From the Hill Country to Home and Garden Television to HGTV.com

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First created to improve broadcast TV reception in rural America, cable TV paved the way for robust television content and then brought the world home via broadband. Optical fiber played a key role in the industry's development.

Though we commonly take it for granted, innovation is apparent every time we turn on the TV. Long before the World Wide Web was a glimmer in the eye of Tim Berners Lee, television offered an array of entertainment and information to the masses, and innovative content continues to develop apace.

From its humble beginnings with Philo Farnsworth in 1927, television is now an enormous economic driver, responsible for more than 1.1 million jobs according to a recent study by Bortz Media, and increasingly a showcase for technological evolution. Early development of the technology was most certainly a source of "Wow!" -- as Corning well knows, having invented the process for mass production of glass TV picture tubes in 1947. And the early days of TV were very much the age of "What?" as in "What will Uncle Milty do tonight?" and "What will they think of next?"

Looking back, let's answer the big question: "How?" How has television developed from the daydream of a 14-year-old Idaho farmboy to a medium that offers a multitude of information and entertainment? While the technological development of the television itself makes for interesting history, an understanding of the infrastructure that now delivers services to over 70 million households in the United States alone is no less fascinating. Optical fiber is nothing less than a critical component of the modern cable TV infrastructure, and has enabled everything from delivery of two-way interactive services to the significant industry consolidation of large multiple system operators (MSOs).

Dave Woodle, Chairman and CEO of C-COR, puts it all in historical context. "In the early years, our board of directors had a heated debate around whether we could justify a move from 3 to 5 channels, because who would actually want so much content? Obviously, a snapshot of today's cable TV world would have looked like science fiction back then. Through 50 years of involvement in this business, we've witnessed and participated in the growth of an industry whose customers now want five *hundred* channels, not to mention broadband data, voice, and everything in between. The

innovative spirit of the system operators and equipment suppliers developed the modern Cable infrastructure that makes what was once pure fantasy now almost commonplace."

First, To Connect the Country

For the first 30-odd years of its existence, the primary focus of the United States cable TV industry was to address problems of poor or non-existent signal reception in outlying areas of the country. It had humble beginnings in 1948 in the hill country of rural Pennsylvania and Oregon, where the new medium of television was frustratingly out of reach to residents who could not receive a broadcast signal due to the terrain. With a few miles of coaxial cable, some surplus World War II electronics, a big antenna on a hilltop and, most importantly, some clever engineering, community antenna television (CATV) was born. And it grew quickly, with penetration approaching 90 percent in areas with poor reception by the mid-1960s.

Still, by 1970 cable TV was represented in less than 7 percent of all TV households in the United States, according to Nielsen Media Research. At that point in time, Cable was still primarily a delivery mechanism for the "Big Three" networks and some occasional local content. Some of us may still remember that most television sets could only accommodate 12 channels!

The mid-70s heralded the dawn of Cable's evolution beyond redelivery of broadcast network content to the medium it is today, delivering dozens if not hundreds of channels with a vast array of content tailored to every interest. Early forays outside the scope of terrestrial broadcast content focused primarily on local delivery of home team sports events. However, the watershed event that ushered in the era of cable TV as a true competitive force against the big broadcasters was the commercial launch of HBO in 1975. Within a few years, more content along the likes of C-Span, ESPN, MTV and Nickelodeon began to fill the cables, and most significantly, *not* the airwaves.

Cable Outgrows Its Rural Roots

An explosion in the amount of Cable-exclusive content resulted in two subsequent and significant phenomena. First, customers enjoying pristine (and free!) terrestrial broadcast reception, who previously had no need for this "hill country" technology, now wanted all the extra entertainment Cable had to offer and were willing to pay for it. Indeed, by 1980, Cable had penetrated nearly 20 percent of TV households and more than 40 percent by 1985, according to Nielsen Media Research. This obviously meant good things for Cable operators, offering them the chance to significantly expand the geographical extent and customer bases of their systems, not to mention expand their revenues. Second, this chance to expand the geographical reach of their systems and increase their customer base -- customers that were beginning to demand even more channels -- meant the network infrastructure would need to grow too.

