How Cable Television Works

by Curt Franklin

In the 1950s, there were four television networks in the United States. Because of the frequencies allotted to television, the signals could only be received in a "line of sight" from the transmitting antenna. People living in remote areas, especially remote mountainous areas, couldn't see the programs that were already becoming an important part of U.S. culture.

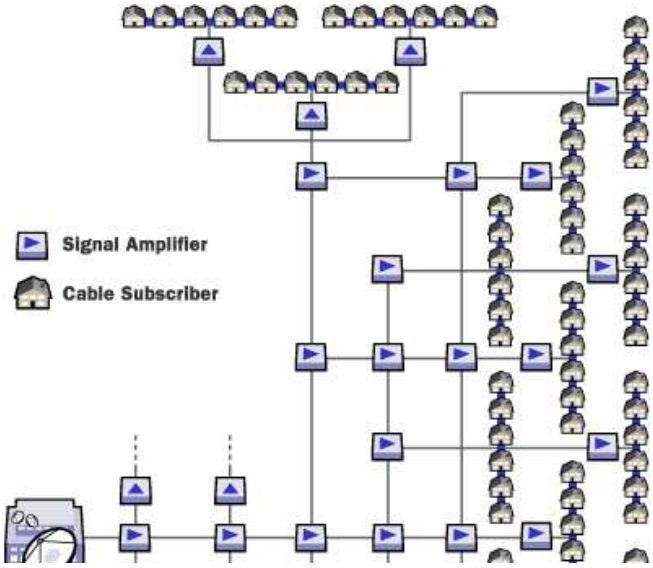
In 1948, people living in remote valleys in Pennsylvania solved their reception problems by putting antennas on hills and running cables to their houses. These days, the same technology once used by remote hamlets and select cities allows viewers all over the country to access a wide variety of programs and channels that meet their individual needs and desires. By the early 1990s, cable television had reached nearly half the homes in the United States.

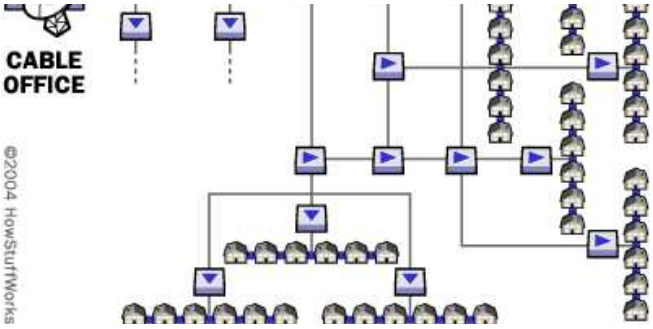
Scientific-Atlanta's 8600 analog set-top box supports services like interactive viewing guides (IVGs), impulse pay-per-view (IPPV) and virtual channels.

Today, U.S. cable systems deliver hundreds of channels to some 60 million homes, while also providing a growing number of people with high-speed Internet access. Some cable systems even let you make telephone calls and receive new programming technologies! In this article, we'll show you how cable television brings you so much information and such a wide range of programs, from educational to inspirational to just plain odd.

A Simple Plan

The earliest cable systems were, in effect, strategically placed antennas with very long cables connecting them to subscribers' television sets. Because the signal from the antenna became weaker as it traveled through the length of cable, cable providers had to insert amplifiers at regular intervals to boost the strength of the signal and make it acceptable for viewing. According to Bill Wall, technical director for subscriber networks at Scientific-Atlanta, a leading maker of equipment for cable television systems, limitations in these amplifiers were a significant issue for cable system designers in the next three decades.





"In a cable system, the signal might have gone through 30 or 40 amplifiers before reaching your house, one every 1,000 feet or so," Wall says. "With each amplifier, you would get noise and distortion. Plus, if one of the amplifiers failed, you lost the picture. Cable got a reputation for not having the best quality picture and for not being reliable." In the late 1970s, cable television would find a solution to the amplifier problem. By then, they had also developed technology that allowed them to add more programming to cable service.

Adding Channels

In the early 1950s, cable systems began experimenting with ways to use microwave transmitting and receiving towers to capture the signals from distant stations. In some cases, this made television available to people who lived outside the range of standard broadcasts. In other cases, especially in the northeastern United States, it meant that cable customers might have access to several broadcast stations of the same network. For the first time, cable was used to enrich television viewing, not just make ordinary viewing possible. This started a trend that would begin to flower fully in the 1970s.

The addition of CATV (community antenna television) stations and the spread of cable systems ultimately led manufacturers to add a switch to most new television sets. People could set their televisions to tune to channels based on the Federal Communications Commission (FCC) frequency allocation plan, or they could set them for the plan used by most cable systems. The two plans differed in important ways.

In both tuning systems, each television station was given a 6-megahertz (MHz) slice of the radio spectrum. The FCC had originally devoted parts of the very high frequency (VHF) spectrum to 12 television channels. The channels weren't put into a single block of frequencies, but were instead broken into two groups to avoid interfering with existing radio services.

