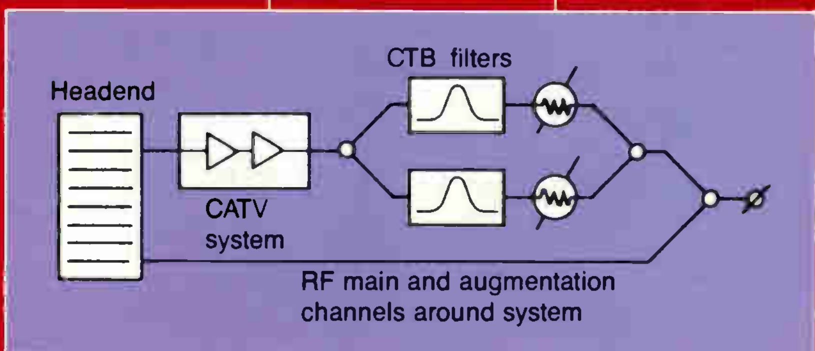
COMMUNICATIONS TECHNOLOGY

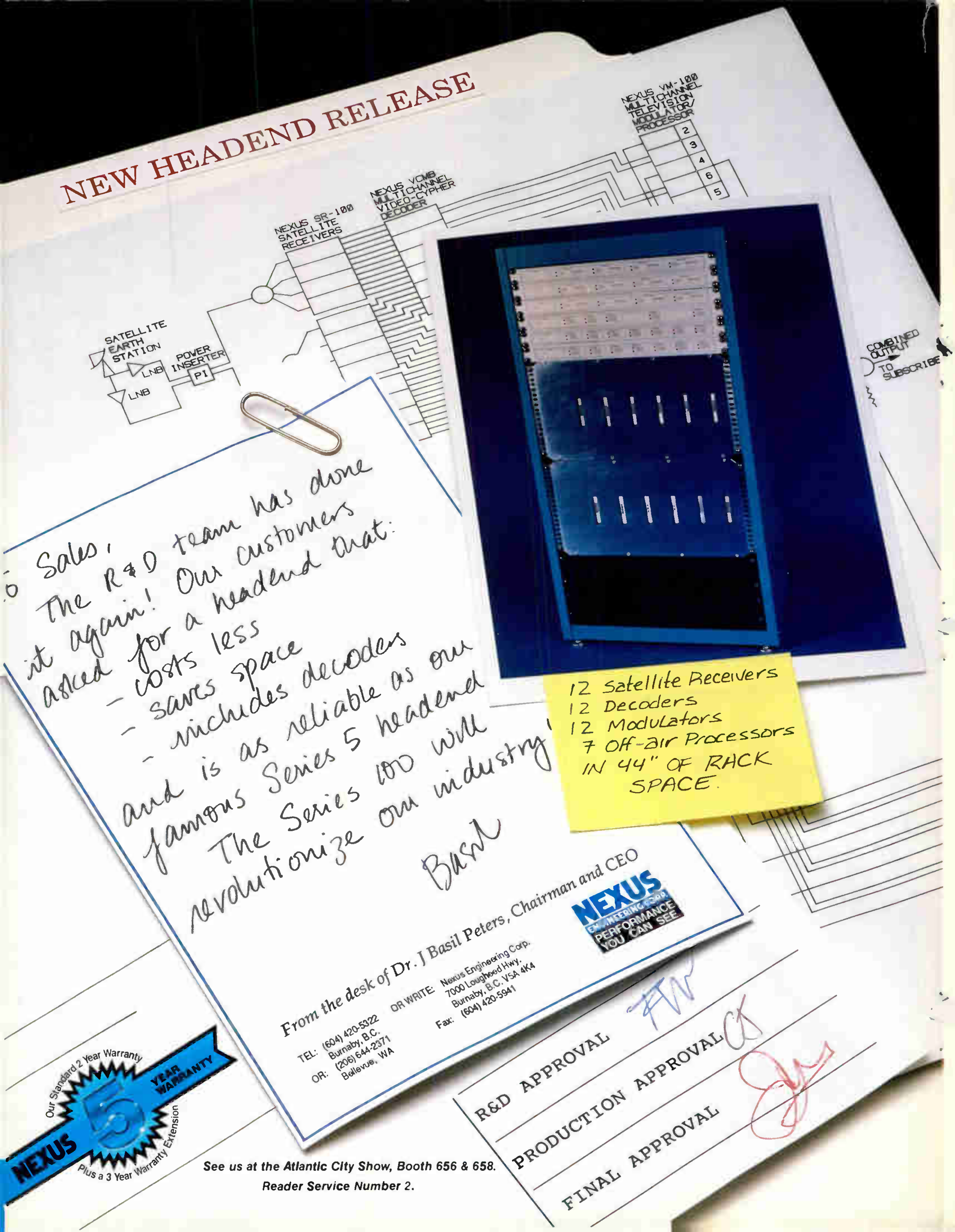
Official trade journal of the Society of Cable Television Engineers

Fiber optics: Shaping cable's future



Testing high-definition performance

October 1988



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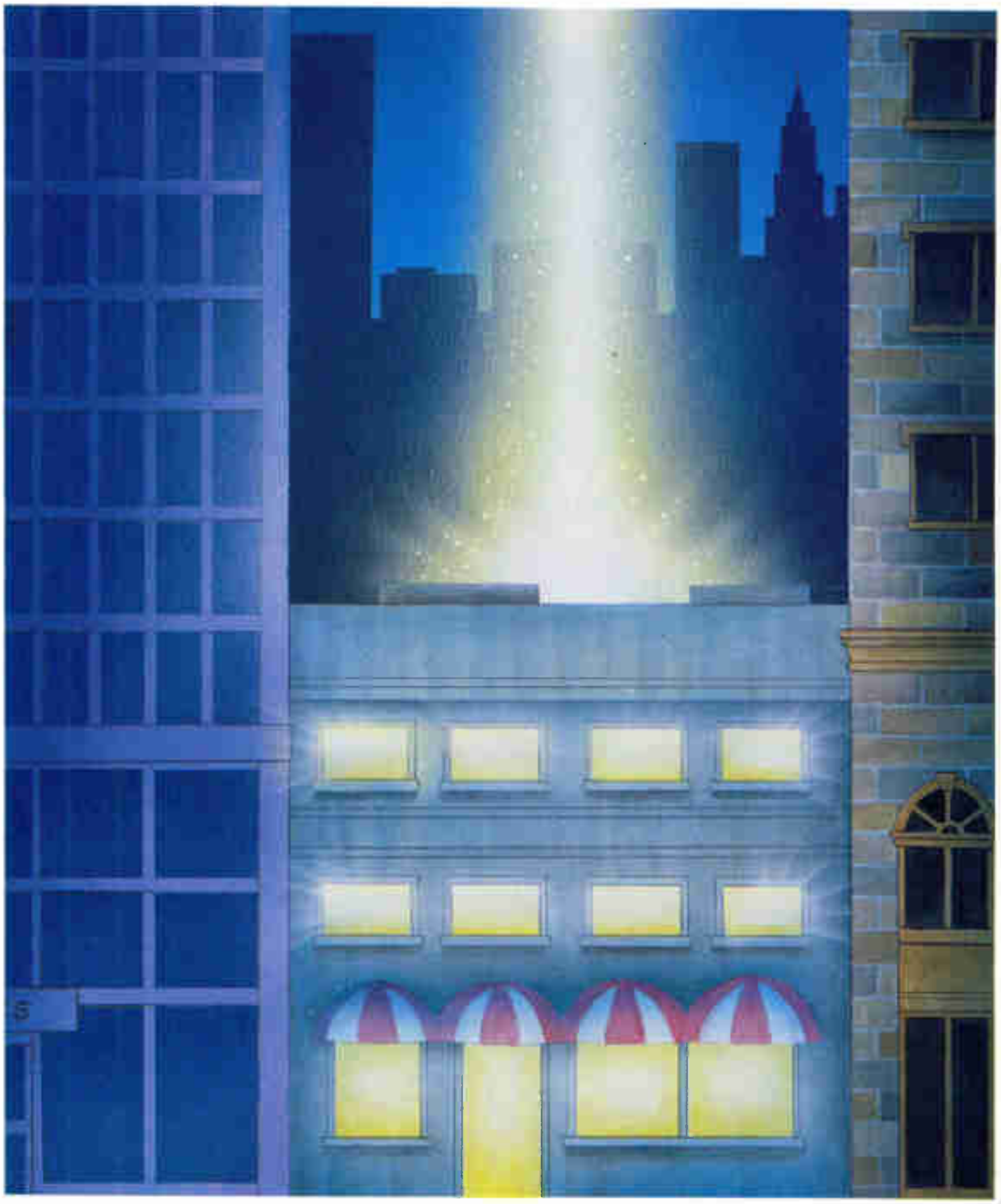

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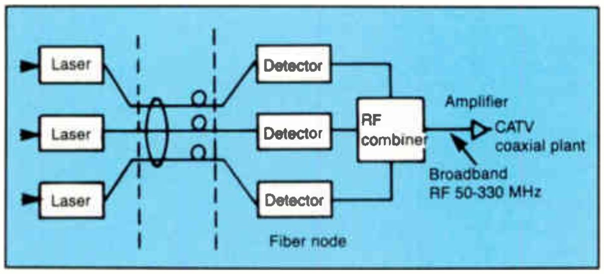

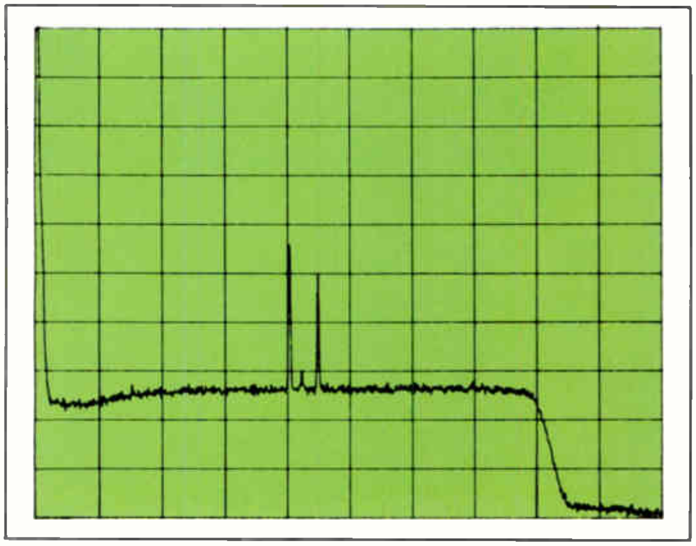

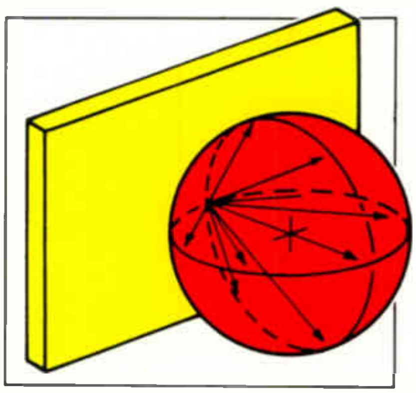

Features

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Jerrold Applied Media Lab

...exploring new paths to cable's future

Cable television's broadband communications "pipeline" into the home is an enormous resource with a potential that remains largely untapped.

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With your input and participation, the Applied Media Lab can serve as a conduit between today's technological innovations and tomorrow's practical applications.

For a brochure on current activity areas, contact Jerrold Division, General Instrument Corporation, 2200 Byberry Road, Hatboro, PA 19040. (215) 674-4800.

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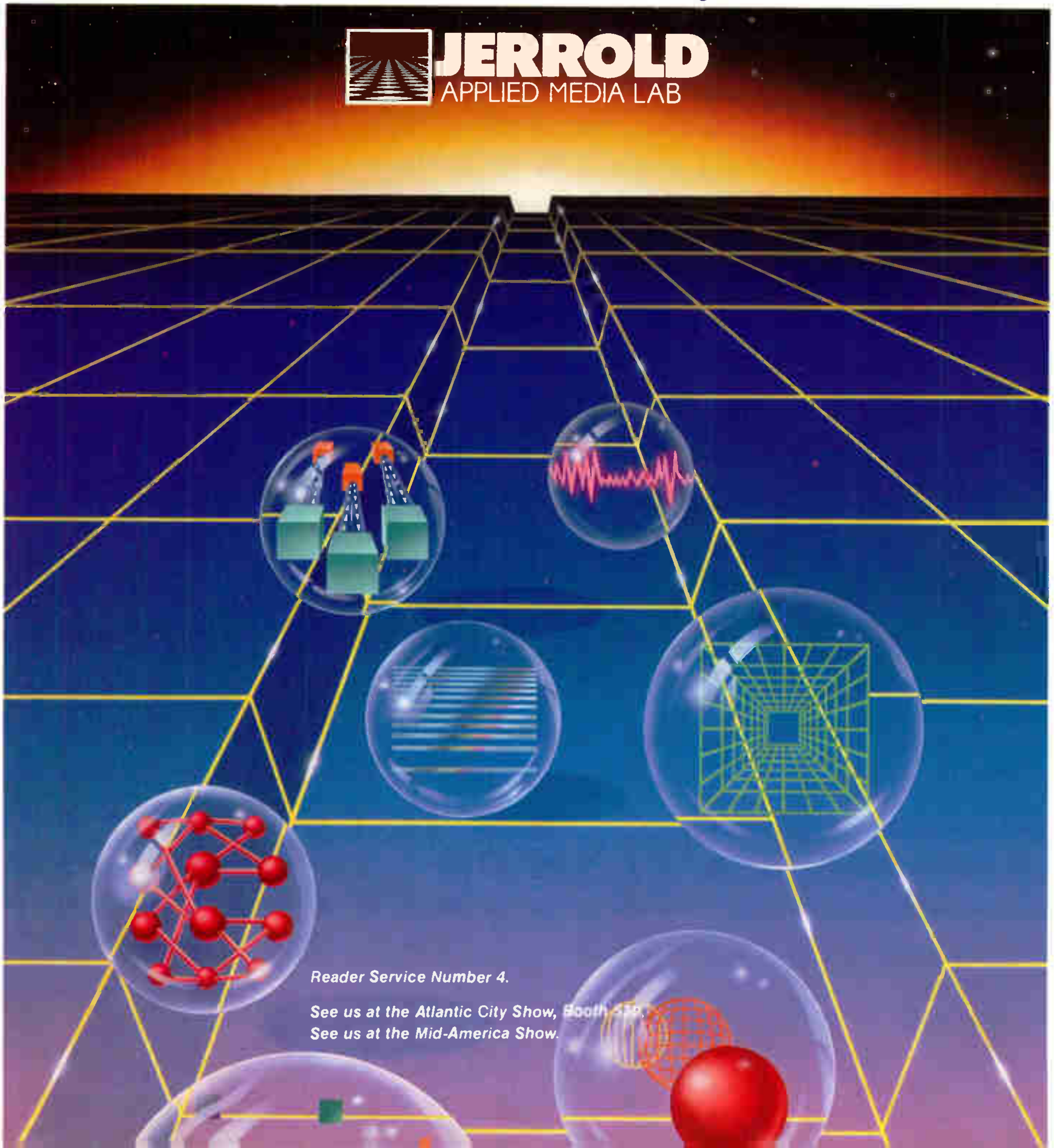

Fiber's here, where are you?

The time for fiber optics to be used in our industry isn't tomorrow but today. As several articles in this issue of *CT* will attest, a fiber/coax hybrid system for the transmission of video is ready and waiting for implementation—and will shortly become necessary for the bottom line. There were at least three events last month that drove home the facts that 1) fiber now can be introduced efficiently and cost-effectively and 2) we shouldn't waste any more time doing it.

In a demonstration Sept. 6 in Orlando, Fla., Anixter Cable TV took the wraps off its new Fiber-Optic Laser Link at Cablevision of Central Florida. Through the joint efforts of Anixter and several cable operators, this system allows the use of fiber in a number of applications for the industry. It first got the green light after tests conducted by ATC's Director of Field Engineering Dave Pangrac in the MSO's Englewood, Colo., labs. It was then field-tested in Orlando under the direction of John Walsh, the local system's vice president of engineering.

The way the whole thing started, Anixter approached AT&T (pioneers in fiber-optic technology) to provide the laser for the system. It was then adapted for CATV's unique applications. For future customers, the electronics of the Laser Link will be manufactured by AT&T and marketed by Anixter. And what makes this even more exciting is that MSOs such as ATC, TCI, Cox, Warner and King Videocable are planning to make initial installations of the Laser Link this year; Jones Intercable also is considering its implementation.

To quote John Egan, president of Anixter Cable TV, "CATV is a very creative industry. Once we begin to understand what fiber can do, the more we'll be able to use it, all the way from the headend to the home. Fiber's an evolutionary application."

In another development, Corning announced a venture with General Instrument to provide fiber optics to the CATV industry.

Carrying the torch

The opening ceremonies last month didn't exactly feature a torchbearer ascending the steps and lighting the Eternal Flame with a fiber-optic cable. However, a fiber system was installed for the 1988 Summer Olympics in Seoul, South Korea, by Catel. The company provided fiber links from the International Broadcast Center to three sites: the Main Stadium, Olympic Park and the International Olympic Committee headquarters. The Korean Telecommunications Authority selected the Catel 3000 Series system to monitor events at those sites.

And that's just the beginning. Catel's President James Hood sees more activity in fiber-optic equipment sales for 1989. This is indeed a prediction of better times ahead, because what it all comes down to is this: When improved technology like fiber optics gains more acceptance

and hence more use, the CATV industry and the cable subscriber are the real winners.

While we're on the subject of the Olympics, I need to mention that Jerrold supplied nearly $250,000 worth of cable TV delivery equipment for use in a 36-channel cable system that also reaches key sites. The system was constructed by Goldstar, a Korean electronics company, but two Jerrold engineers, Jon Ridley and Jim Jackson, are responsible for seeing that the system runs smoothly during the games.

Speaking of new technology, I am hereby encouraging all the readers of *CT* to attend the Society of Cable Television Engineers' seminar "HDTV and beyond," which will occur Oct. 28-30 at the Sheraton Tech Center in Denver. If you haven't heard of it by now, where have you been? The seminar is being coordinated by the SCTE and its Rocky Mountain Chapter; the agenda appears in the "News" on page 11 and should give you an idea of the size and scope of the topic. For your convenience, a registration form can be found in the "President's Message" on page 98. Fill it out and send it in now (be sure you sign up for the BCT/E exams as well).