A consideration of the typical CATV network architecture of the late '60s and early '70s brings into stark relief the issues that came hand-in-hand with this opportunity. For an expanding cable TV system, the most common configuration at the time was the tree-

and-branch architecture, illustrated in Figure 1. Satellite receivers for Cable networks as well as antenna and microwave feeds from local broadcast network affiliates were received at the headend, then distributed over the coaxial cable “trunks,” branching out along the way (get the tree analogy?) to feed multiple pockets of subscribers. While coaxial cable is inherently a broadband medium, with up to 1 GHz of usable bandwidth, video transmission is very fickle and is incredibly sensitive to noise and interference. Coaxial cable has relatively high attenuation, which also scales with frequency, as shown in Figure 2. Radio frequency (RF) television signals transmitted over coax could travel maybe 1,000 to 2,000 feet before requiring amplification. So, to pass more homes and serve more subscribers, many RF amplifiers were hung from many a telephone pole, each one representing a point of failure that could potentially drop service for a large portion of a system's subscribers. Unfortunately, more active electronics in the field became a necessary evil.

The solution, however, created a new problem; RF amplifiers couldn't be infinitely cascaded, because noise and distortions accumulate at each stage. The video signal eventually would degrade beyond recognition. Worse yet, at extended distances, system bandwidth was de-rated to a few hundred MHz to allow for acceptable signal quality, well below the fundamental capability of the cable itself. Even with current state-of-the-art amplifiers, 20-30 amplifiers is the maximum number that can be supported with reasonable signal quality. So, in short, more amplifiers were needed, but more amplifiers were bad.

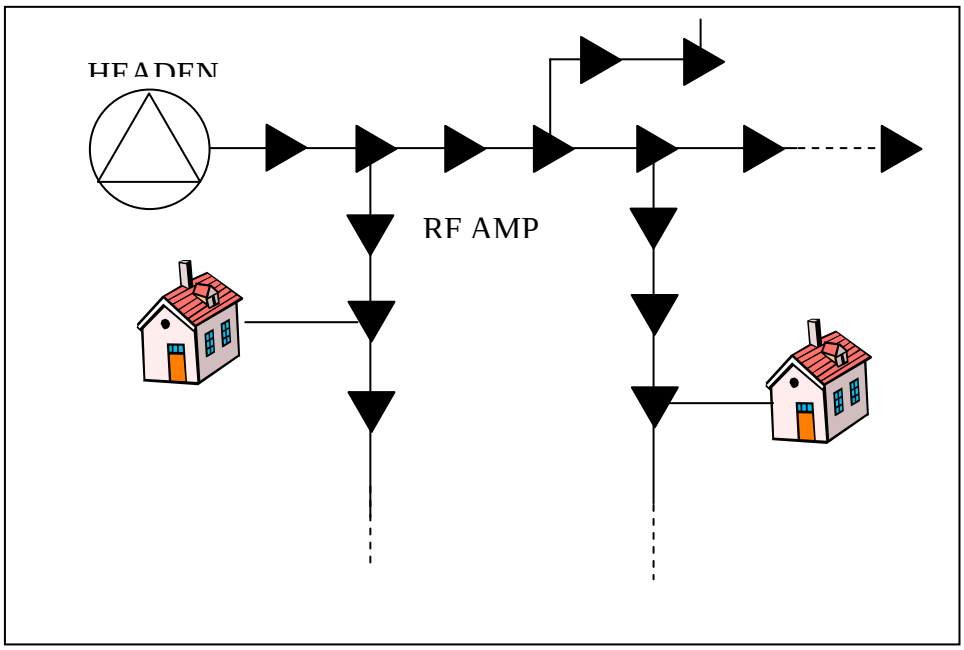

Figure 1: Typical coaxial cable-based tree-and-branch CATV system.

