75-222.75
Italy	I	A-B	52.5-68
	II	C	81-88
	III	D-H, H1-H2	174-230
Europe	I	2-4	47-68
	MID BAND	S2-S10	111-174
	III	5-12	174-230
	SUPERBAND	S11-S38	230-446

allowing it to support up to Channel 61 in North America. Table 5 shows some of the CATV channels supported by CATV baluns with a bandwidth of 550 MHz.

**CONNECTOR.** The connector on the coax side is an F-Connector. On the UTP side, the CATV balun may have screw-terminals or a modular jack. A modular jack allows connections to be made more quickly using standard line cords.

**PIN CONFIGURATION.** There is no CATV industry standard for which pins must be active on the RJ-45. Some vendors put the signal on pins 7 and 8.

**SIZE.** Look for a balun that is compact enough to place behind TV sets and narrow enough to fit side-by-side on an RF splitter (Figure 12).

## Cabling Guidelines

When planning and installing a CATV system using UTP, the following guidelines are suggested.

1. Use Category 5 UTP cable or better and make sure there are no splices or

cable run.

7. On cable runs where the signal may overdrive a TV set, use attenuators. No more than 15.5 dB should be at the TV set.
8. If the system needs to be amplified, install amplifiers as far upstream as possible. For example, place one amplifier at the headend and one tilt-gain amplifier in each wiring closet where the baluns are located.
9. Try for 10 dBmV of signal strength at each television. When in doubt, run the signal a little high to the television and use an attenuator to lower the signal strength going into the TV. Attenuators may be combined (i.e. two -3 dBmV attenuators will equal -6 dBmV). According to industry experts, many TV sets operate well at 0 dBmV (1 mV).
10. Ensure that all splitters and amplifiers are broadband. For UTP installations, splitters should have at least 5 MHz to 550 MHz bandwidth with a bidi-

**Table 6**

CATV Equipment Vendors
Blonder-Tongue Channel Vision Multiplex Technology Home Automation Systems Inc.
CATV Balun Vendors
NHC Communications Inc. Lucent Technologies Vision Televideo Technologies Inc. Energy Transformation Systems Computer Systems Products AMP

rectional filter at 5 to 50 MHz.

11. Check and make sure all televisions are ready to receive the desired channel frequencies.
12. Always compensate for insertion loss with a good amplifier. There will always be a drop in signal strength to an existing system from inserting a combining modulator.
13. When combining an existing signal with a modulated signal, make sure to have equal signal strength at the point of the combiner so one signal does not degrade the other.
14. For channels outside the supported frequencies, use a channel converter to place the channel on a carrier that is within a frequency band supported by the cabling. When possible, use the lowest frequencies available for the modulated channels in order to achieve maximum distance. If channels are available, allow one to two channel spacing between modulated and active channels.
15. If using modulators, install them as close to the headend as possible.

Structured cabling techniques, when applied to CATV can be an effective way to offer CATV services more easily to a greater number of viewers in a school, office or home environment. Structured CATV cabling requires more planning and pre-testing than other cabling systems. For more information, contact an expert in the design and installation of CATV services. Several CATV equipment and balun vendors are listed in Table 6. **CBM**

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# CATV Glossary

**AMPLIFIER.** A device that boosts signal strength to compensate for signal insertion loss due to coax cable and splitters.

**ATTENUATOR.** A device that decreases signal strength. Used to balance a system or to lower the signal strength going into a particular TV.

**AUDIO VIDEO SOURCE.** A baseband audio/video signal from VCR, laserdisc player, satellite receiver or security camera that is going to be modulated.

**BALANCED VIDEO DISTRIBUTION SYSTEM.** An RF video distribution system that has equal signal strength at each TV regardless of distance or number of TVs.

**BALANCED SIGNAL.** In CATV, this refers to a type of video signal transmission through a twisted pair cable. It is called "balanced" because the signal travels through both wires, thus being equally exposed to external interference. As a result, the noise will be canceled out at the input of a balun by the time the signal gets to the receiving end.

**BALUN.** Stands for BALanced/UNbalanced.

anced. Converts an unbalanced signal into a balanced one to allow data/video transmission over UTP.

**CATV BALUN.** A passive impedance matching device that allows coax-based, unbalanced broadband CATV signals to be transmitted via UTP cable. Typical bandwidth: 550 MHz.