Beware of gremlins

In last month's issue, we made a small but unfortunate error in Archer Taylor's article "A converter for premium channels only." On page 63, unidentified gremlins at *CT* mischievously added the word "no" to the sentence: "There is reason to hope it (the IS-15 multiport) becomes a universal feature of new TV sets." In effect, we turned Archer's well-known position on the subject topsy-turvy. You see, Archer is still an enthusiastic supporter of the IS-15. So, just cross out the offending word "no" right now.

Darn it, it doesn't happen often with us, but we goofed. We apologize for the error and plan to keep our eyes open for those nasty gremlins.

Paul R. Levine

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Official trade journal of the Society of Cable Television Engineers

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SCTE announces agenda for "HDTV and beyond"

DENVER—The Society of Cable Television Engineers and its Rocky Mountain Chapter is hosting a three-day conference on high-definition television at the Sheraton Tech Center here Oct. 28, 29 and 30. The conference, called "HDTV and beyond," will include lectures from industry leaders, as well as live demonstrations of HDTV and various advanced television formats.

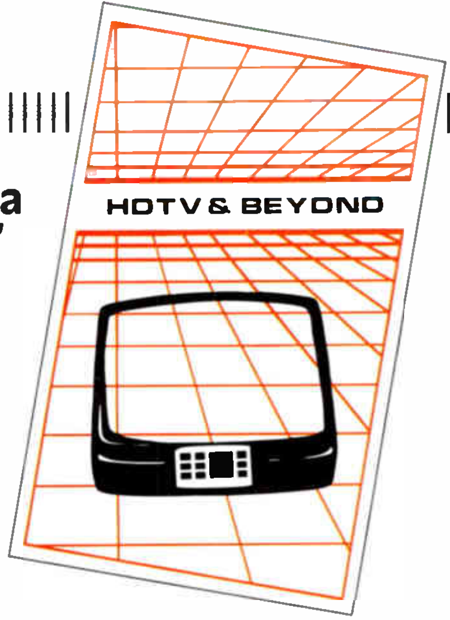
The following is the tentative agenda of the seminar (subject to last-minute changes):

Thursday, Oct. 27
Registration

Friday, Oct. 28
8:30-10:35 a.m.—HDTV overview
● *Session chairman:* Bob Luff (Jones Intercable). *Speakers:* Bill Thomas (Nielsen Media Research), "Introduction to HDTV"; Willem Mostert (Magnavox CATV), "Coaxial technology"; Jim Chiddix (American Television and Communications Corp.), "Fiber technology"; Tom Straus (Hughes Microwave), "Microwave technology"; and "Satellite technology," speaker to be announced.
10:35-11 a.m.—Break
11 a.m.-12:15 p.m.—ATV Systems I: Proponents
● *Session chairman:* Ed Horowitz (HBO). *Speakers:* Yves Faroudja (Faroudja Labs), Denes Ilkovics (High Resolution Sciences) and Arpad Toth (North American Philips).
12:15-1:30 p.m.—Luncheon (speaker to be announced)
1:30-3:35 p.m.—ATV Systems II: Proponents
● *Session chairman:* Ed Horowitz (HBO). *Speakers:* Bill Schreiber (Massachusetts Institute of Technology), Jim Carnes (Sarnoff Labs), Anne Hageman (NHK), Bill Glenn (NYIT) and Richard Iredale (CVC).
3:35-4 p.m.—Break
4-5:30 p.m.—Demonstrations/breakout sessions

Saturday, Oct. 29
8:30-10:35 a.m.—Industry perspective I
● *Session chairman:* Walt Ciciora (ATC). *Speakers:* Allan Ecker (Scientific-Atlanta), Vito Brugliera (Zenith), David Del Beccaro (Jerrold), Judson Hofmann (Panasonic) and Larry Thorpe (Sony).
10:35-11 a.m.—Break
11 a.m.-12:15 p.m.—Industry perspective II
● *Session chairman:* Walt Ciciora (ATC). *Speakers:* Ben Crutchfield (National Association of Broadcasters), Paul Heimbach (HBO) and Phil Garvin (NORAC Productions).
12:15-1:30 p.m.—Luncheon (speaker to be announced)
1:30-5:30 p.m.—Demonstrations/breakout sessions

Sunday, Oct. 30
8:30-10:35 a.m.—Industry activity reports



● *Session chairman:* Wendell Bailey (NCTA). *Speakers:* Bill Hassinger, Federal Communications Commission, "FCC activities"; Bob Hopkins, "ATSC activities"; Michael Rau (NAB), "NAB activities"; and Nick Hamilton-Piercy (Rogers Cablesystems), "NCTA activities."
10:35-11 a.m.—Break
11-11:30 a.m.—Conference wrap-up (Bill Riker, SCTE)
1 p.m.—BCT/E testing

A registration form can be found in this issue's "President's Message," page 98. For more information, contact Jan Vicalvi at Executive and Convention Services, (303) 691-8380.

NCTA Engineering Committee report

WASHINGTON, D.C.—The bimonthly meeting of the NCTA Engineering Committee was held Aug. 17-18. A premeeting session was held with Jerrold Heller of General Instrument/VideoCipher. He updated the attendees on upcoming changes to VideoCipher as well as modifications to reduce piracy.

Wendell Bailey updated the committee on activity by the Federal Communications Commission and Congress. The FCC has issued new implementation dates for technical standards for antenna selector switches but has not issued dates for reimposition of the cable operator education requirements. Comments have been submitted regarding changes to the rules covering signal leakage from TV sets, VCRs, computers, etc., but the commission has not issued a Report and Order on the changes.

Petitions for reconsideration have been filed on syndicated exclusivity (syndex) implementation. The NCTA requested a longer implementation period and a longer notification period from broadcasters. The 60-day notification period is too short to obtain and install new equipment if that is necessary for a new program substitution.

The commission is reviewing the cable/telco cross-ownership issue and is considering changing the waiver requirements to make it easier for a telephone company to provide cable in its service area. In addition, the commission will review the ban on television network ownership of cable systems.

The station coverage for meeting effective competition requirements has been modified. The Grade B contour must now cover the complete system rather than just touching the system. If it is believed that the contour is incorrect and a field survey is conducted, then the loser will have to pay for the survey. Three-station coverage is still required to meet the effective competition requirement.

Subcommittee reports

National Electrical Code: The preprinted edition of the 1990 National Electrical Code has been released for comment until the end of September. The comments must refer to proposed changes to the code and cannot address suggestions for additional changes.

Advanced television: There has been a lot of activity in advanced television (ATV), mainly in the FCC Advisory Committee working parties. The Planning Subcommittee has prepared a list of desired attributes for ATV systems and procedures for testing and evaluating the systems. The System Subcommittee has requested that the proponents submit descriptions of their systems by the beginning of September. These will be evaluated by the beginning of December, at which time tests of the physical systems will begin. The Advanced Television Test Center has been funded by the broadcasters to set up a lab to perform the broadcast tests. The source of funds for the cable and alternative media tests has not yet been determined.

Attendance at the various committee meetings includes broadcasters, manufacturers and telephone company representatives with only token cable representation. If the cable industry wishes to have any significant influence on the selection of the system it will have to put more effort into attending the committee meetings.

Test procedures: A number of test procedures has been prepared for performing acceptance tests on cable and BTSC performance tests for cable equipment are nearly complete. These will be issued in the second edition of the *NCTA Recommended Practices*, due to be published in 1989.

Signal leakage: All cable systems operating in the aeronautical band must meet the CLI or flyover requirements by July 1, 1990. The systems that have performed tests have generally found that if a very good monitoring and repair procedure was not in place then there was no possibility of meeting the requirements during the first test. With a good program in place it was possible to meet the requirement with some additional effort.

There must be on file with the FCC by the July 1, 1990, deadline a certification that the system meets the requirements and that all channels in the aeronautical bands comply with the standard offsets or they will not have authority to operate in the aeronautical bands. The NCTA will be sponsoring seminars in the fall and winter to inform operators of the requirements for operating in the aeronautical bands.

Multiport: The booth at the SCTE expo was well-attended with many operators showing an interest in the port. It is still necessary to convince decoder manufacturers that there is a market for equipment supplied with the multiport. Development of specifications to allow impulse pay-per-view through the TV set remote control is nearing completion.

Smart House: Equipment is now in the breadboard stage and it is expected that 10 to 20 prototype homes will be built across the country in 1990. These will incorporate many of the advanced features of the Smart House concept.

National Electrical Safety Code: The preprint of the next edition has been distributed; the comment period ended Sept. 30. One proposed change in definitions would have resulted in a reduction in power passing on communications cables to 150 watts. This type of change could get through to the final version if the industry does not show an interest in the changes and read the proposed revisions.

Multichannel TV sound: The test procedures for BTSC on cable systems are near completion. The Canadian Cable Television Association has issued a systems operations guide for BTSC.

American Radio Relay League: There have been no complaints received through the ARRL regarding cable/amateur interference. However, there have been three instances of complaints going directly to the FCC from local amateurs after the cable company did not react to interference problems. Operators should work with local amateur groups to ensure cooperation and minimize problems getting to the FCC.

Advanced Television Systems Committee: A proposal to reorganize the committee along the lines of the FCC ATV committee is being reviewed. Under the proposed organization the technology groups would be responsible for production and for distribution regardless of the number of scan lines and resolution. The main action in ATV is taking place in the FCC Advisory Committee working parties.

Emergency Broadcast System: The system is under review with the intention of updating the cueing signal to allow more information to be sent. The additional cueing information could be used to trigger audio overrides at cable headends to ensure that the emergency messages reach as many people as possible.

Anixter unveils fiber-optic link

ORLANDO, Fla.—On Sept. 6, Anixter Cable TV unveiled its Fiber-Optic Laser Link CATV system here at the Cablevision of Central Florida facility. The new technology allows for the transmission of multiple amplitude-modulated analog TV signals over long distances. It is expected that a number of MSOs, including American Television and Communications Corp. and Tele-Communications Inc., will be making initial installations of the system this year. Jones Intercable also is considering installation.

The analog laser system, designed for backbone trunking applications, is capable of transporting a 42-channel VSB/AM spectrum over one single-mode fiber with a 5 dB loss budget. It is based on a technology developed by AT&T and adapted for the CATV industry. The electronics of the Laser Link are being manufactured by AT&T and marketed by Anixter.

FCC lists guidelines for compatible HDTV

WASHINGTON, D.C.—The Federal Communications Commission listed new technical guidelines for high-definition television transmission. In a unanimous vote, the FCC ruled that existing TV sets, using the NTSC standard, must be able to receive advanced TV signals. This in effect precludes the current MUSE system (proposed by NHK, the Japanese Broadcasting Co.) for use in the United States, although MUSE systems compatible with U.S. standards are now being developed.

In a related event, Zenith submitted a proposal for its "Spectrum Compatible HDTV System" to the FCC's Advisory Committee on Advanced Television Services. The Zenith system takes 30 MHz of video and audio data and compresses it into a 6 MHz signal, which is transmitted over an unallocated NTSC channel in the VHF/UHF spectrum , simultaneously with an existing allocated channel transmitting the NTSC signal.

Catel adds fiber to Summer Olympics

SEOUL, South Korea—Catel Telecommunications installed a fiber-optic TV transmission system in use at the 1988 Summer Olympics. The company provided links from the International Broadcast Center to three sites—Main Stadium, Olympic Park and the International Olympic Committee headquarters. The Korean Telecommunications Authority selected the Catel 3000 Series system, which carries 16 channels for distances up to 23 kilometers.

This was the second time Catel has supplied equipment for the Olympics. Earlier this year, ABC used the company's audio equipment for its coverage of the 1988 Winter Games in Calgary, Canada.

- Pioneer Communications of America opened a new field sales office near Denver for its cable TV division at Greenwood Plaza, Third Floor, 5680 Greenwood Plaza Blvd., Englewood, Colo. 80111, (303) 740-6718.
- SCI Systems, an electronics manufacturer headquartered in Carlsbad, Calif., recently acquired Southwest General Industries, whose service and repair division holds in-warranty repair contracts for Oak products.

The myth of free trade

By Isaac S. Blonder
Chairman, Blonder-Tongue Laboratories Inc.

This month we will adhere to the classic construction of a working paper. First the proposal, then the exposition, followed by a summation reinforcing the proposal.

Proposal: The United States shall impose a 100 percent duty on all imports at the rate of 20 percent yearly, until the full tax is achieved.

Free trade advocacy in the United States began with the Jefferson and Jackson Democrats, who responded with free trade bills to the demands of their tobacco- and cotton-exporting Southern constituents. These Democrats were weakly countered with tariff raises proposed by the Federalists led by Alexander Hamilton and the Whigs led by Henry Clay to protect the infant industries of the East. Tariffs under the Republican Party tended to increase, with some reversals, as in the Democratic Wilson-Gorham Tariff of 1894 and the Underwood Tariff Act of 1913. Every congressman sought protection for the principal industries in his district.

Perhaps the most vigorous push for free trade came directly after World War II. We survived that conflict as the biggest, most efficient and technologically advanced economy in the world. We could outprice, outproduce and outshine any other country, so naturally the politicians wrapped themselves in the moral and populist slogans proclaiming "free trade" the dominant economic principle for the general welfare of the world. Remnants of this euphoria are still evident today. The official position of the United States, both at the White House and in Congress, still verbalizes an undying love for free trade, even as they enact restrictive trade bills.

The economists

So far we have only mentioned politicians. What role has been seized by that agglutination of experts, self-proclaimed as scientists in the economics arena? They are a prestigious gaggle of highly educated and publicized savants with impressive credentials as analysts and commentators but possessed with lamentable experience in the non-academic skills of business management and sales. I remember the occasion when President Lyndon Johnson, with a rosy proclamation of solving our economic dilemmas, called over 200 economists to the White House for a definitive summit conference to set the economic goals for his administration. Alas, the March lions turned into April lambs—what he got were 200 programs all at odds with one another!

It seems that each economist seizes one aspect of trend analysis for himself and forevermore explains the movement of the economy from that exalted position. If by chance the forecasts fit today's economics, that gentleman and his theory is praised to the sky. But, inevitably, a new king of the hill appears and the press proclaims the skill of the new hero.

The first duty of a country is survival. This indispensable goal cannot happen with free trade. With unrestricted free trade no country would be able to retain all of the industries needed to support an army within its borders. Our steel industry is on its knees today, joined by the shipbuilding plants, crucial segments of the semiconductor manufacturers and numerous suppliers of electronic components. In World War II we had time to construct new armament plants, but with today's nuclear and sophisticated weapon systems, we will need instant replacement of our weapons stock as the battle conditions demand. Free trade is an enemy of preparedness.

Under our Constitution we have mandated free trade between the states. In theory, if one of the states is the most efficient producer of some item of manufacture or agriculture, it deserves, and all the citizens benefit, from the prosperity it brings to that state. Nevertheless, there are numerous examples (for instance, milk prices in New York City) of local tariffs to preserve local industry at the expense of the consumer. However, we do have free trade between the states and free movements of our citizens. Free trade is possible and worthwhile under a constitution and with the obligation for a common defense.

"The first duty of a country is survival. This indispensable goal cannot happen with free trade."

The free trader seems willing to give up our steel and TV industries to the countries willing to import our agricultural products without tariffs. The exchange has not only worsened our trade balance but it has perilously weakened our defense posture. Thus my proposal for 100 percent tariff on imports. True, the good life and the cheap imports may fall considerably, the populace will grumble and the politicians will play politics, but freedom is worth any price.

Having imposed the 100 percent tariff and preserved the smokestack industries, what course should we pursue for the future? First and foremost, we need to meet or beat the competition. Our students are taking the easy road to a degree (as they did in my school years). A Korean high school student has to take 18 mandatory subjects each semester; science and math are always included. Why don't we set the same goals? Degrees should only be awarded to the students able to pass through an exacting examination picket fence. Today we are selling off our capital assets in order to live beyond our means. Tomorrow's reckoning will come as surely as the dawn (trite phraseology but true). Government must favor industry R & D without antitrust legal barriers. Above all, the public should coddle and love the manufacturer, breathe deep his pollution, ignore the noise and eyesores and revel in the higher living standard and guarantee of freedom ensuing from these currently unpopular beasts!

To summarize: I suggested a 100 percent duty imposed over a five-year period as a shield to allow our native industries time to recover their lost markets and products. The final import duty can be set at a level that will allow the manufacturers to survive, along with enough competition from imports to keep them honest. Free trade is beneficial only to political entities under a common defense umbrella.

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Single-mode fiber-optic technology

By Douglas J. Eccleston
Manager, North American Applications Engineering
Telecommunications Products Division, Corning Glass Works

You have just left a management meeting where a radical decision was made. For the first time, a system design analysis has proven-in optical fiber. Your cable system's upgrade, scheduled for next year, will include fiber-optic distribution all the way to nodes in the neighborhoods.

Single-mode fiber, with its virtually unlimited bandwidth and low loss, seems to be the way to go, but you have a question about fiber technology—namely, are all single-mode fibers created equally? In fact, depressed-clad and matched-clad single-mode fibers are roughly comparable except for bend performance. In bending, matched-clad fibers have equivalent or better performance in the normal operating regions, but show higher losses in loops much smaller than the minimum bend recommended by any fiber manufacturer. This minimum recommendation is out of consideration for bend-induced stresses.

In 1970, when the first practical low-loss optical fiber was developed, it was actually a single-mode fiber. However, the laser diodes required to power single-mode were not yet commercially ready and splicing technology was not advanced enough. In fact, for these reasons, multimode fibers, with their larger cores, were the first fibers to be installed and transmit commercial traffic.

These early single-mode fibers were made by the inside vapor deposition (IVD) process, which requires a pre-made silica tube that becomes an integral part of the finished fiber. The IVD process most commonly used today is the modified chemical vapor deposition (MCVD) process.

MCVD starts with a previously made glass tube into which layers of glass soot are deposited. The soot (pure, ultrafine glass dust) is built up in layers. This pre-form is then consolidated by heating. The resulting blank is heated and drawn into hair-thin fiber.

The original glass tube, now the outside of the blank, forms the cladding or outside of the fiber. And herein lies a serious concern. The glass tube that is required to start the IVD is actually the weakest link in an IVD/MCVD fiber. The manufacture of this glass tube, by a melting process, is much less controlled than the fiber manufacturing process, making the glass tube inherently less pure. Impurities are a source of material weakness in fibers. Since it isn't possible to eliminate all impurities in the glass tube, fibers with an outer surface formed of tube glass tend to have more flaws than those whose outer surface is formed of soot. Fibers with more flaws are intuitively weaker and more susceptible to breaks.