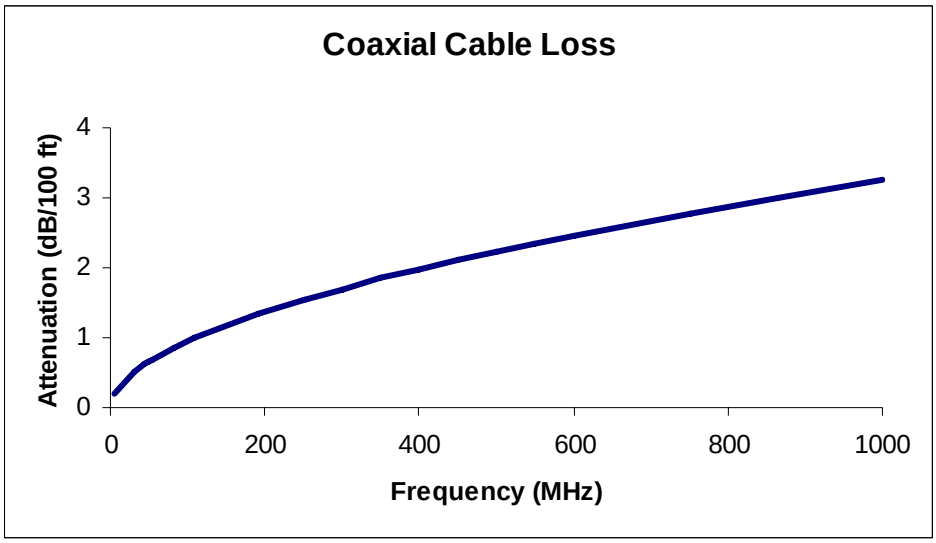

Figure 2: Frequency dependent loss of coaxial cable

Customer demand drove a need for larger system coverage, but RF limitations on the coaxial cable plant restricted total system size and bandwidth. As a result, multiple smaller systems appeared, with nearly 5,000 cable TV systems in the US by 1980, according to data from The Cable Center. With many early pioneers expanding their reach to a wider audience with multiple systems, thus was born the multiple system operator. In fact, the largest MSO today has more subscribers than the entire industry had in 1980. Satellite farms and headend real estate were required to support each system. The demand and desire to grow cable TV was there, but ironically enough it was fundamentally limited by the technology that gave it its name. Some other medium was needed to increase the capacity and reach of existing and new systems in order for operators to capitalize on the opportunities that faced the industry.

The Glass "Outside the (TV) Box" Revolutionizes Cable Television

Corning's groundbreaking invention of low-loss optical fiber in 1970 did not long go unnoticed by the hungry minds of the cable TV world. By the middle of the decade, the nation's first fiber-optic communications system was installed by -- whom else? -- a cable TV company. The cable TV industry's pioneering ingenuity was evident again, now with a powerful new enabling technology capable of expanding CATV networks beyond what anyone could have envisioned in 1948. Those early trials of fiber supertrunking proved too expensive to be practical, but the genie was out of the bottle.

"The word 'revolutionary' is often an overused term, but optical fiber truly rewrote the Cable industry's history books," says Roger Brown, publisher and editorial director of CED Magazine. "Optical fiber enabled Cable operators to segment their networks, which in turn allowed them to add compelling new services like interactivity, digital video, high-speed data and telephony. If fiber hadn't been in the right place at the right time, Cable networks today would be playing second fiddle to the satellite industry and the telephone companies."

It took some time for the full promise of a union between coaxial cable and optical fiber to be truly realized. Intervening progress was made in refining fiber applications for supertrunking through the late 70s and early 80s, primarily employing bandwidth-intensive frequency modulated (FM) transmission. Many of the fundamental and tangible benefits of fiber were explored and demonstrated in that time, especially improved signal quality, significant reduction in active electronics in the field and more robust cable designs than coax could provide. Indeed, considering all the factors of installation and operation, the relatively new optical technology often was found to be less expensive than the long-standing copper alternative.

The late 80s finally introduced us to the Cable network architecture that forms the basis for the robust two-way high-bandwidth systems we see today, the hybrid fiber-coax (HFC) network. Initial analysis and design, culminating with actual deployments in 1988, showed the promise of an integrated fiber and coax architecture that could increase usable bandwidth and segment the network into smaller serving areas to allow for increased flexibility and upgraded services. The concept of an HFC network is illustrated in Figure 3, significant in its contrast with the historical tree-and-branch design shown in figure 1. The availability of optical hardware capable of supporting the rigorous demands of amplitude modulated (AM) transmission throughout the network was key to integrating HFC networks with the large base of existing consumer equipment, as well as ensuring practical economics.