Later, when the growing popularity of television necessitated additional channels, the FCC allocated frequencies in the ultra-high frequency (UHF) portion of the spectrum. They established channels 14 to 69 using a block of frequencies between 470 MHz and 812 MHz.

Frequency (MHz)	Channel
54-60	2
60-66	3
66-72	4
76-82	5
82-88	6
174-180	7
180-186	8
186-192	9
192-198	10
198-204	11
204-210	12
210-216	13

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Because they used cable instead of antennas, cable television systems didn't have to worry about existing services. Engineers could use the so-called mid-band, those frequencies passed over by broadcast TV due to other signals, for channels 14-22. Channels 1 through 6 are at lower frequencies and the rest are higher. The "CATV/Antenna" switch tells the television's tuner whether to tune around the mid-band or to tune straight through it.

While we're on the subject of tuning, it's worth considering why CATV systems don't use the same frequencies for stations broadcasting on channels 1 to 6 that those stations use to broadcast over the airwaves. Cable equipment is designed to shield the signals carried on the cable from outside interference, and televisions are designed to accept signals only from the point of connection to the cable or antenna; but interference can still enter the system, especially at connectors. When the interference comes from the same channel that's carried on the cable, there is a problem because of the difference in broadcast speed between the two signals.

Radio signals travel through the air at a speed very close to the speed of light. In a coaxial cable like the one that brings CATV signals to your house, radio signals travel at about two-thirds the speed of light. When the broadcast and cable signals get to the television tuner a fraction of a second apart, you see a double image called "ghosting."

Up in the Sky

In 1972, a cable system in Wilkes-Barre, PA, began offering the first "pay-per-view" channel. The customers would pay to watch individual movies or sporting events. They called the new service Home Box Office, or HBO. It continued as a regional service until 1975, when HBO began transmitting a signal to a satellite in geosynchronous orbit and then down to cable systems in Florida and Mississippi. Scientific-Atlanta's Bill Wall says that these early satellites could receive and retransmit up to 24 channels. The cable systems receiving the signals used dish antennas 10 meters in diameter, with a separate dish for each channel! With the beginning of satellite program delivery to cable systems, the basic architecture of the modern cable system was in place.

As the number of program options grew, the bandwidth of cable systems also increased. Early systems operated at 200 MHz, allowing 33 channels. As technology progressed, the bandwidth increased to 300, 400, 500 and now 550 MHz, with the number of channels increasing to 91. Two additional advances in technology -- fiber optics and analog-to-digital conversion -- improved features

and broadcast quality while continuing to increase the number of channels available.

The Glass Cable

In 1976, a new sort of cable system debuted. This system used fiber-optic cable for the trunk cables that carry signals from the CATV head-end to neighborhoods. The head-end is where the cable system receives programming from various sources, assigns the programming to channels and retransmits it onto cables. By the late 1970s, fiber optics had progressed considerably and so were a cost-effective means of carrying CATV signals over long distances. The great advantage of fiber-optic cable is that it doesn't suffer the same signal losses as coaxial cable, which eliminated the need for so many amplifiers. In the early fiber-optic cable systems, the number of amplifiers between head-end and customer was reduced from 30 or 40 down to around six. In systems implemented since 1988, the number of amplifiers has been further reduced, to the point that only one or two amplifiers are required for most customers. Decreasing the number of amplifiers made dramatic improvements in signal quality and system reliability.

Another benefit that came from the move to fiber-optic cable was greater customization. Since a single fiber-optic cable might serve 500 households, it became possible to target individual neighborhoods for messages and services. In the 1990s, cable providers found this same neighborhood grouping to be ideal for creating a local-area network and providing Internet access through cable modems.

From Analog to Digital

In 1989, General Instruments demonstrated that it was possible to convert an analog cable signal to digital and transmit it in a standard 6-MHz television channel. Using MPEG compression, CATV systems installed today can transmit up to 10 channels of video in the 6-MHz bandwidth of a single analog channel. When combined with a 550-MHz overall bandwidth, this allows the possibility of nearly 1,000 channels of video on a system. In addition, digital technology allows for error correction to ensure the quality of the received signal.

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The Explorer 8000HD Home Entertainment Server features digital reception and DVR capabilities.

The move to digital technology also changed the quality of one of cable television's most visible features: the scrambled channel.

Scramble to Blue

The first system to "scramble" a channel on a cable system was demonstrated in 1971. In the first scrambling system, one of the signals used to synchronize the television picture was removed when the signal was transmitted, then reinserted by a small device at the customer's home. Later scrambling systems inserted a signal slightly offset from the channel's frequency to interfere with the picture, then filtered the interfering signal out of the mix at the customer's television. In both cases, the scrambled channel could generally be seen as a jagged, jumbled set of video images.

In a digital system, the signal isn't scrambled, but encrypted. The encrypted signal must be decoded with the proper key. Without the key, the digital-to-analog converter can't turn the stream of bits into anything usable by the television's tuner. When a "non-signal" is received, the cable system substitutes an advertisement or the familiar blue screen.

For more information on cable television and related topics, check out the links on the next page.

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