One significant hurdle to overcome in improving the process was the shortcomings and limitations imposed on the process by the need to use a tube. A new process, known as *outside vapor deposition* (OVD), was developed. With OVD, instead of beginning with a tube and filling it with layers of soot, you begin with a thin rod. Layers of pure soot are built up on the outside of the rod—beginning with the core glass, then changing the chemical formula for the cladding glass. The rod is removed later. In essence, an OVD fiber is manufactured from the inside out, instead of the outside in. The core is made first; the cladding follows. Every part of the fiber is made using the same ultrapure process. The OVD process yields optical fibers with inherently fewer flaws, since the procedure successfully eliminates the need for the impure silica tube.

Figure 1: Single-mode designs

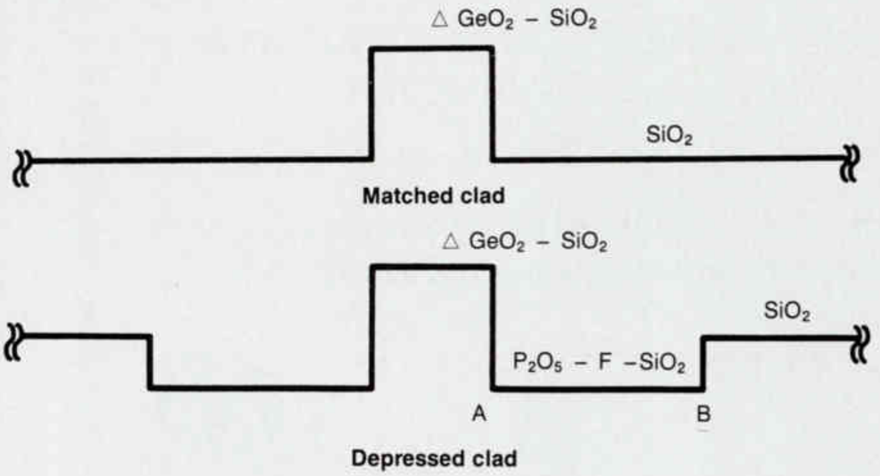
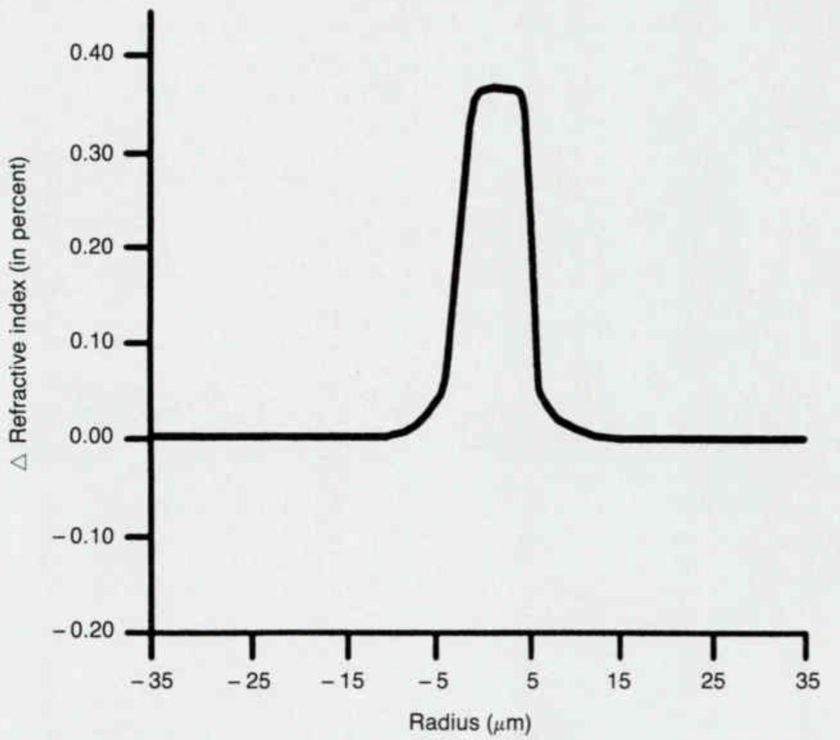


Figure 2: Typical refractive index profile



All fibers not created equal

As a result of the two manufacturing processes (OVD and IVD), there are two distinct single-mode optical fiber designs — matched and depressed clad (Figure 1). The main difference here is in the boundary between the core (or light-carrying path of the fiber) and the cladding (or outer glass layer of the fiber). In all single-mode fiber, it is normal for the fringes

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of the light mode, or ray, to travel in the cladding. Thus, where light travels in the cladding, you must have optical quality glass — as pure as possible. To accomplish this, the optical quality glass must be deposited both for the core and the light-carrying portion of the cladding.

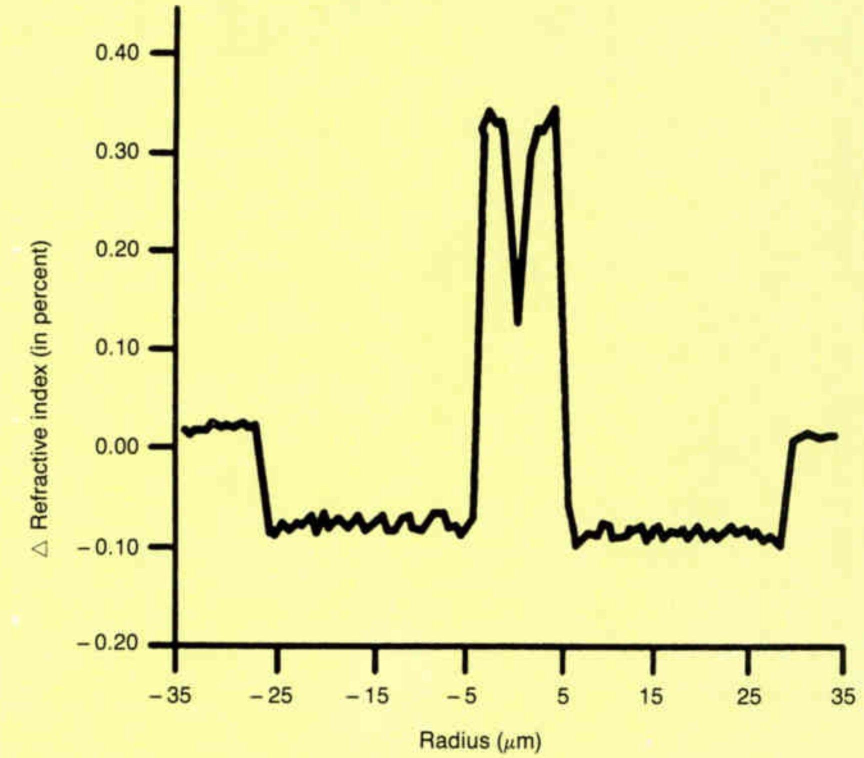
With OVD, this is not an issue; all of the glass is deposited. There is a clear "match" of the index of refraction between the outermost cladding and the light-carrying portion of the cladding (Figure 2). Thus, OVD yields a matched-clad fiber — a fiber that can efficiently move light in the core/clad boundary.

However, for manufacturers using IVD, creating this efficient light-carrying core/clad boundary is more difficult because of the lower purity of the glass tube. Depositing silica that is pure enough inside the tube isn't practical without adding chemicals to the glass. Historically, the ability to control this "doping" of the silica has not been precise enough to ensure an exact match of the index of refraction to that of the tubing material. Without this exact match, the tube portion of the cladding in IVD fibers may have a lower index, thereby producing a multimode waveguide. To eliminate this problem, IVD manufacturers "depress" the soot-deposited cladding (Figure 3) to ensure the light travels down the core of an IVD fiber as effectively as it does in an OVD fiber.

This distinction becomes important if you require lot-to-lot consistency among fibers. Matched-clad OVD fibers do not require this complex and hard-to-control depressed-clad region but utilize the simplest and easiest to control fiber design — and yield fibers with the most consistent performance.

An additional benefit of eliminating the tube is that you also eliminate the dependence on melted-tube geometry. In fact, OVD yields fibers with better geometric control of physical parameters such as core concentricity and outside-diameter roundness. This translates to very low joint loss — an important consideration for today's fiber installations. Additionally, the matched-clad design coupled with the OVD manufacturing technology yields fibers with lower power loss, smoother index profiles and longer commercially available unspliced lengths on the market today.

Figure 3: Measured refractive index profile on depressed-clad single-mode fiber



Bending performance

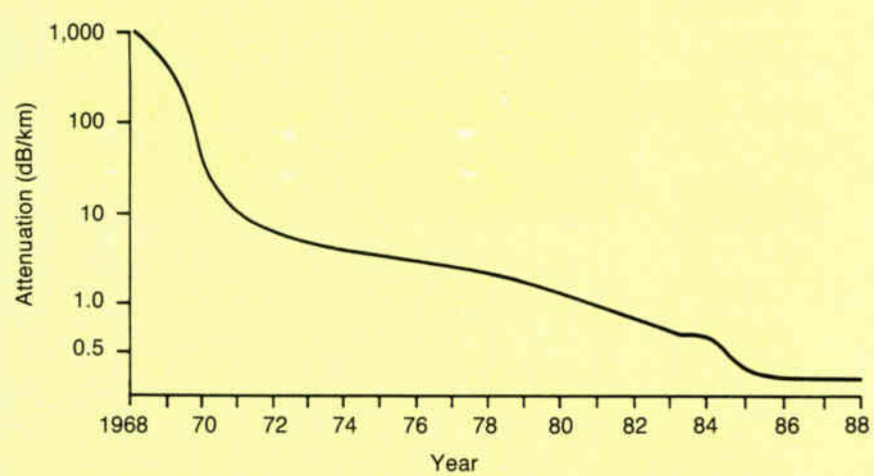
One key performance difference between matched- and depressed-clad fibers is their relative bending performance. Generally, you'll get better bend performance with matched-clad fibers in the normal operating regions. Specifically, matched-clad fibers exhibit lower losses at bend diameters greater than 2 inches (50 mm) — an important consideration since this is the region used most often in daily practice. Depressed-clad fibers generally exhibit higher losses in this region.

At large-diameter bends greater than or equal to 3.2 inches (80 mm), such as those commonly found in stranded cable designs, matched-clad fibers also exhibit lower losses. Helical stranding of fibers into cables introduces extra fiber length in the cable, minimizing stress on the glass. Due to the poor performance of depressed-clad fibers at these large-scale bends, they must be laid straight into a cable. This potentially can result in the fibers being installed under permanent stress.

The only region where matched-clad exhibits higher losses than depressed-clad is at tiny bend diameters of less than 1 inch (25 mm) — considerably smaller than the minimum bend radius recommended by any fiber manufacturer (which is about 2 inches or 50 mm). A minimum bend diameter is recommended to eliminate the risk of spontaneous fiber fracture over time. If you subject a fiber to tiny bends (less than 1 inch or 25 mm), both depressed- and matched-clad exhibit unacceptably high losses at 1,550 nm.

The higher loss of matched-clad fibers at those tiny bend diameters is a blessing in disguise. If a fiber is accidentally bent too tightly (below the recommended 2-inch or 50-mm radius), matched-clad provides a high loss "alarm" to alert the installation crew to a potentially serious problem with long-term mechanical reliability. Depressed-clad provides no such alarm, thereby increasing the likelihood

Figure 4: Progress in reducing attenuation



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that a too tightly coiled fiber may experience breakage at some undefined future date.

Finally, it's important to consider the minimum cable repair length when discussing the relative merits of matched- and depressed-clad. Available data show that if single-mode fibers are bent to diameters typical of those found in splice enclosures (2 to 3 inches, or 50 to 75 mm), matched-clad attenuates higher order modes much more quickly than depressed-clad. This is key in repair sections where it's possible that higher order modes may be generated at poorly made splice joints and then coupled back into the fiber at the next splice joint. If the higher order modes are not attenuated, they can result in modal noise and degrade system performance.

With matched-clad, the fiber bend (after the splice joint) in the splice enclosure will quickly attenuate any higher order modes that may be present before they leave the splice enclosure. The same situation can only be avoided in depressed-clad fibers by specifying a minimum repair length. This length of cable, typically 20 meters for depressed-clad, is sufficiently long to attenuate any higher order modes before they reach the second splice in the repair section.

However, burying or storing this extra 20-meter cable section can be a problem, especially during emergency repairs when it's critical to get the network up and functioning in the shortest amount of time. With matched-clad, there's no need to specify a minimum repair length to avoid modal noise—and no need for the extra 20-meter cable section.

Fiber advancements

Today's single-mode fibers are light-years more advanced than the primitive lightguides first developed in 1970. Advancements have been numerous in the areas of geometric control, attenuation, water content, strength and consistency—all resulting in a product optimized for cable TV applications.

Given improvements in manufacturing technology, fibers have markedly improved geometric tolerances. This ensures ease of interconnection by either fusion or mechanical splicing.

Fiber losses have improved dramatically since the 20 dB/km breakthrough in 1970 (Figure 4). Today's losses are 0.35 dB/km at 1,310 nm and 0.25 dB/km at 1,550 nm. Operation at both the 1,310 nm and 1,550 nm wavelengths now is common. Lower loss fibers enable unamplified transmission distances of more than 20 miles, substantially reducing signal degradation caused by repeated reamplification.

Additionally, this increased amplifier spacing translates into fewer in-line or remote electronics and correspondingly fewer system failures, thereby yielding lower maintenance costs.

Today's single-mode fibers have lower water content as a result of improved manufacturing processes. This is another factor making possible the lower loss at 1,310 nm, and adds flexibility in selecting light sources around the 1,310 nm window of operation. ■

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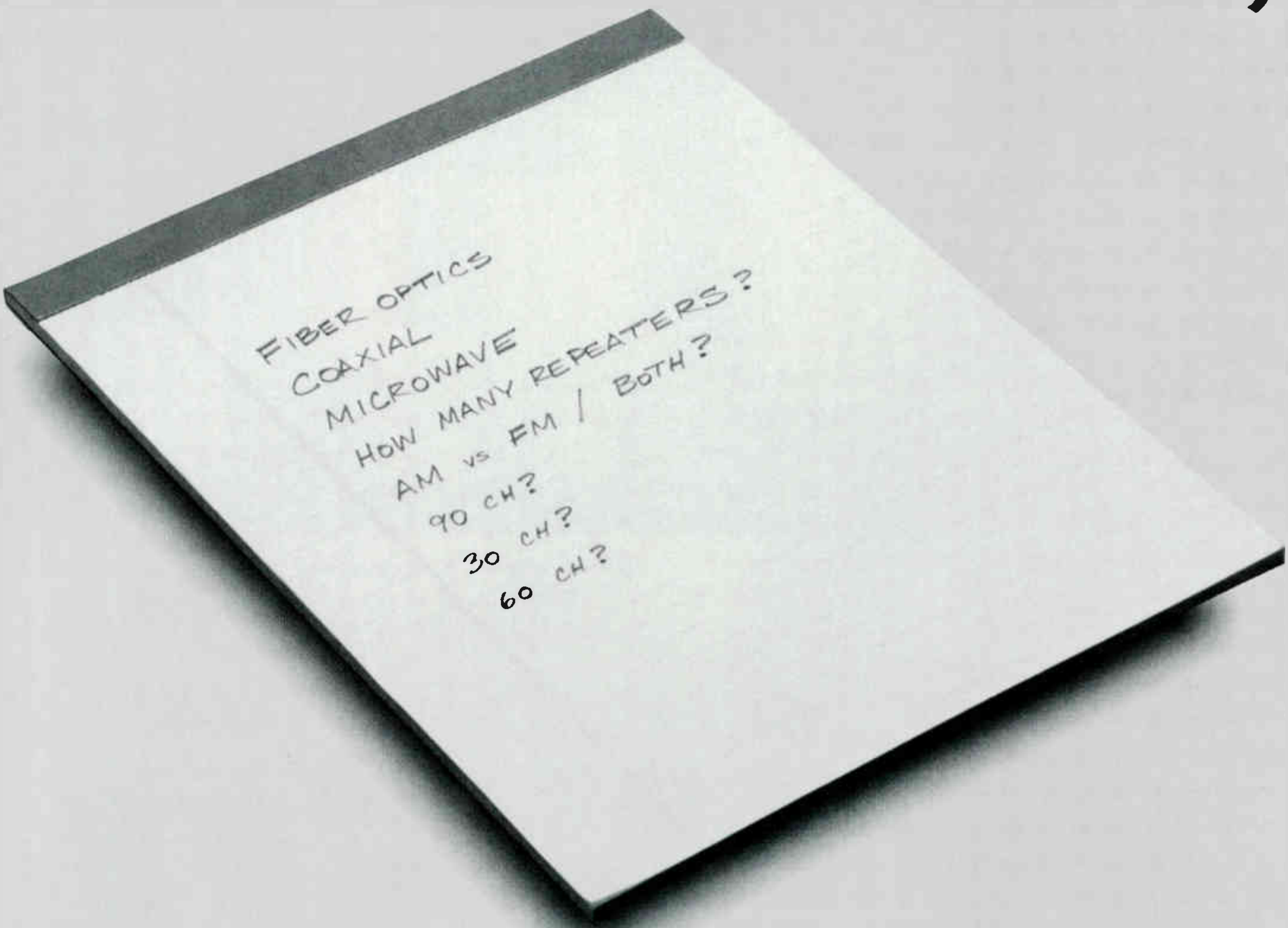