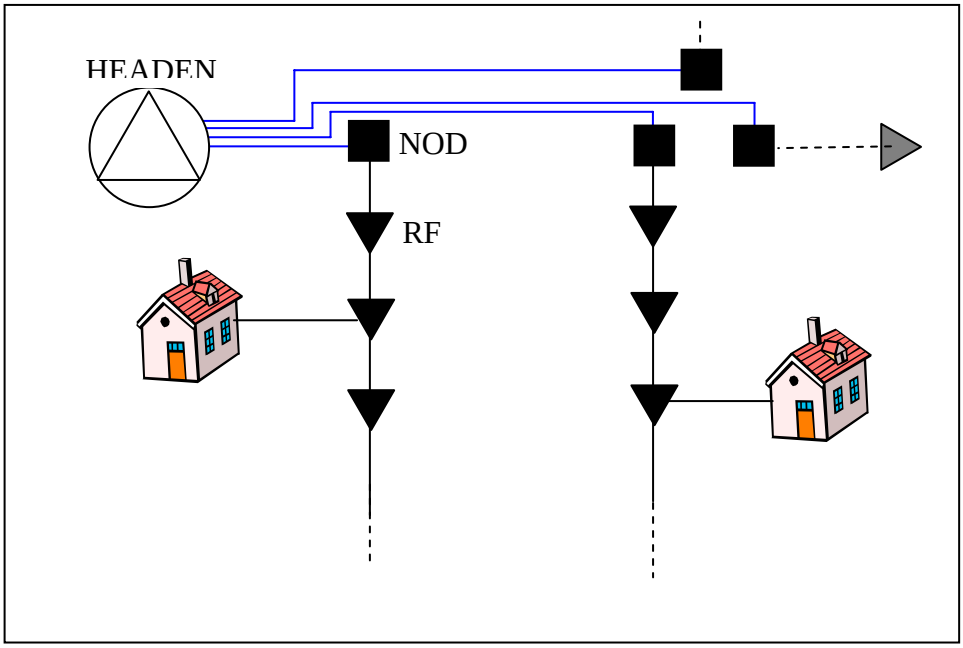

Figure 3: Simple hybrid fiber-coax (HFC) architecture.

Ron Hranac, noted industry expert, Cisco Systems Technical Leader and Senior Technology Editor for Communications Technology Magazine, sums up the significance of AM transmission and early HFC network development: "…This critical milestone allowed the introduction of new non-entertainment services, and is clearly among the handful of major technical revolutions that changed the way we do business."

Cable TV in the 90s and Beyond

As HFC networks continued to evolve, advancements in optical components, system design, and even the fiber itself, allowed system engineers to push the limits of bandwidth, reach and overall flexibility. While the advantages of transmitting signals end-to-end in the same ubiquitous format standardized in the 1950s was obvious, maintaining the necessary signal quality over large optical networks was far from trivial.

All segments of the network faced significant demands. Early deployments largely transmitted in the 1310 nm wavelength window, which led to numerous demands on manufacturers and suppliers. Lasers and transmitters were continually refined to deliver high optical powers, excellent signal linearity and very low noise and distortions. Reducing fiber loss was critical, in order to gain the most advantage from whatever power could be squeezed out of the laser sources. Similar demands were placed on optical connectors, with additional demanding requirements on minimizing reflections. Optical receivers were subject to like demands as transmitters were, again, driven to low noise and distortion levels to allow for superior sensitivity.

Of course, the interplay of transmitters, connectors, fiber, and receivers introduced issues greater than the sum of the parts, so cable TV engineers were tasked with designing workable networks around the advanced technology. As systems grew and consolidated, operation at 1550 nm made sense to take advantage of lower fiber loss and higher power capabilities through optical amplifiers. This introduced a host of new problems, chief among them new demands on transmitter linearity and dispersion-induced distortions. The high powers demanded of optical amplifiers were also beyond the likes of what were seen in the traditional telco world. Yet again, system and component manufacturers met the challenge, and cable TV operators pushed their new systems to their limits.

Jim Farmer, chief technical officer of Wave7 Optics, author, and widely recognized cable TV industry authority, suggests that “the modern hybrid fiber-coax (HFC) architecture has made it possible to cost-effectively increase bandwidth, signal quality and reliability. By also reducing the challenges of providing two-way services, the introduction of fiber allowed cable TV system operators to develop into some of the nation's largest and most innovative telecommunications companies. Operators continue to improve the performance of their networks by pushing fiber further toward the subscriber.”

As the world of telecommunications changes and adapts in the current climate, cable TV operators are positioned better than ever to have a seat at the table. Indeed, it's clearly not just about television anymore. Cable has consistently led broadband

penetration in the US, and voice services are now on the horizon. Built on the robust foundation of the hybrid fiber-coax architecture, the cable TV industry is well positioned. Technologies like gigabit Ethernet, DWDM and coarse WDM (CWDM), all based on fiber optics, are now being examined and deployed in earnest in the cable TV market. Based on the cable TV industry's history of innovation and calculated risk-taking, just imagine what the future holds.