**CATV INSTALLATION.** A CATV system, or an associated group of systems, together with all necessary hardware, auxiliary lighting, etc., located at the protected site. Also refers to the act of installing.

**CATV SYSTEM.** An arrangement comprised of a camera and lens with all ancillary equipment required for the surveillance of a specific protected area.

**COAXIAL CABLE.** The most common type of cable used for copper transmission of video signals. It has a coaxial cross-section, where the center core is the signal conductor, while the outer shield protects it from external electromagnetic interference.

**COMBINER.** A device that combines

two broadband signals into one output. This is used to combine a modulated audio/video source with a cable TV or antenna signal. Combiners should be placed as far upstream or as close to the local channel feed point as possible to ensure the modulated signal reaches all TV sets. A combiner may be built into a modulator.

**CROSSTALK.** The interference caused by a signal traveling over one cable pair on a signal traveling on an adjacent cable pair.

**dBmV.** Decibels, a unit of measure of signal strength or loss expressed as  $20 \log_{10} (V_1/V_2)$ , where  $V_1$  and  $V_2$  are the output and input signal voltages respectively in volts. The reference input voltage is 1 mV for CATV video. For example, if the reference input is 1 mv and the output is .01 mV, then the dBmV loss would be  $20 \log (.01/1)$  which is  $20 \log (.01)$ , which is  $20 (-2)$ , which is -40 dBmV. dBmV is not a measurement of millivolts; only the ratio of voltages.

**DISTRIBUTION PANEL.** A system of

amplifiers, splitters and combiners designed to receive multiple RF signals, and in some cases, satellite signals, and combine, amplify and split them out to multiple locations.

**DOWNSTREAM.** The direction which information is sent from the cable modem service provider to the subscriber.

**EQUALIZATION.** Selectively amplifying certain video channel frequencies in order to improve overall performance.

**FREQUENCY BAND.** The carrier frequency range in which a given TV channel is located.

**GAIN.** The amount of amplification that is applied to a signal. Usually expressed in dBmV.

**GROUND LOOP.** An unwanted interference in the copper electrical signal transmissions with shielded cable, which is a result of ground currents when the system has more than one ground. For example, in CATV, when we have a different ground resistance at the camera versus the switcher or monitor end. The induced electrical noise generated by the surrounding electrical equipment (including mains) does not discharge equally

through the two grounds (since they are different) and the induced noise shows up on the monitors as interference.

**HOME RUN VIDEO SYSTEMS.** This video system uses a separate coaxial cable run for each television in the system. Each video run originates from a distribution point comprised of the main local channel feed and modulated inputs, splitters and amplifiers. This type of system is much easier to troubleshoot and is more capable of upgrades.

**MODULATOR.** A device used to change a baseband video signal into a broadband signal in order to distribute over a CATV network.

**OPTIMUM TV PICTURE.** The optimum TV picture is the main goal when designing a system. The TV is looking for a signal between 8 and 12 dBmV (1 to 2 millivolts).

**RF SPLITTER.** A device that takes an input signal and divides it into two or more outputs. A signal going into a splitter will suffer insertion loss and a slight degradation of the picture quality. The more outputs a splitter has, the higher the insertion loss. Splitters typically have one input to two, three, four, eight

or 16 outputs.

**TAP.** This is used in an application where insertion loss needs to be as low as possible. The pass-through port on a tap suffers a minimal insertion loss of .5 dBmV to 1.5 dBmV, while the tap-off port suffers from 7 to 36 or more dBmV of signal loss. Taps work well for institutional installations where many TVs will feed off a single trunk line. Coax can be run in a straight line while a tap will pull off a determined signal.

**TILT.** The slope of the gain of amplification from the lower to higher frequency channels. Due to the fact that the signal losses are higher at the higher frequencies, a tilt amplifier provides more gain at the higher frequencies than at the lower frequencies. In more technical terms, this is called equalization.

**UNBALANCED SIGNAL.** In CATV, this refers to a type of video signal transmission through a coaxial cable. It is called unbalanced because the signal travels through the center core only, while the cable shield is used for ground.

**UPSTREAM.** The direction that information is sent from the subscriber to the cable modem service provider.