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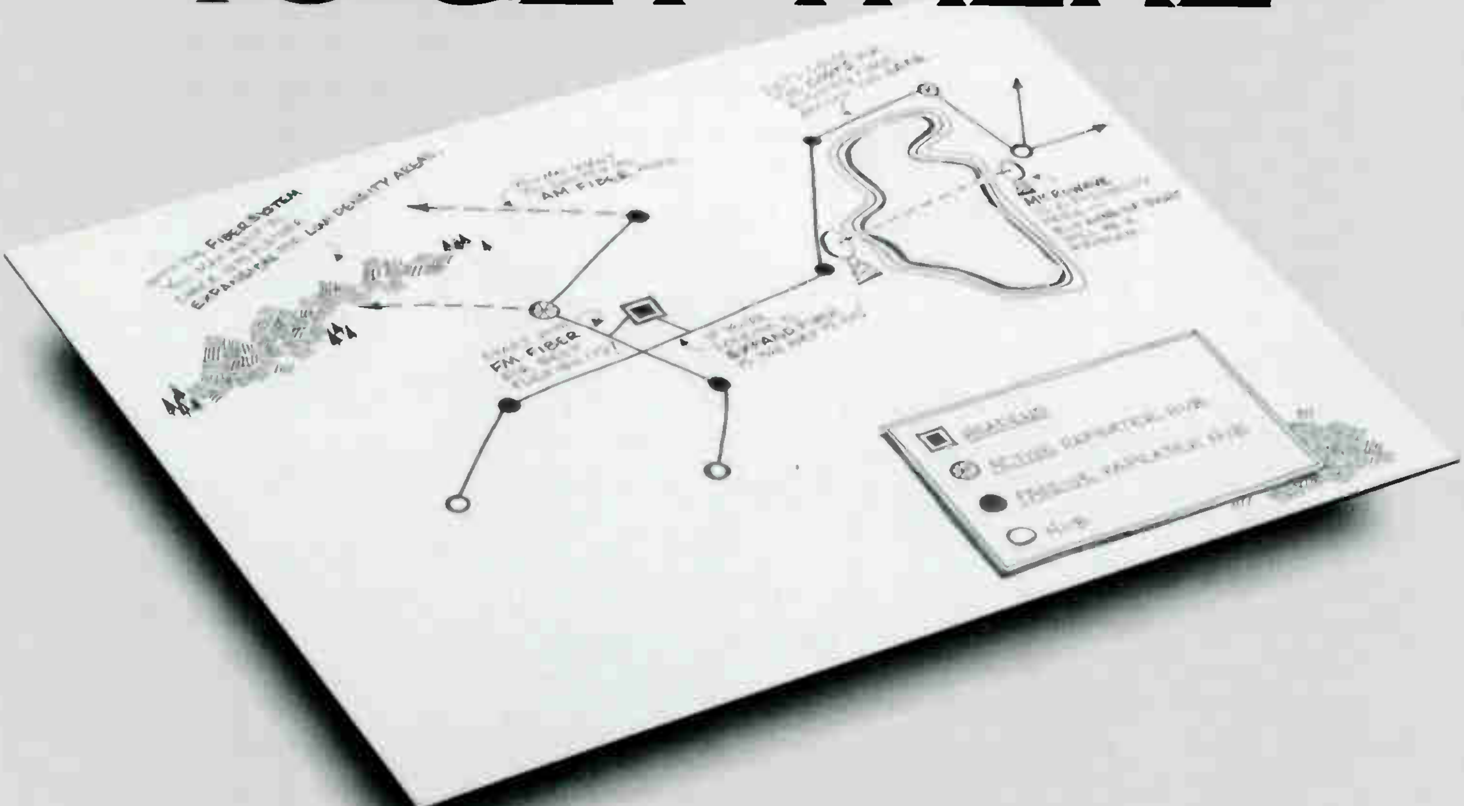

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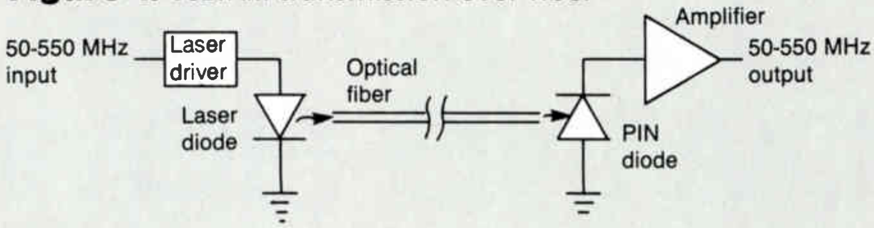
Figure 1: VSB/AM transmission over fiber



AM fiber-optic trunks

By David Grubb III
Manager, Analog Programs
Jerrold Broadband Engineering Group, General Instrument Corp.

A certain amount of attention has been focused on the possibility of carrying VSB/AM (vestigial sideband/amplitude modulated) signals on optical fiber links. This has been proposed as an ideal way to implement a "fiber backbone"[1] system because of the apparent simplicity and compatibility with existing CATV practices.

Figure 1 shows a block diagram of the proposed system. The standard CATV RF spectrum is used to intensity-modulate a laser diode. The output of the laser travels through the fiber to a photodiode at the receiver, which converts the optical signal to an electrical current that is buffered by the receiver amplifier. The output of the amplifier is used to feed the CATV distribution system.

Obviously, questions arise as to the limits of AM video transmission over fiber. Making the assumption that the lasers can be linearized to provide acceptable distortion performance, the question then centers on the theoretical limits on system noise performance. In order to determine this, two things have to be resolved: the upper limit on input power for single-mode fiber and the lower limit on the system noise floor.

Table 1: C/N limit assumptions

	Case 1 Theoretical limit	Case 2 Practical limit	Case 3 Available DFBs
Laser coupled power (mW)	10	5	1
m	1	0.5	0.35
Photodiode quantum efficiency (in percent)	100	86	86
Laser RIN (dB/Hz)	No laser noise	−160	−145
Amplifier transimpedance (Ω)	No thermal noise	1,000	1,000
Amplifier noise factor		2	2

Table 2: C/N in single-laser AM fiber-optic systems

Link loss in dB	C/N (80 channels) in dB Theoretical	Practical	Available
0	77.085	62.499	47.306
1	76.085	62.181	47.167
2	75.085	61.804	46.988
3	74.085	61.361	46.761
4	73.085	60.846	46.470
5	72.085	60.254	46.101
6	71.085	59.580	45.637
7	70.085	58.820	45.057
8	69.085	57.973	44.346
9	68.085	57.037	43.490
10	67.085	56.012	42.481
11	66.085	54.896	41.320
12	65.085	53.693	40.015
13	64.085	52.403	38.580
14	63.085	51.030	37.033
15	62.085	49.577	35.392
16	61.085	48.050	33.674
17	60.085	46.454	31.895
18	59.085	44.797	30.069
19	58.085	43.084	28.204
20	57.085	41.323	26.310

Power limit

There is a non-linear phenomenon called *stimulated Brillouin scatter* (SBS) that limits the amount of power that can be coupled into a fiber. When the SBS threshold is reached, the energy in the forward (signal) wave couples to a wave at the slightly longer wavelength propagating in the reverse direction. The result is that the forward wave, which is the desired signal, is severely attenuated. Because it is a relatively narrowband phenomenon, this only affects narrow line-width sources.

Unfortunately, the type of laser that seems best suited to this application is a distributed feedback (DFB) laser, which has a very narrow line width. DFBs are preferred because they typically have very low relative intensity noise (RIN). Conventional Fabry-Perot laser diodes do not seem to be capable of comparable noise performance. The SBS threshold can be calculated using Formulas 1 and 2[2].

$$P_{TH} = 21\left(\frac{A_e K}{g_B L_e}\right) \qquad (1)$$

$$L_e = \frac{1 - \exp(-\alpha l)}{\alpha} \qquad (2)$$

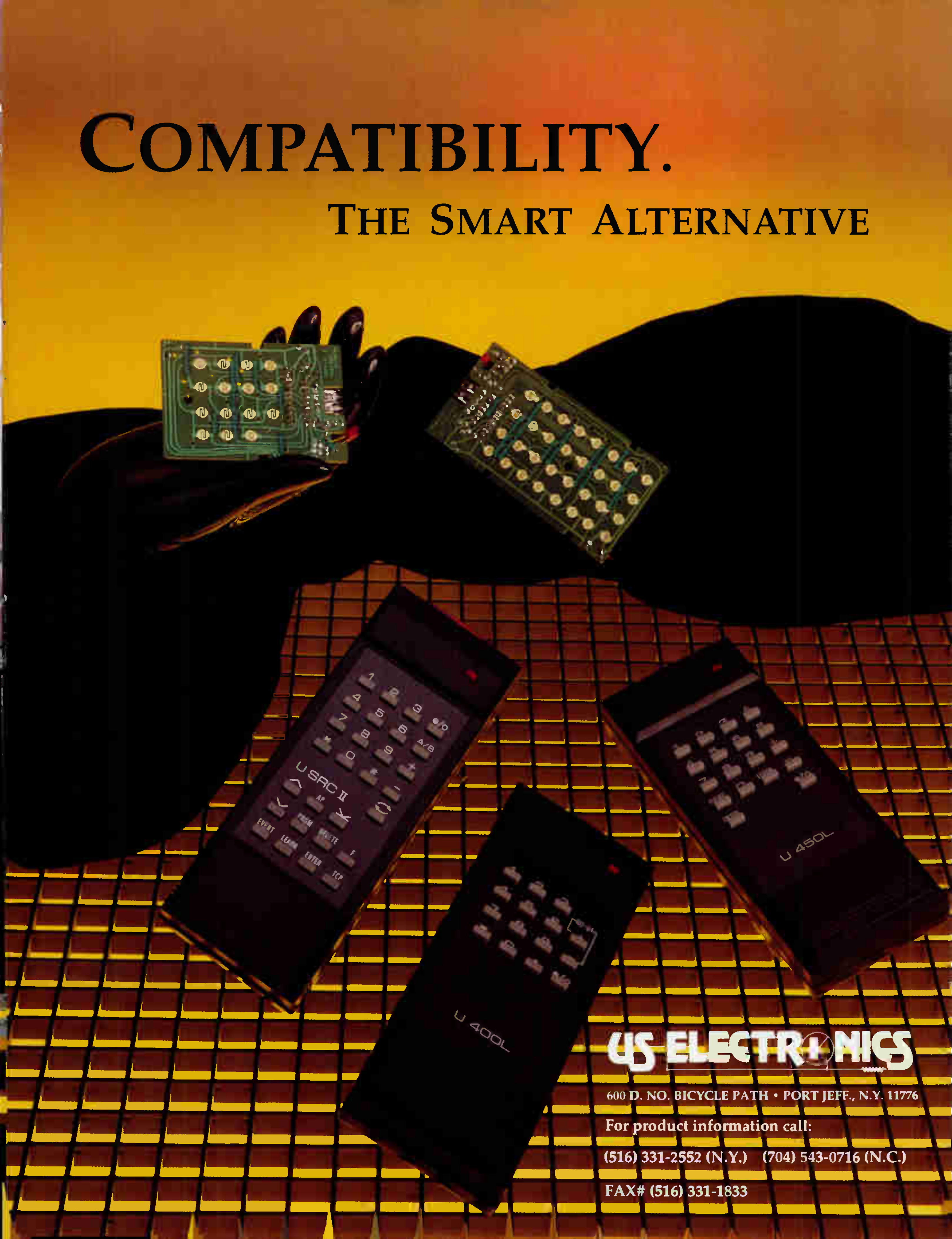
where:
A_e = effective core area of the fiber
K = polarization factor ($1 \leq K \leq 2$)
g_B = peak Brillouin gain coefficient (4.6×10^{-11} m/W)
L_e = effective interaction length
α = fiber loss (m^{-1})
l = fiber length

Figure 2 shows the SBS threshold for single-mode fiber as a function of fiber length for two different attenuation rates corresponding to 1,310 and 1,550 nm operation. It is assumed that the effective core diameter is 11.5 μm and that K = 2 (complete polarization scrambling). This shows that for long links the maximum input power at 1,310 nm is about 10 mW.

System noise and performance

In a fiber communication system there are three types of noise: quantum, laser RIN and receiver thermal noise. Theoretically, the laser RIN and the receiver thermal noise can be reduced because they are a function of component design. Quantum noise (also called *shot noise*) cannot be eliminated or reduced because it is inherent in the process of detecting light in a photodiode due to the statistical nature of the process. For a given optical power, wavelength and photodiode quantum efficiency the average rate at which electron-hole pairs are generated can be calculated. The noise arises from the fact that both the actual number of pairs generated in any unit of time and the generation time of any given pair are random processes. This causes a broadband noise current at the output of the photodiode. The mean-squared noise current is proportional to the output photocurrent.

The carrier-to-noise (C/N) ratio at the output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of the link can be calculated using Equation 3[3].

$$C/N = \left(\left[\frac{1}{2 \times n} \right] \times \left[(m \times R \times P_r)^2 \right] \right) \div \left(\left[(2 \times e \times B_v \times R \times P_r) + (RIN \times B_v \times [R \times P_r]^2) \right] + \left[\frac{4 \times k \times T \times F}{R_z} \times B_v \right] \right) \qquad (3)$$

where:

- n = number of channels
- m = RMS optical modulation index
- B_v = video bandwidth
- e = charge of an electron
- k = Boltzmann's constant
- T = receiver temperature
- RIN = laser noise
- P_r = received optical power
- R = photodiode responsivity
- R_z = receiver transimpedance
- F = noise factor of preamp

The C/N is calculated in terms of mean-squared currents at the input of the receiver amplifier. The terms before the division sign represent the mean-squared signal current of each video carrier. The terms after the division sign are due to quantum noise, laser noise and the receiver thermal noise (transimpedance receiver) respectively. Three sets of conditions are considered. The number of channels (n) is 80 in all three cases and the receiver is assumed to be at room temperature. The assumptions are summarized in Table 1.

The estimated laser performance for the practical limits column is based on recent trends in this area. By definition, the RMS modulation depth cannot exceed one and for real signals it has to be somewhat less to avoid clipping on the peaks of that signal. The usable modulation depth for today's lasers is somewhat lower due to distortion. The photodiode quantum efficiency of 86 percent corresponds to a responsiveness of 0.9 A/W at 1,310 nm. This level of performance is available today through selection. Although the high-performance receiver assumed in Cases 2 and 3 does not yet exist with the low distortion that this application demands, it is assumed that it could be designed using available components. In this case, the modulation depth is reduced by 3 dB as an approximation of the penalty due to the distortion characteristics of available lasers.

Figure 2: Single-mode fiber power limit (due to stimulated Brillouin scattering)

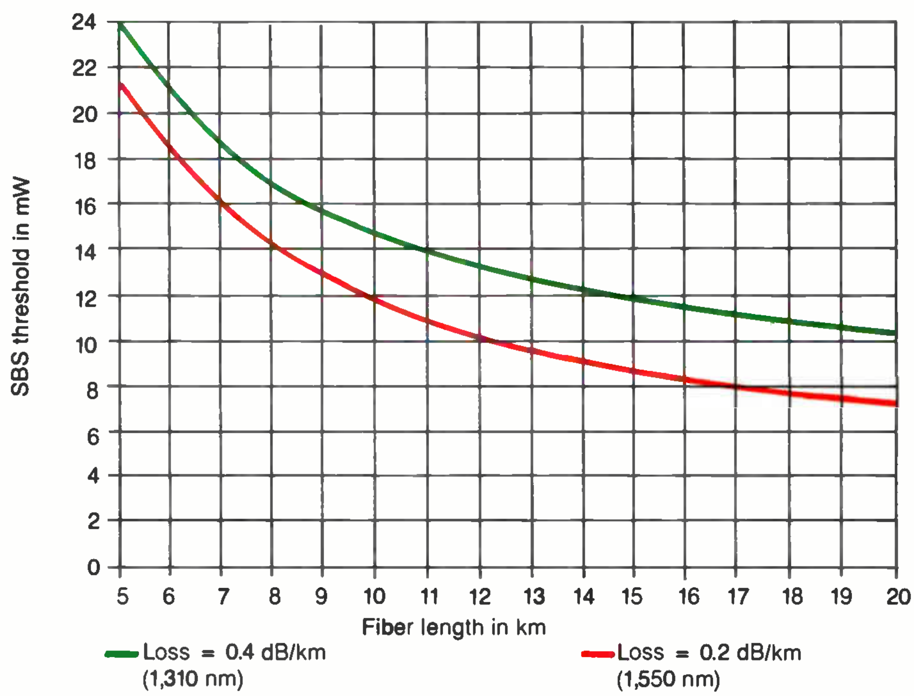
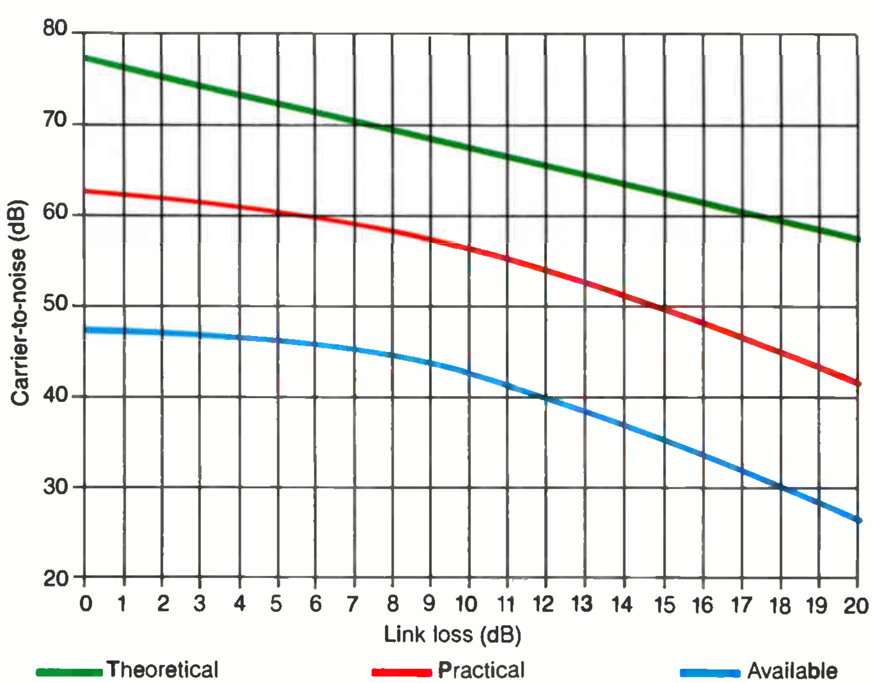


Figure 3 and Table 2 show the output C/N as a function of link attenuation for the three sets of assumptions. A link loss of 10 dB corresponds to about 15 km, assuming 0.4 dB/km of fiber loss, 0.1 dB/km of splice loss, 0.5 dB loss for a connector pair at the transmitter and 2 dB allowance for aging and repair, indicating that the theoretical limits of the technology are well above desired performance levels at 15 km. The "practical" performance limit at 15 km is 56 dB C/N for 80 channels, showing that the goal of a single-laser AM fiber trunk carrying 80 channels with good performance seems to be achievable, although it may take a few years to get there at a reasonable cost.

Figure 3: AM fiber-optic trunks (80-channel single-laser systems)



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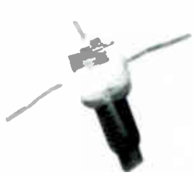

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Multichannel AM on fiber: A status report

In the past year a considerable interest in AM (amplitude-modulated) transmission of multichannel video on fiber has grown. The reason is mainly direct compatibility of the modulation format with existing coaxial CATV plants. This is especially true for scrambled signals, which cannot be transmitted easily when FM (frequency modulation) is used. Many performance numbers have been mentioned, optimistic as well as pessimistic ones. Synchronous developed an AM laser transmitter and optical receiver and tested them using a standard test setup for CATV amplifiers: a multicarrier generator, filters and amplifiers, and a spectrum analyzer. Here are some of the results.

By Vince R. Borelli
President
And Hermann Gysel
Director of Engineering, Synchronous Communications Inc

Figure 1 shows the test setup for a 42-channel AM link. The signal source is a Dix Hills multicarrier generator. All measurements are done with unmodulated (or CW) carriers. The used channels are Ch. 2 (55.25 MHz) up to Ch. HH (343.25 MHz). Ch. J (217.25 MHz) is switched off for the measurement of composite triple beat (CTB). Figure 2 shows the transmit spectrum. The multicarrier signal generator feeds a Synchronous AM laser transmitter LXAM-01. The optical signal goes through a 7 km-long fiber spool and then into an optical attenuator. The receive power is −2 dBm. It is fed into an optical receiver (Synchronous ORAM-01).

The results

Figure 3 shows the received spectrum. The Channels I and J are filtered out. Ch. J is switched off. The marker (dot) shows the CTB ratio to be 64.7 dB. The other spurs are composite second-order products. They are at least 62 dB down. The uncorrected carrier-to-noise (C/N) ratio is 73.5 dB. The correction factors are:

− 2.5	dB	for peak-log detection and Gaussian filters of the spectrum analyzer
− 21.5	dB	from 10log (30 kHz/4.2 MHz)
+ 1	dB	for analyzer noise floor being 6 dB below measured noise
− 23	dB	total correction factor

The C/N is therefore 73.5 − 23 = 50.5 dB.

If better performance is to be achieved, a lower number of channels has to be transmitted. We tried the following split: Laser 1 transmits the low-band, mid-band, and high-band. Laser 2 transmits the super-band and part of the hyper-band up to Ch. HH. Figure 4 shows the transmit spectrum of Laser 1. Figure 5 shows the received (filtered) spectrum. Ch. F (151.25 MHz) is switched off for CTB measurements. CTB is 64.8 dB down, composite second-orders at least 62 dB. The laser drive level was increased by 4 dB, resulting in a C/N of 54.5 dB.

Figure 6 shows the transmit spectrum of Laser 2; Figure 7, the received (filtered) spectrum. Ch. U (283.25 MHz) is switched off for CTB measurements. CTB is 64.8 dB down, composite second-orders are out-of-band. The laser drive level was increased by 3 dB, resulting in a C/N of 63.5 dB.

In a general form the laser drive level is a function of the number of channels:

$$P_{drive}/\text{channel} = P_{drive}/(1\ \text{channel}) - K \times \log(N)$$

Figure 1: Test setup for a 42-channel AM link

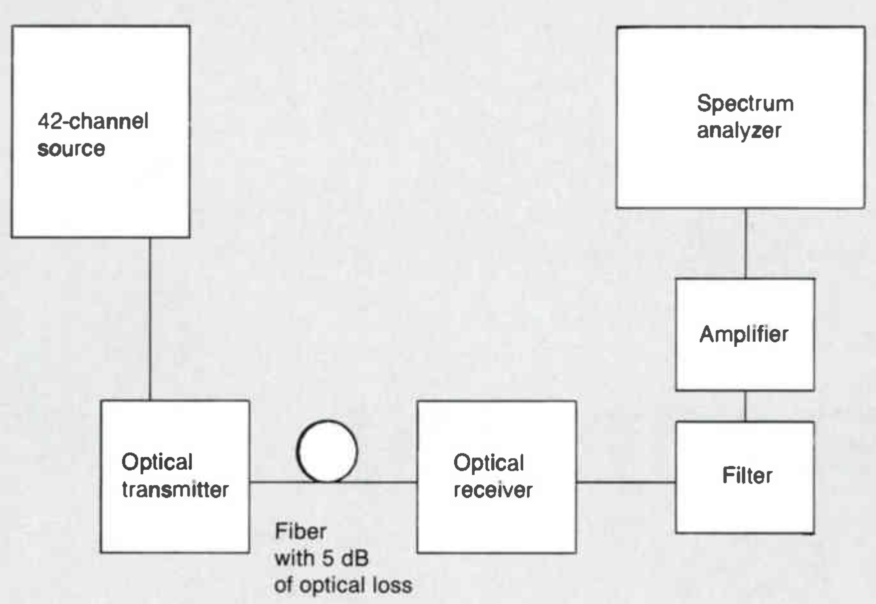


Figure 2

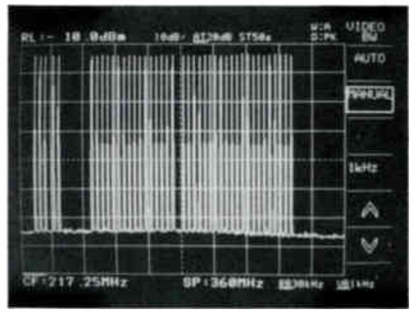


Figure 3

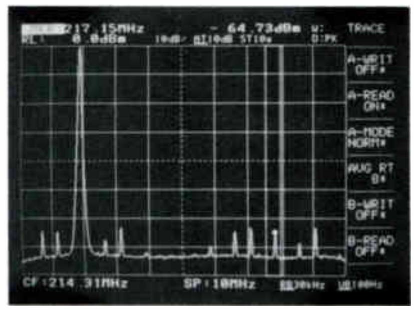


Figure 4

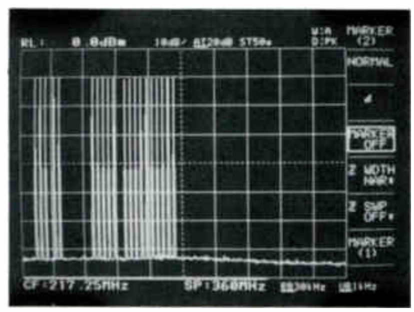
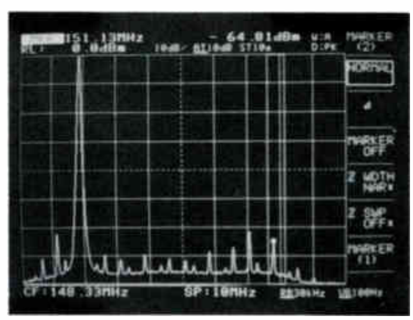


Figure 5



Reader Service Number 21.

New LAN OTDR maps fiber optic cable routing

The TD-9960 high resolution OTDR is available with disk-drive mass data storage for easier cable system documentation and trouble-shooting

Laser Precision's new high resolution optical time domain reflectometer for LAN applications offers a wide range of features and capabilities. The mass data storage option enables you to store the test trace of the total length of each fiber optic cable link on convenient floppy disks. Upon retrieval of a trace, you can obtain readout of dB loss and location at any point along the trace, such as at a splice or connector. You can also expand any point of interest along the trace for close analysis. This can be done on the TD-9960's CRT, or on an IBM type personal computer with the TD-958 OTDR emulation software to provide an easy method for maintaining and trouble-shooting the cable system. The full ASCII keyboard enables you to add notes, such as date, location, and code, as well as retrieve any trace on the floppy disk. This convenient method for mapping the routing of the cable system also makes it easier and faster to pinpoint any location of a cable problem.

The superior capabilities of Laser Precision's LAN OTDR are to the real benefit of the user. It has the capability to zoom in on any area along the total length of the trace, without having to rescan and reaverage the data. The TD-9960 eliminates the time consuming and irritating requirement of having to constantly rescan. During splicing, only a single marker is required to establish the splicing location on the TD-9960's CRT. This position is maintained, going from fiber to fiber, during sequential splicing. No reprogramming required. The TD-9960's real-time display with continuous dB readout makes it easy to optimize the fiber core alignment prior to splicing.

The TD-9960 features plug-in modules for 850 and 1300nM, ±0.01% base accuracy, 0.01dB resolution, 20dB backscatter range, 10cm resolution, short 3 meter dead zone which is compensated by the pigtail, 40 kilometer distance range, real-time display, dual cursers, built-in digital X-Y plotter, and available IEEE-488 or RS-232 interface, as well as the TD-959 mass data storage option.

For more information, contact LASER PRECISION CORPORATION, 1231 Hart St., Utica, NY 13502, or call (315) 797-4449, or telex: 646803

At a low number of channels (N less than 12) the drive level per channel into the laser has to be reduced by a factor of N. Therefore K is 20. With a higher number of channels K is decreasing to 15. Figure 8 shows the measured drive level into the laser transmitter. A second curve shows the corresponding value of K in the previous equation.

Varying the optical receive power does not affect C/N as long as laser relative intensity noise (RIN) is the predominant noise source. This is normally the case with receive powers above 0 dBm. Between 0 and −5 dBm we typically find a quantum noise dominated 1:1 dB change in C/N vs. input power. Below −5 dBm, electrical receiver noise predominates, which eventually ends with a 2:1 dB change in C/N vs. optical input power.

Interpretation of results

The availability of laser diodes with RIN numbers of −150 dB/Hz and better makes multichannel AM transmission on fiber possible with channel numbers that have never before been achieved, when more traditional laser structures were used. High loss budgets (like the ones we see when using FM) are not feasible yet, the main limitation being optical transmit power.

Fiber installations have to be designed for minimum loss. High return loss connectors and splices have to be used if the laser RIN is not to be degraded.

The upper limit of transmit power will be set in the future by non-linear effects in the fiber itself and is expected to be around 50 mW. There is therefore room for a substantial improvement in loss budget if the laser manufacturers are motivated to come up with higher power laser designs. For now 42 channels can be transmitted with a 50 dB C/N over up to 7 dB optical loss. If better performance is needed (approximately AML microwave quality) two links can do the job, one transmitting low-, mid- and high-band and the second the super- and some high-band channels.

Figure 6

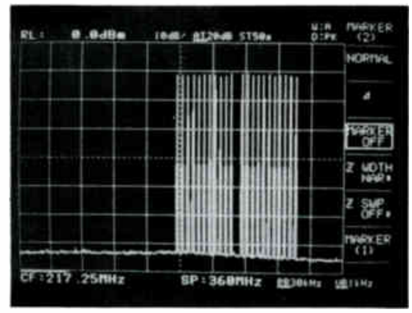


Figure 7

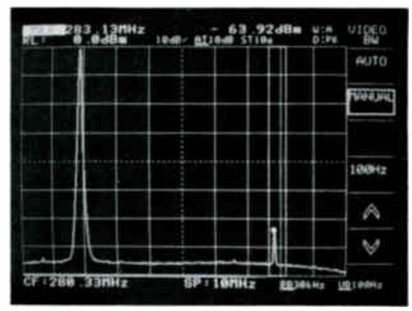
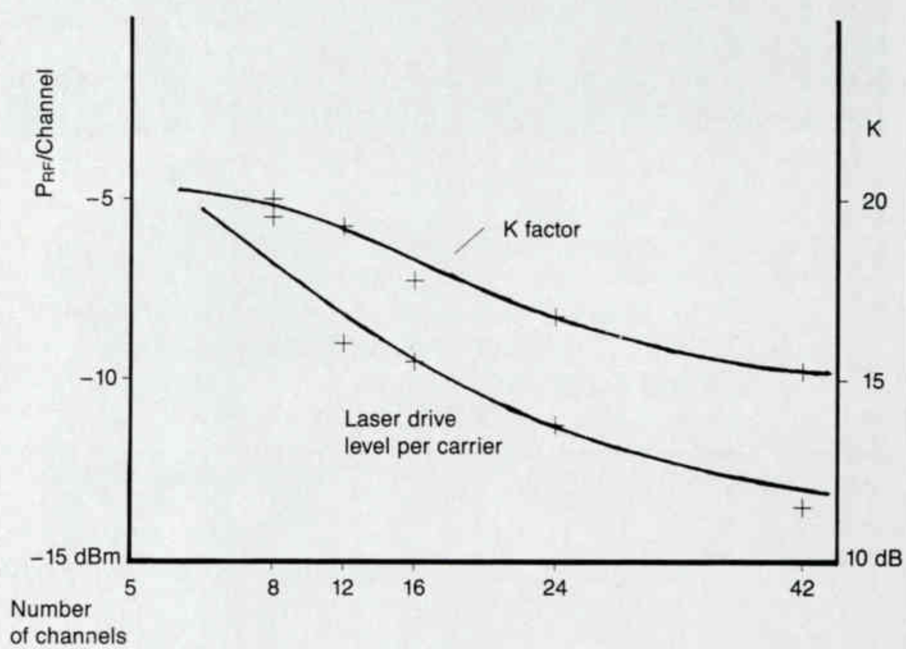


Figure 8: Laser drive level and K factor as a function of the number of channels



Fiber-optic supertrunking

By Britt McQuaide
Independent Communications Technician and Consultant

Different considerations must be taken into account when designing and building a fiber-optic system. These include cable use, design and routing as well as placing and splicing methods. We'll discuss each of these.

As a design consideration, single-mode fiber offers greater advantages than multimode. This is because of the greater bandwidth and lower attenuation single-mode offers. The lower attenuation will allow greater distance between headends and/or hub sites without the need to install expensive repeaters.

The number of fibers in the cable will be determined by how the system will be used. If the operator wants to lease fiber to other businesses (long distance carriers, government agencies, corporate businesses, etc.), additional fibers would be included in the cable. This is usually limited to densely populated areas due to increased traffic on the fibers. Factors such as channels per fiber, future growth expectations and the initial number of fibers also will help dictate the cable size.

Having made these decisions, the total number of fibers in the cable should be approximately double the number of "working" fibers. This is a common practice in the telephone industry, made justifiable by today's high quality fiber and lower prices.

The physical structure of the cable will be determined by how well protected the fibers are, ease of identification of individual fibers and the extent to which it is "craftsman-friendly." There are a variety of designs offered by competing manufacturers. Cables with a "loose tube" design (with color-coded tubes and fibers) offer the best protection, are easier to work with and do not have as many potential splicing errors as other designs.

The final factor concerning cable design will be determined by where the cable will be used. Many companies are using dielectric cable, which is non-metallic, for aerial use. This type will not conduct induced energy from lightning storms or nearby power lines; thus, service is not interrupted unless direct electrical contact damages the cable. Its lighter weight facilitates easier handling during placement.

If used in an underground or buried application, additional protection is required. A steel sheath and a strength member (made of steel or kevlar) will normally give the cable sufficient protection. The sheath provides "crush strength" against rocks, compacted soil and debris, as well as preventing rodents from chewing through the cable.

Determining the route of the cable is the next step. Relevant factors include the type of area (urban or rural), existing conditions and what applications are being used. Many systems take a different route from the existing coaxial supertrunk route and use the coax trunk as an alternate or backup route. This will be dependent upon whether both the coax and fiber are terminated or pass through the same locations.

Splice points should be approximated prior to the placement of the cable. Splice and cable slack locations should be well identified and accessible by a vehicle if possible. This will make it easier for any future work and allow personnel to have a quicker response time during emergencies.

Now, the construction of the physical plant can begin. The two most significant factors during the placement are the bend radius and pulling pressure of the cable. Custom pulling harnesses and other specialized tools are available and should be used to prevent damage to the cable.

In an aerial use, all existing poles should be inspected and replaced if necessary. This is also the time to place new poles if a different route is to be used. Fiber should not be overlashed to existing coax. Instead, a new strand should be placed specifically for the fiber. This will help reduce potential interruption of service when maintaining or wrecking out coax lashed to the same strand. Approximately 10 inches of slack should be left at each pole to provide additional strain relief for the cable.

When burying cable, the use of subduct provides additional protection and will give the owner flexibility in working with the outside plant

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in the future. This will increase construction costs, so decisions by management must justify the additional costs. With subducts, "slack points" also should be planned into the system. Whether buried vaults or pedestals are used, the slack points should be placed between splice locations. Depending on how far apart the splice locations are and through what type of area the cable route is going will dictate the number and location of slack points. These are beneficial for reducing extra splices required in the future (restoration), give access to the system if another cable is to be spliced going to a third location (minihub site, etc.) and can be used when the cable has to be moved or relocated.

For underground applications, subducts should be placed in an existing or new conduit. This will enable the use of one conduit to house many cables with each cable having individual protection. The number of subducts per conduit will depend on the diameter of the conduit and the company's future needs.

When placing cable at splice locations, considerable slack should be left coming from both directions. This slack should be carefully coiled and secured to avoid any damage. Enough cable length should be left so that craftspeople can strip back the correct amount of sheath at least two times (after the original opening) and still be able to work on the splice in a desirable work area (the inside of a vehicle, tent, etc.) at ground level. Given that splice locations create opportunities for human error, a form of insurance is provided by the additional slack. This gives the company and the craftspeople some "breathing room" when building or maintaining its cable system. The amount of slack left at splice locations will depend on which application is being used and how much excess cable is available.

One of the final phases is splicing and testing the cable. There are many considerations when it comes to splicing. Mechanical vs. fusion, splice loss budget, number of fibers to splice and number of locations are some of the major elements. Low loss splicing is made achievable by current high standards of fiber, fusion machines and mechanical connectors.

Fusion splicing is the preference of this author for supertrunk applications in the CATV industry. It permits the optimal aligning of the fiber cores and forms two fibers into one. With the correct arc current, temperature and time, the actual splice will be stronger than the fiber itself. Mechanical connectors rely on springs, epoxys and optical adhesives, depending on which type of connector is being used. Any mechanical connector will cause a reflection or "end spike," which may cause problems for AM transmission. Fusion splicing reduces this potential problem.

The two most common tests that are used on single-mode trunks are splice loss and span (end-to-end) testing. All splice loss measurements should be made from one termination point or the other. If mismatched fibers are being joined, splice loss measurements will need to be taken from both directions and then averaged. Once the cable is spliced from point to point, these will be the only access points to test from in the future.

The test equipment being used should be compatible with the fiber and optical transmission equipment in the system. Important factors required for accurate testing include the fiber size, average index of refraction, attenuation level (dB/km loss) and the operating wavelength of the system. Splice loss testing is measured by an OTDR (optical time domain reflectometer), while span testing should be completed with an attenuation test set, or a light source and a power meter.

OTDRs have been used for span loss testing but the measurements are not as accurate because of "dead zones" and the fact that the measurement is based on a reflection and not actual optical power. If the span consists of multimode instead of single-mode fiber, a bandwidth test also would be required.

Training and restoration

Training in emergency restoration is a necessity regardless of whether the company will contract out the construction, splicing and/or testing or elect to do it with their own personnel. In order to effectively reconnect a cable, restoration kits coupled with proper training are required. Training on restoration should occur yearly (or sooner) if the operating company is contracting out the splicing and testing of these cable systems.


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Fiber backbone: A proposal for an evolutionary CATV architecture

By James A. Chiddix
Senior Vice President of Engineering and Technology

And David M. Pangrac
Director of Engineering and Technology, American Television and Communications Corp

Supertrunks are used in our industry for point-to-point delivery of video signals. This is often necessary in large systems to provide high quality signals to major processing points feeding broadband signals to traditional CATV networks. In the past, supertrunks were often constructed using coaxial cable. A common practice was to frequency-modulate (FM) video signals at a variety of RF frequencies for carriage on such a trunk in order to minimize the effects of noise and intermodulation distortion on those signals from the broadband amplifiers necessary to compensate for coaxial cable losses. An alternative was often microwave distribution. Other applications for supertrunks are the delivery of video signals from remote earth station locations or between systems sharing common signal sources for local advertising insertion.

In recent years, a number of fiber supertrunks have been built by the cable industry[1,2]. These generally use frequency-modulated video and frequency division multiplexing (FM/FDM) of a number of signals onto a laser feeding a single fiber and have proven cost-competitive with other techniques. They are also highly reliable, provide very little signal degradation and have been shown to be capable of providing transmission for more than 20 miles without the need for repeaters.

The use of fiber video transmission technology in supertrunks has opened the door to the possibility of further uses. It has demystified the technology for CATV engineers and has provided practical experience with the design, construction and operation of fiber systems. It is natural that the cable industry should look for additional applications where fiber may be of use.

Limitations of current CATV systems

In order to understand ways in which fiber may be useful in CATV, it is important to focus on the limitations of present system architecture. Figure 1 illustrates the kind of "tree-and-branch" architecture used in current coaxial systems. All of the signals to be delivered to subscribers are gathered at a central headend. Typical sources are satellite earth stations, off-air antennas, videotape playback facilities and supertrunks providing delivery of signals from remote locations. At the headend the various video sources are vestigial sideband/amplitude-modulated (VSB/AM) at various frequencies, combined into a single broadband signal and transmitted over a single coaxial cable. This coax undergoes repeated branching until it passes down each street in the community. Broadband amplifiers are required every 1,000 to 2,000 feet in order to overcome cable and branching losses.

This architecture is quite straightforward and practical and is the historical basis of the cable industry. Nevertheless, it has a number of inherent problems and limitations. Fundamental to many of those problems is the fact that a number of broadband amplifiers are required to operate in series, or cascade, in order to transport signals to system extremities. Each of these amplifiers contains active components and must be provided with power, both providing limits to the reliability that can be attained. In addition, each amplifier adds noise and intermodulation distortions to the signals passing through it. The addition of these phenomena over long cascades of amplifiers gives rise to systems that have real limitations in the achievable reliability and quality of the service delivered to subscribers.

Another effect of tree-and-branch systems with long amplifier cascades is on system operating tolerances. In order to realize design specifications, each amplifier in such a system must be adjusted to provide very flat gain over a wide range of frequencies and must provide rather precise signal output levels. Such close operating tolerances require frequent alignment by highly trained technicians.

Another obstacle arising from this system architecture is a practical limitation on channel capacity. The types of coaxial cables used in CATV systems have a relatively wide potential bandwidth, perhaps approaching 1 GHz. Such cables have in fact been used for many years in small MATV (master antenna TV) systems to carry UHF channels, often at frequencies above 700 MHz. Typical cable systems operate with the highest frequency of only 300 to 400 MHz, however, with a few recent systems operating to 550 MHz. The difficulty in realizing the potential bandwidth of coax arises with the limitations of the broadband amplifiers themselves, particularly when those amplifiers are operated in cascade. It is expected that it will be difficult to push channel capacity dramatically further than today's numbers as long as systems employ long cascades of amplifiers.

If there is a pressing problem with today's CATV systems that might be addressed through the application of fiber, it is that posed by long cascades of broadband amplifiers in coaxial tree-and-branch structures. One constraint that must be recognized, however, is that of embedded investment. Most communities have been wired for CATV, and the enormous investment this represents is not one that can be casually discarded with the arrival of new technology. Thus, it seems logical that we

Figure 1: Typical CATV system

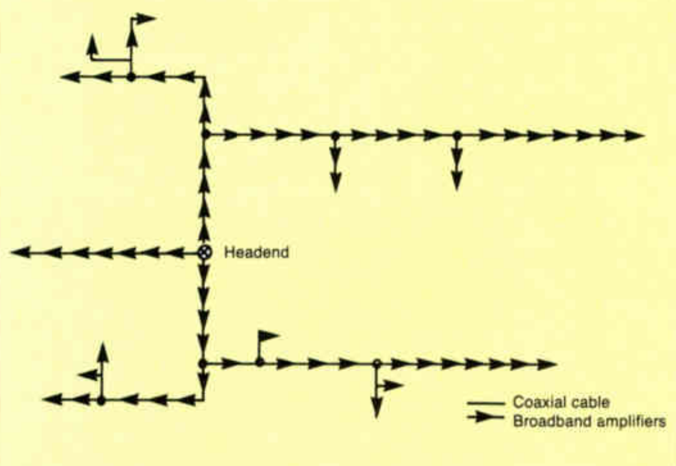
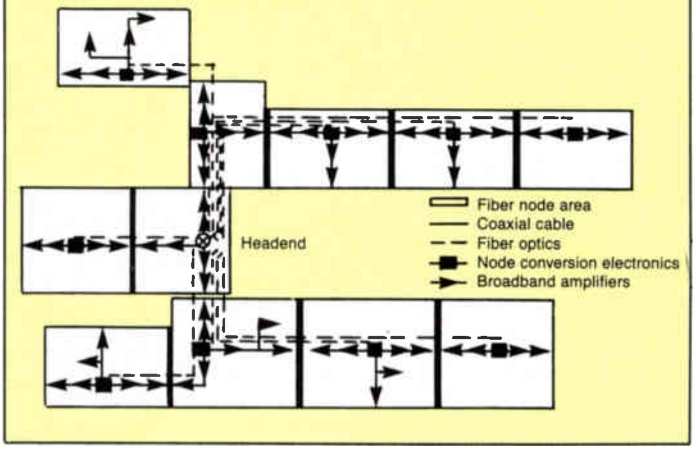
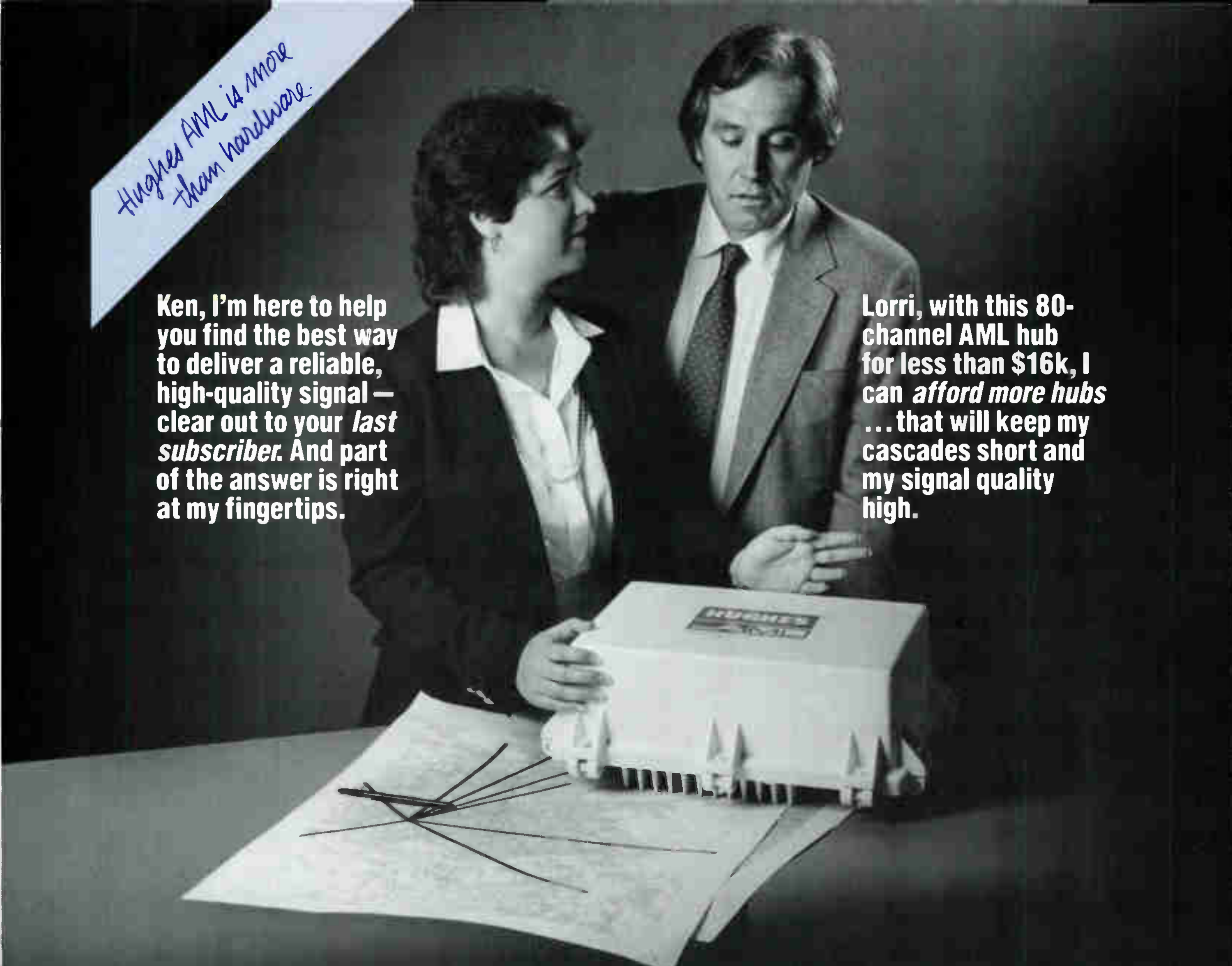


Figure 2: Hybrid fiber backbone/coaxial distribution system





And Ken won't have to worry about implementation time, high costs, prolonged outages or other problems associated with supertrunk or fiber.

If you're cost/quality conscious, Hughes AML® microwave transmission is the way to go. Because it's so flexible and easy to install, Hughes AML can save you thousands of dollars in time and hub construction costs, compared to other transmission methods.

Signal quality delivered to a hub is only one element in a CATV system design. It's the amplifier cascade length from each hub to the last subscriber that really determines the signal quality of a system. With Hughes AML, you have affordable hubs which allow you to design for short cascades.

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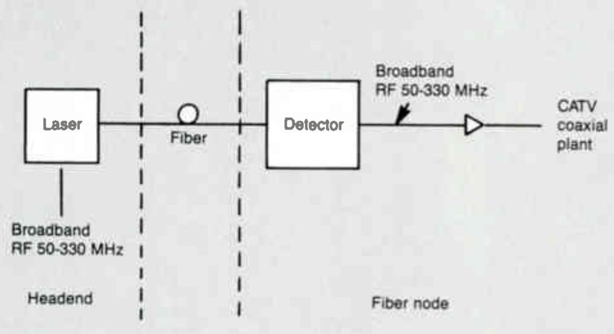
Figure 3: Direct modulation of broadband spectrum



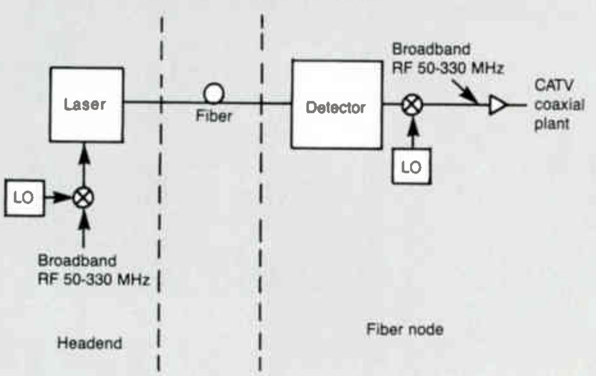
should search for ways to apply new technology to a hybrid fiber/coax system that makes use of at least some existing plant structures, but which focuses the use of fiber technology on relieving the most serious weaknesses of today's systems.

The fiber backbone

In view of the shortcomings of today's system architecture and the practical constraints on outright network replacement, we have developed an evolutionary concept for the integration of the fiber into our systems. We have termed this approach "fiber backbone." The approach is illustrated in Figure 2 and essentially consists of overlashing some percentage of the existing trunk system with optical fiber cables. Thus, a direct fiber path is established from the headend to "nodes," a number of feed points in the distribution system. From that point on, the existing coaxial plant is utilized, with some amplifiers being reversed in direction and some spans of trunk cable between node areas being abandoned. The effect of this is to break up the system into a number of very short systems. The length of those systems can be described by the maximum trunk amplifier cascade allowed. At one extreme, fiber could be taken to each existing bridger amplifier location and the resulting coaxial system would consist only of distribution cable and line extenders. At the other extreme, a maximum trunk amplifier cascade of eight or 10 might be defined, breaking a typical cable system into a few node areas. To illustrate, if present power supply locations were used as fiber node feed points, the maximum trunk amplifier cascade would be two, with a maximum of three or four, and the average node would serve several hundred subscribers.

The selection of the maximum trunk amplifier cascade is constrained by tradeoffs between the cost of the fiber backbone with its associated electronics and the benefits to be gained by the degree of shortening amplifier cascade and coaxial plant. Regardless of node area size, however, the effect of this approach is to break the existing tree-and-branch coaxial plant into many small tree-and-branch systems, with each fiber node feeding anywhere from a few homes to a few thousand homes.

Figure 4: Direct modulation of broadband spectrum with block conversion



Electro-optical components of a fiber backbone system

In examining implementation of a fiber backbone system, the least problem is provided by the installation of the fiber cables. Single-mode fiber has become relatively inexpensive in recent years and is available in a variety of cabled packages, containing from one up to 144 fibers in a physically rugged cable 1/2 inch or less in diameter. "Field-enterable" cable packages have been developed that allow the extraction and splicing of one or a few fibers from a multifiber bundle within a cable without the need to splice the other fibers. This type of cable would be particularly helpful in routing a single fiber to each node location in the fiber backbone approach.

The more challenging part of fiber backbone implementation lies with the electro-optical components. These consist first of a laser diode transmitter feeding each fiber (or split to feed several fibers) leaving the headend. At each node location, an environmentally rugged optical receiver must be installed, capable of converting optical signals back to a broadband RF spectrum suitable for coaxial distribution. The optical link must be relatively transparent to the CATV signals if the advantages of the fiber backbone approach are to be realized. For the sake of investigation, we have postulated minimum performance specifications for such a link.

Optical link power budget	10 dB
Channel capacity	42 (50-330 MHz)
Carrier-to-noise (C/N)	55 dB
Composite triple beat (CTB)	65 dB
Composite second order	65 dB
Cross-modulation	65 dB
Output frequency response	±1 dB
Output video carrier level	+40 dBmV
Maximum terminal equipment cost	$5,000/node

While better performance might be desirable, an optical transport system meeting such specifications would enable a CATV operator to construct a useful fiber backbone. While there exists today no economically feasible off-the-shelf equipment meeting these requirements, there are a variety of design approaches that have potential to provide the desired result.

Figure 3 illustrates the simplest possible approach to the problem. In such a system, the laser transmitter would be directly modulated with the entire CATV spectrum, complete with video channels, scrambling (if present), FM radio services and pilot and data carriers. The output of the detector would be this same broadband spectrum, ready for amplification and delivery to the coaxial portion of the plant. While highly attractive because of its simplicity, this approach is also relatively challenging because of the linearity and noise requirements established by necessary system specifications. A laser capable of meeting these requirements might need a relative intensity noise (RIN) specification approaching −160 dB/Hz and a third-order intercept of +38 dBm or better. These are ambitious performance levels in today's off-the-shelf devices. Nevertheless, laboratory measurements of systems using selected lasers approach the system requirements closely enough to be encouraging. Far greater emphasis to date has been placed on digital than on analog performance by the electro-optical component industry because of telecommunication industry needs. It appears that there is room to revisit device optimization with new applications in mind.

Figure 4 illustrates a variation of the direct modulation approach, with the input RF spectrum being mixed to a higher frequency to take advantage of potentially better laser performance in the 1 to 2 GHz range, as well as avoiding second-order intermodulation products by keeping all carriers within a single octave. A corresponding downconversion would be required at the receiving end.

Figure 5 shows a variation of the direct modulation scheme with several lasers, each modulated with a segment of the total RF spectrum. This should improve performance and require less expensive, more readily available lasers. This approach has been demonstrated in the laboratory, but the investment in additional fibers provides significant system cost penalties.

Figure 6 shows the same approach, again using multiple lasers, but combining their optical outputs onto a single fiber. This approach has

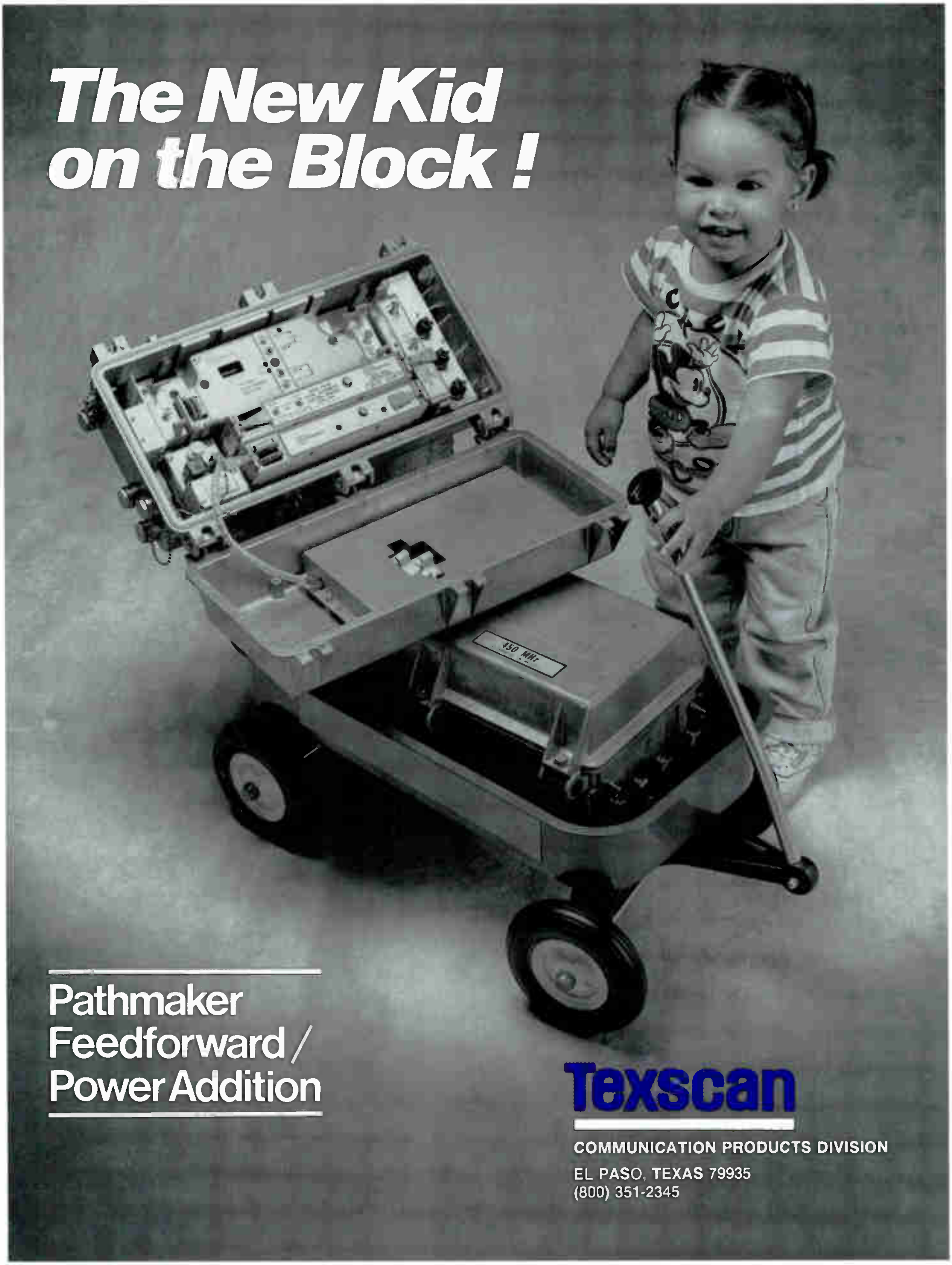


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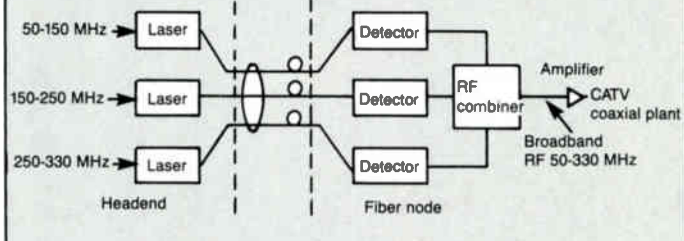
Figure 5: Direct modulation using multiple lasers and multiple fibers



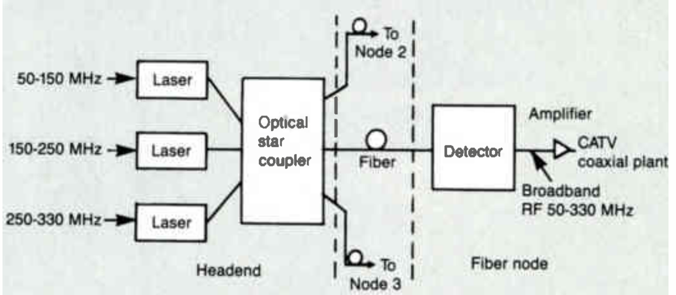
two constraints. The first is the additional link loss created by the passive combining device.The second is the necessity of ensuring that the optical wavelengths of the lasers are sufficiently separated so that frequency beats are not present in the RF spectrum of interest. At the operating node receiver, a single detector responds to the sum of the intensity variations in the received light. It thus effectively recombines the various segments of spectrum back into a continuous one. One advantage of this approach is the possibility of using a star coupler for the combining of the laser outputs. This would provide multiple outputs that could feed fibers going to multiple nodes.

Figure 7 shows the FM/FDM system of the type used in today's fiber-optic supertrunks. Such a system is capable of very high quality video transmission and, were the node equipment sufficiently compact, inexpensive and environmentally rugged, could be applied to a fiber backbone application. To be economically interesting, however, such a system would have to cost no more than $100 to $200 per channel at the receive end (because of the large power budget available with FM, a single laser could feed a number of nodes through splitting at the headend, and a single bank of modulators could drive an unlimited number of laser transmitters). It is possible that this goal is achievable through large scale integration (LSI) of demodulator and modulator circuitry. A high level of reliability and stability also would be operationally important for node link electronics using this approach. The system also would need to accommodate video signal scrambling.

Figure 8 shows a digital pulse code modulation/time division multiplexed (PCM/TDM) system for delivery of video to fiber backbone nodes. Several manufacturers have demonstrated the practicality of coding and compressing full motion video to a DS-3 (45 megabits per second) channel. It is conceivable that 36 such channels could be time division multiplexed onto a single 1.7 gigabits per second data stream and transported using optical systems that are commercially available for telecommunications applications. This approach may become practical in the future, but would provide severe economic challenges today.

Figure 9 shows a highly speculative digital solution to this problem, one that is not workable today. In such a system, the entire CATV RF spectrum would be directly converted to digital form through sampling at a frequency some multiple of the highest RF frequency of interest. The sampling rate would certainly be in the 1+ GHz range. The resulting exceedingly high bit rate data stream would then be applied to a single laser. A corresponding decoding process at the receive end would yield the broadband CATV spectrum as an output. While the electronics to do such high-speed encoding and decoding are not available, it is possible that high-speed gallium arsenide chip technologies may offer this capability in the future. Laboratory work is under way at Bell Labs and in Japan on optical links in the 7-10 Gbps range. Such links would be required to transport these signals. There may be variations on this approach that could make digital transmission a practical mode for transporting signals to fiber backbone nodes with relatively simple reconversion to broadband RF. Systems implemented today with other types of terminal electronics could easily take advantage of such developments without the need for costly replacement of the fiber itself.

Figure 6: Direct modulation using multiple lasers, single-fiber to node



Operating advantages

There are a number of direct operating advantages to be derived from a hybrid fiber backbone/coaxial tree-and-branch delivery system architecture. They can all be viewed as direct outgrowths of two facts. First, the worst-case length of the coaxial portion of such a distribution system would be dramatically shortened, eliminating the majority of the amplifiers as well as power supplies, connectors and directional couplers to be found in the signal path between the headend and any given subscriber. The second is the fact that each small area of the community served by a node would be delivered signals via a dedicated connection to the headend, with the capability of delivering a separate mix of signals to each node area, rather than having to broadcast all signals to the entire system, as in traditional CATV architecture.

Reliability:

Under the fiber backbone scenario, there would be essentially the same number of active components in the distribution network as in a traditional CATV system. It is likely that some trunk transportation amplifiers (without distribution bridging circuitry) could be discarded from the system completely. On the other hand, while it is foreseen that most node locations would replace a trunk amplifier, there would be the addition of optical transmitters at the headend. Thus, the number of components that could fail is not likely to change dramatically. On the other hand, from the standpoint of each subscriber, the network would be substantially more reliable because there would be far fewer active and passive network components between the subscriber and the headend. Thus, the impact of any given equipment outage would be substantially reduced in terms of the number of subscribers affected. This should give rise to the perception on the part of cable subscribers that the network had become substantially more reliable. While this is a highly desirable end in itself, it also gives rise to the effect that massive system outages, with their tendency to overload the resources of a cable operation, should become less common.

Signal quality:

Most of the degradation of signals in current CATV systems is the effect of cumulative noise and intermodulation contributions from broadband amplifiers in cascade. Significant reduction of the number of active components in cascade would certainly yield quality benefits, assuming that the optical link portion of the hybrid system was relatively transparent by comparison with the broadband coaxial amplifiers. Since the majority of the intermodulation contribution to degradation occurs, however, in the feeder portion of the system, there would be limitations to the degree of improvement unless and until the coaxial portion of the system underwent some degree of redesign. Nevertheless, overlay of the backbone, by itself, would provide some immediate quality improvement stemming directly from the reduction in amplifier cascade. Full-quality benefits would be harvested when system design was rethought, with reoptimization of the balance between noise, intermodulation and channel loading.

Operating tolerances:

Current trunk amplifier cascades can be as high as 30, 40 or even 50 amplifiers. Such systems necessarily must be operated within very tight operating level and response flatness tolerances if design specifications are to be realized. Maintenance of these specifications is a significant operating challenge, requiring the attention of highly trained technicians. A dramatic reduction in maximum amplifier cascade through construction of a fiber backbone should result in the opportunity to operate the system within wider tolerances, offering some degree of cost savings and operational simplification. This is based on the assumption of very stable and reliable operation of the optical link portions of the system. It must be recognized that such a loosening of tolerances is only one way to "spend" the improvements arising from the construction of a fiber backbone and must be balanced with allocations resulting in improved signal quality or increased channel capacity.

Channel capacity:

As previously discussed, the potential bandwidth of the coaxial cable in use in today's CATV systems (including many of the cables installed over the last 10 to 15 years) is significantly greater than we are currently able to use, given our present architecture. The move to a hybrid fiber backbone/coaxial distribution system would ease some of the current constraints on channel capacity. A small number of amplifiers in cascade and broader system tolerances should make it possible to significantly push channel capacity with relative economy. In addition to the construction of the backbone itself, it is assumed that most or all of the active and passive elements of the coaxial portion of the system would be replaced, except for the coaxial cable itself.

A new system design would take advantage of the short cascade and would seek the optimum balance between channel capacity and signal quality. Indeed, preliminary design studies indicate that a current 270 MHz system (30 channels) could be upgraded to 550 MHz (80 channels) through the construction of a fiber backbone allowing no more than four trunk amplifiers in cascade, and by fully replacing all active components with high performance wide-bandwidth amplifiers. All passive components (couplers, taps, etc.) also would be replaced, but the enormous investment in coaxial cable and its construction would be reused. While this undertaking would still represent substantial capital investment, that cost would be some fraction of the cost of building a new 550 MHz plant. It is possible that with wider bandwidth distribution amplifiers, the fiber backbone/coaxial hybrid approach may make it possible to upgrade existing systems even more aggressively or to build new plant with truly spectacular channel capacity.

The history of the CATV industry is a never-ending quest for more channels driven by new types and varieties of programming sources. There are indications that fiber backbone technology may provide a way to deal with the next phase of this challenge.

Network flexibility:

Because a hybrid fiber backbone/coaxial system would no longer automatically broadcast the same signals to every point in the community, there is an opportunity to rethink signal strategy. Different combinations of channels could be delivered to different areas to meet local community needs, or to target advertising. Clusters of hotels could be fed with entirely different channel lineups than residential sections. Scrambling could be used in one neighborhood with plant security problems, a high rate of turnover, or a good market for pay-per-view, while unscrambled signals could be delivered and controlled using traps in other types of areas. Different types of scrambling could be used in different areas as new kinds of addressable set-top converters were phased in. System upgrade and maintenance work would be far less disruptive than today, and could be approached on a node-by-node basis. Ultimately, a hybrid system could provide a certain number of channels in each node area that would be reserved for pay-on-demand signal delivery to an individual subscriber. This would require a degree of switching at the headend and addressable delivery at each home but begins to be practical if the pay-on-demand business opportunity is real. This flexibility begins to shift our focus to the long-term advantages of a hybrid fiber/coaxial network.

Strategic benefits

In addition to the relatively immediate operating benefits, there are a number of long-term strategic benefits that would accrue to a hybrid fiber backbone/coaxial distribution system architecture.

Two-way services:

The cable industry has yet to reach consensus on new businesses that make effective use of the two-way capabilities of CATV plant. Current systems are technically capable of providing some degree of return services, although because of noise summing and the reliability constraints of today's architecture, there are significant challenges to maintaining such a system. In addition, there is a relatively small amount

of return bandwidth available within most system designs.

To the extent that two-way services begin to provide genuine business opportunities, hybrid fiber backbone/coaxial architecture could provide significant advantages. The short cascade of the return plant and the relatively small number of branches being summed at each node point should yield a substantially more reliable and tolerant return signal path. In addition, because of the relatively large number of discrete node areas in a given network and the ability to reuse the same upstream frequency spectrum to return signals to each node, the effective return bandwidth of the overall network would be greatly increased. This is all based on the assumption that the same fiber providing downstream services to a node area could also be used for return signals, using wavelength division multiplexing (WDM) or other techniques allowing for transmission of signals in both directions on the same fiber. In our thinking about long-term strategy, this potential to provide significantly more effective two-way services is a significant consideration.

Commercial services:

The CATV industry has been experimenting with a variety of commercial services in recent years. Most of these consist of providing data links for businesses. Should this prove to be a significant opportunity for the cable industry, the existence of a fiber backbone network could facilitate its expansion. The availability of single-mode fiber at neighborhood node points throughout the community could provide a significant amount of capacity beyond that required for a residential coaxial distribution system. That capacity could relatively easily be applied to commercial types of services, either by extending fiber from node points to commercial customers, or utilizing short links of two-way coaxial plant for that purpose. There is also an opportunity to build in a degree of route redundancy and switching between key nodes to provide the levels of reliability that commercial customers expect.

Competition:

The industry faces a broad variety of potentially competitive video delivery systems in coming years. These include direct broadcast satellites, multichannel MDS microwave, overbuild by other CATV operators and video delivery via the kinds of switched fiber-to-the-home voice and video networks now being experimented with by telephone operating companies, as well as videotape and videodisc sales and rentals. The keys to meeting such competitive challenges lie in providing excellent service (including signal quality and reliability), reasonable pricing, and a large number and wide diversity of programming channels. These goals, while straightforward, pose significant challenges given today's CATV networks. The fiber backbone architecture described here provides an opportunity to significantly improve both quality of service and channel capacity in a gradual way, with reasonable economics. This gives it the potential of being a significant tool in the strategic planning of the CATV industry as it faces a competitive future. ➞

Figure 7: FM/FDM video fiber transmission

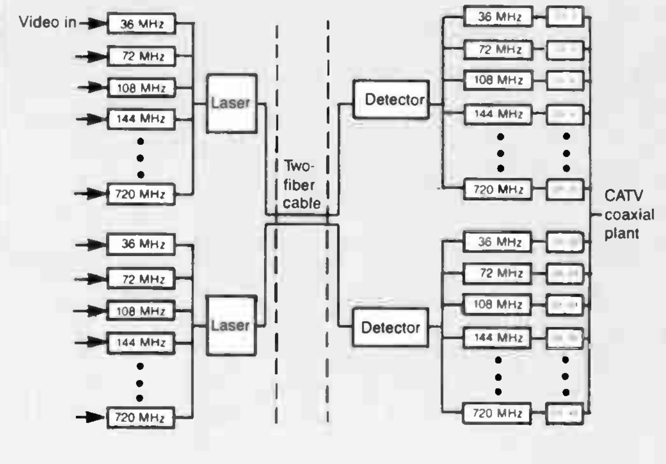
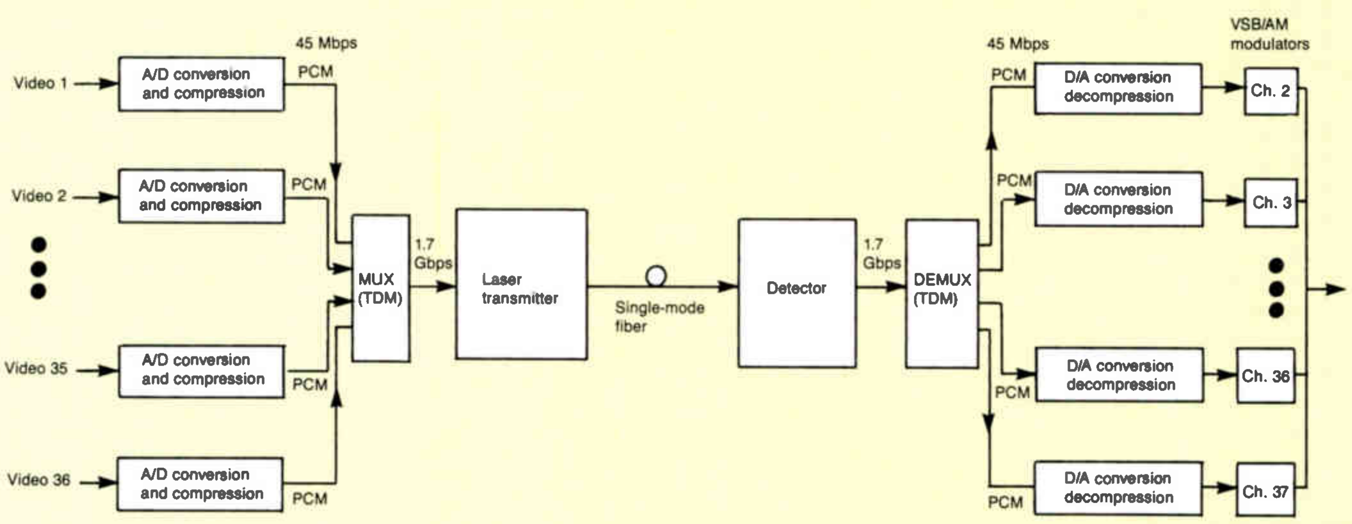


Figure 8: Digital (PCM/TDM) video fiber transmission



High-definition television:

It appears probable that HDTV will develop as a significant home entertainment force over the next decade. While all the implications of this are not yet clear, it appears likely that HDTV will provide significant challenges in terms of signal transmission and channel capacity requirements for CATV systems. While NTSC-compatible enhanced television systems are in the development stage, it appears likely that services that must be delivered to both standard NTSC receivers and to full quality high-definition receivers will require the equivalent of at least two to three standard 6 MHz channels. If such services become widespread, the magnitude of pressure on channel capacity is apparent. A movement toward a fiber backbone-type of architecture over this same period should put the CATV industry in good position to be a high quality provider of these new signals because it helps address both transmission quality and channel capacity issues.

Evolutionary change:

In thinking strategically about its future, it is critical that the CATV industry seek a series of evolutionary steps, moving its plant in directions that will satisfy the needs of coming decades. In order to maintain business health, it is important that these steps be of a relatively gradual, pay-as-you-go nature. The enormous investment in completely new plant necessitated by a radical change in system architecture would be highly imprudent unless offset by huge new revenue streams.

Business caution, as well as our belief that the most expensive portions of the existing plant (the coaxial cable and its placement) have a significant amount of additional potential, encouraged us to look hard for the kind of hybrid architecture we have outlined. It is possible to envision a carefully orchestrated scenario whereby fiber backbone would first move into the neighborhood as described here, then move to bridger amplifier locations and next to the tap, increasing channel capacity, improving system operation and customer satisfaction and enabling new services each step along the way. Complete replacement of plant with fiber all the way to the home is an attractively dramatic concept. We believe, however, that there is a far more practical approach, with each step being taken when it makes business and economic sense, that can enable the CATV industry to improve its business and meet the array of challenges that the future holds.

Implementation

There are several steps required for effective implementation of a hybrid fiber backbone/coaxial distribution system. The first is the achievement of cost-effective optical link electronics that meet the technical demands of such an architecture. A variety of approaches are under investigation by ATC and a number of component and system vendors; these general approaches were outlined earlier. The second step to implementation is developing an understanding of economic and technical tradeoffs leading to a decision on the maximum size of the coaxial subsystems that should be fed by a given fiber node. The technical benefits involved must be defined not only in terms of immediate system improvements with the addition of fiber backbone, but also the channel capacity upgradeability that is desired of the resulting system. The economic and technical issues involved are quite complex, and it is hoped that work on these issues will continue to emerge in coming years as the backbone concept itself is proven valid.

An initial approach to both economic and technical issues is presented in two NCTA papers[3,4]. Broadly stated, these works indicate the cost

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of overlaying a fiber backbone on an existing CATV system should be somewhere in the $30 to $60 per subscriber range, depending upon depth of fiber penetration. Further, they indicate that a fiber backbone overlay may make relatively dramatic channel capacity upgrades feasible. In the typical network examined, a system upgrade from 270 MHz (30 channels) to 550 MHz (80 channels) was achievable, maintaining current system specifications, and using off-the-shelf coaxial cable equipment in addition to a fiber backbone performing to the specifications outlined in this article.

The architecture of the fiber backbone system is such that many small, unique cable systems are created out of one large operation. As a result, several implications resulting from its implementation can be seen:

1) The short amplifier cascades created by this architecture provide us with an opportunity to enhance the performance of our plant. The additional operating overhead that results from the short cascades can be used to improve the quality of the signal delivered to the home and/or to increase bandwidth.

2) If we are trying to position the system to handle such new technology as HDTV without having to rebuild the plant to accommodate the first one or two HDTV channels, with a requirement for better system specs, then this might be provided by the fiber backbone.

3) Later, as HDTV and other needs for expanded bandwidth advance, a system upgrade becomes a good alternative to a complete rebuild. An upgrade assumes, of course, that the coax in the plant is capable of carrying additional spectrum. A system could be expanded in bandwidth a number of times. This is a result of the relatively short distances between the fiber distribution point (node) and the end of the plant that the node feeds. To understand this point, we must consider that we have broken our large cable plant into many small plants with short cascades. When we upgrade, it may be necessary to not only change the electronics and passives, but to add additional amplifiers as well to make up the losses of the higher frequencies needed. While doing this and maintaining specifications in a system that may be 30 amplifiers or more in cascade could be impossible, it could be a relatively easy task within a fiber backbone system.

4) The small "neighborhood cable systems" created by the fiber backbone allow a CATV operator to consider new concepts in advertising. While cable TV can now "narrowcast" ads on selected stations, one could, using a "neighborhood cable" approach facilitated by backbone architecture, produce neighborhood-specific advertising. Neighborhood merchants rarely want or can afford citywide advertising, but could be interested in ads reaching a few system nodes serving their potential customers. The fiber backbone makes this possible because of its unique feature of having a direct feed from the headend to each "neighborhood."

5) The neighborhood cable system lends itself to new approaches to programming as well. Since each system has a direct fiber feed from the headend, we may wisn to consider providing different programming to selected areas. For example, in some cities there may be ethnic communities that would like specific programming. Once the primary boundaries were defined, additional ethnic channels could be delivered to the nodes serving that area. We might find a large concentration of hotels and motels in another area, requiring a completely different channel mix. The flexibility of the backbone architecture opens up many options with regard to targeted program delivery.

6) The hotel/motel possibilities of a fiber backbone-fed system lead us into some enhanced commercial services possibilities. For example, the ability to use the reverse band on our cable plant starts to look more attractive. We can now look at the short cascades that equate to less noise addition on the reverse system and see that it becomes a much more reliable data path than before. This path could be used for pay-per-view signaling, interactive programming like home shopping, etc. Because we are dealing with neighborhood systems we might consider using our more reliable reverse path for local area networking in business areas.

7) Metropolitan area networks may become practical. In such a network, we would be able to provide data communications between points located anywhere in the city. This is a result of having a node that is in every neighborhood connected directly to the headend with fiber that is passive and two-way. As a result, we would have established a very

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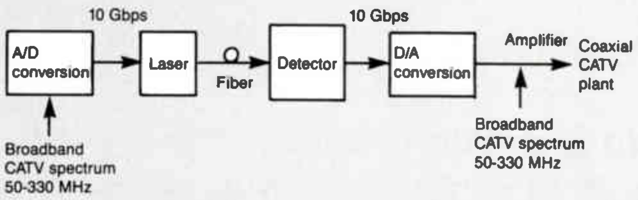
Figure 9: Directly encoded digital transmission of CATV spectrum



reliable communications path throughout the city.

8) Operating a cable system today can be a complex venture. Implementing a fiber backbone system might help reduce some of the day-to-day problems that exist. Because of the short cascades, we would probably see a reduction in the need to sweep the cable plant. That means a potential reduction in labor. In addition, we may see a reduction in phone traffic that would normally be caused by large system outages. Often, system failures overload the capability of our phone systems.

For example, if the first in a 32-amplifier cascade fails, it can affect 7,000 or 8,000 subscribers (based on studies of actual systems). If only one-third of the affected customers were to call in, the phone system and customer service department would be unable to handle the load in an efficient manner. The result is that subscribers often feel that they are unable to contact the cable company when they need it the most. The phone system overload will often affect all lines going to the cable company office. With backbone architecture, there will still be amplifier failures, but those failures will affect fewer people and create fewer calls. Thus, there is the potential for improved customer relations and a better image within the city.

9) Another use for the fiber backbone system could be in new construction. If we consider the rural and low density areas we would like to serve, but find conventional coaxial systems to be too costly, we might look at a fiber backbone-fed node feeding a "tapped trunk" system. We could benefit from the use of passive, low maintenance fiber to transport the signal and maintain reasonable quality to the start of such a system. It is probable that the cost of such a system would be less than traditional architecture.

10) Still another variation of the backbone could be a system that has no trunk at all, only a distribution system. That would say that the node would be at a bridger location and would feed line extenders rather than trunk amplifiers. It could be possible to cascade a few high quality distribution amplifiers with AGC circuits and still maintain the node performance quality without the need for trunk cable or amplifiers.

Overall, the implications of implementing a fiber backbone system are far-reaching, from marketing to operations to customer relations as well as improved image in the community. The system has a potential for assisting in solving, or at least reducing, a number of problems that exist in most cable systems today. There is also the opportunity to increase revenues through the neighborhood cable system concept that lends itself to new advertising sales and marketing ideas.

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Cable's advanced television priorities

By Walter S. Ciciora, Ph.D.
Vice President of Technology
American Television and Communications Corp.

My first five *CT* columns of 1988 dealt with advanced television (ATV) systems. Since the Society of Cable Television Engineers is holding a national seminar on the subject of high-definition television (HDTV) this month, it's appropriate to review and summarize the thinking on cable's HDTV priorities.

The cable industry is a diverse collection of companies with different approaches, goals and opinions. There really can't be just *one* cable industry position on ATV. I've put forth my thoughts on the subject based on talking with others in the cable industry, other related industries and potential competitors. But after all is said and done, this is just one opinion.

What is ATV?

"ATV" is the preferred term for the family of advanced television systems. There are three major branches to the family—HDTV, extended definition TV (EDTV) and improved definition TV (IDTV).

HDTV is intended to have twice the resolution of our current NTSC system in both vertical and horizontal directions, a wider aspect ratio (ratio of picture height to width), elimination of all of the NTSC artifacts and compact disc-quality digital sound. NTSC artifacts include scan line visibility, scan line flicker, large area flicker, crawling dots induced into the luminance channel from crosstalk with the chrominance channel and spurious rainbows of color caused by the luminance signal talking to the color circuits. The question of compatibility with NTSC is left open; both compatible and non-compatible HDTV proposals are under consideration.

EDTV systems have been proposed that are compatible with existing NTSC receivers. Little or no degradation is observed on older receivers while new EDTV units would show noticeable improvement. There have been other EDTV proposals that would require an adapter box if they are to be used with old sets. The number of scan lines and their frequencies are the same, but bandwidths and the way in which color information is added to the luminance signal have been changed. These adapter boxes would give best results on sets with baseband video terminals on the back. The most logical application for EDTV is in the DBS delivery of better-than-NTSC video, which can alternatively be displayed on older sets or new high quality monitors.

IDTV is completely compatible with NTSC since no changes are made in the transmitted signal. IDTV is a series of receiver design improvements meant to reduce the problems with NTSC. Typical features include scan line doubling, NTSC artifact reduction and noise processing. Since there are no standards, IDTV receivers from various manufacturers will vary greatly in the amount of performance achieved. On the low end, the viewer will know it's IDTV only because it says so on the cabinet. On the high end, it may cause the customer to wonder why one would ever need HDTV.

Opportunity or problem?

ATV has been proclaimed as an opportunity for cable. It is important to put this in proper perspective. A business opportunity should do at least one of the following: 1) increase the number of customers, 2) increase revenue per customer, 3) decrease costs or 4) serve to prevent erosion of the business. Taking these issues in turn, cable penetration will probably be in excess of 75 to 80 percent by the time ATV is commercially significant.

It's unlikely that ATV will be the principal cause of a meaningful further increase in subscribers. It may be possible to generate more revenue from some ATV services. But competitive forces will minimize the amount of extra charges ATV may command. It will certainly not decrease costs; it is most likely to increase the cost of doing business. The safest thing to say is that as other delivery means become able to provide ATV, cable will need ATV signals to prevent erosion of the business. To a large extent, cable must be in ATV to remain competitive.

Who stands to benefit the most from ATV? Certainly the viewing public will have a better viewing experience. But it is important to appreciate that there is no evidence that the viewing public is dissatisfied with good old NTSC. This doesn't mean they won't embrace ATV when it is available. Black and white was good enough until color came along. Monaural sound was good enough until stereo came along. It's likely that NTSC is good enough until ATV comes along. However, there is a difference between public *acceptance* of a new technology and public *demand* for it. Acceptance is a bit more uncertain than demand.

Who stands to make the most money? Broadcasters will have major capital expenses and a likely continuing loss of viewership. They won't be big winners and may be the biggest losers in all of this. By the time ATV is a real product, cable will have matured significantly and will not benefit greatly. The principal beneficiary of ATV technology will be the consumer electronics manufacturer and retailer. Since the U.S. consumer electronics business is "on its knees," the ultimate winner is the Japanese consumer electronics manufacturer. If we look to where the money is being spent to push ATV, the vast majority of it is spent in Japan. The Japanese have been working on ATV for over a decade and have invested several hundreds of millions of dollars. The sum total of all other expenditures worldwide on ATV pales in comparison.

The Japanese consumer electronics industry

(Continued on page 67)

(Continued from page 50)
is the big driver behind ATV and is likely to be the principal beneficiary. This will likely be the case even if non-Japanese ATV technical standards are adopted in the United States. Most of the consumer electronics hardware for ATV will come from Japan unless some drastic and highly unlikely measures are taken in our country. We need to understand who owns the baseball and the bat as we start to play this game.

Large-screen TV

ATV and really large-screen TV displays are so synergistic that one can't happen without the other. All of the early consumer research on ATV has indicated that viewers see little difference between NTSC and ATV if they are more than three or four picture heights away from the display. In normal living rooms, people sit six to eight feet from the screen. For ATV to be noticeably better than NTSC, the screen must be 2 to 3 feet high. Since sets are normally described in terms of diagonal measure, the size of screen needs to be 50 to 75 inches for the wider aspect ratio. Less than that and most viewers won't see the difference.

Conversely, anyone who has seen a large NTSC projection set is dismayed at how poor the picture can be. This is due to the shortcomings of NTSC, which was created at a time when technology had to strain to provide a 12-inch picture. ATV is critical to the sale of large-screen TVs.

If we keep in mind who the drivers are behind ATV, we can see a parallelism. The goal is to sell expensive, large-screen TVs in a market saturated with 25-inch and smaller sets that are highly reliable and have a long life. The path to increased consumer electronics equipment sales is through dramatically better large-screen pictures.

ATV cable issues

With this discussion as background, what are cable's issues in ATV? The single most important issue is that cable must preserve its ability to compete. This boils down to the need to ensure that no artificial ceilings are placed on the quality cable can deliver. Cable's most important competitors in the ATV arena are, in order of importance: 1) prerecorded media, 2) telcos, 3) direct broadcast satellite (DBS) and 4) broadcast. The first three of these are in a position to deliver excellent video. Cable must not be second-rate.

The second most important issue is that we must be able to deliver the signal chosen by the broadcasters. The cable subscriber must see no apparent loss of quality. It is important that this be done cost-effectively.

A third issue is that of compatibility. NTSC receivers will be around for the foreseeable future; they must be served. But must all ATV signals be viewable on NTSC receivers? For those signals viewable on both formats, what is the best way to achieve this?

A fourth issue is a need to ensure that ATV is capable of those things that are somewhat unique to cable service. Included here are the need for addressability, truly secure scrambling and delivery via satellite to headends. These must be accomplished cost-effectively. They must not be "band-aids" or "add-ons"; they must be built into the ATV system itself. The addressing rate must be secure, fast enough and capable of a large enough audience. The scrambling must both hide the video from young eyes so parents don't object and be undefeatable to those who would wish to steal it. If it can be occasionally made unrecordable on consumer VCRs, perhaps early pay-per-view windows can be enjoyed. But it must be switchable to recordable mode for more normal use.

The last issue is cost. This includes the matters of spectrum space, signal quality and the most difficult question of all: "How good is good enough?" Cost also has a time horizon; what may be adequate today may be embarrassing tomorrow.

Prerecorded media

The most immediate concern is over prerecorded media. Magnetic and optical recording technologies are the arts that have made the most progress in the last 10 years. They are also the areas most likely to make dramatic progress in the future. A startling demonstration was provided to the NCTA HDTV Blue Ribbon Panel members who participated in the March 1988 visit to Japan. Mitsubishi showed a 20 MHz baseband VCR prototype that recorded and played back near studio quality, wide-screen HDTV. Since the recording was at baseband, no video compromises were required. There were none of the motion artifacts we've come to expect from bandwidth-reduced HDTV. The mechanism of the prototype machine was nearly identical to standard VHS design. What we saw was an eminently practical approach. Mitsubishi subsequently demonstrated the device at the 1988 NCTA convention in Los Angeles.

The 1988 Institute of Electrical and Electronic Engineers International Conference on Consumer Electronics (IEEE-ICCE) in Chicago included several papers on digital VCRs for consumer electronics. The IEEE-ICCE technical papers generally appear two to five years before products are introduced. The message is clear: Consumers will have digital quality VCRs in the near future. First, they will record ordinary NTSC; then they will evolve to ATV.

The optical disc is slowly building momentum. A huge and growing list of titles are available; rental stores are popping up. The disc is a low-noise media providing cleaner video. The best prerecorded video I've ever seen comes from a Sony professional HDTV videodisc. The absence of noise adds tremendously to the realism.

From cable's perspective the concern is this: A subscriber rents or buys a disc or tape to view at home on a large-screen display and afterward watches a cable channel. The tape or disc was recorded at baseband using 20 to 30 MHz with no compromises. The cable signal is bandwidth-compressed video with motion and other artifacts. On the large screen, the direct comparison may prove embarrassing.

Telcos

The Federal Communications Commission Advisory Committee on HDTV has several hundred members working in three major commit-


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tees and dozens of working parties. These meetings are attended by representatives of broadcasting, consumer electronics, video equipment manufacturers, cable and telcos. When the chairman of a committee requests volunteers to do work, most of the representatives hunker down in their chairs and try to become invisible. The representatives from the telephone industry put up their hands and volunteer. They seem to be the ones with serious resources to commit to ATV work.

Scanning the technical literature and attending a few telco conferences reveals that the telephone industry is serious about delivery of digitized ATV video over fiber optics to the home. Bellcore, the billion-dollar-a-year R & D consortium of the Bell Operating Companies, has done truly excellent technical work on making such delivery of video to subscribers practical for the future. The timeframe for this is at least five and probably 10 years away. However, the fiber infrastructure will be going in place relatively soon. BellSouth, the most aggressive proponent of fiber to the home, believes it can cost-justify fiber in new construction in affluent developments. The factor that drives the use of fiber is the penetration of a reasonable number of multiple phone numbers per home. Once the fiber is in place, video delivery can be implemented by adding electronics to the ends.

The concern for cable is that digital delivery results in near-perfect video.

Direct broadcast satellite

Satellite delivery of video is by frequency modulation (FM). Current TV receivers require a vestigial sideband/amplitude modulated (VSB/AM) signal. Some new receivers have baseband video inputs. So the satellite-delivered FM signal must be demodulated and provided to the receiver as either baseband video or remodulated to VSB/AM. FM has noise and distortion advantages over VSB/AM. In addition, the DBS receiver is almost free of ghosts or multipath. The signal-to-noise ratio is a function of the antenna size. In principle, truly excellent ATV pictures could be delivered by DBS.

Broadcast

Broadcasters are in an extremely difficult position: Spectrum is scarce. Most importantly, the spectrum that is available may not be of sufficient quality to provide ATV. Broadcasters also face the problem of multipath. Reflections from hills, mountains, towers, airplanes, buildings, etc., cause multiple signals to be received. These appear on the screen as ghosts or as blurring of the main signal. The vestigial sideband nature of the signal makes the ghosts particularly bothersome. ATV's doubled number of scan lines means that the scanning speed is doubled. This doubles the displacement of a ghost on the screen.

Since the objectionability of a ghost is an exponential function of its displacement, ATV ghosts are nastier than NTSC ghosts of the same severity. Additionally, many ATV systems use time compression to separate the luminance information from the chrominance signals. When these signals are compressed in the receiver, a single ghost is converted into two ghosts with different locations and sizes.

The consumer electronics industry has worked on "ghost cancellers" for a couple of decades. They still remain impractically complex systems with marginal performance for even the less demanding case of NTSC. It is likely that ghost cancelling will remain out of reach for quite some time to come.

Compatibility

"Compatibility" is a rubber word often stretched to meet the needs of the moment. One respondent to the FCC's Notice of Inquiry has created an elaborate six-level hierarchy of compatibilities. From the cable operators' perspective this is nonsense. NTSC compatibility can only mean that an ATV signal is also viewable on essentially all existing NTSC receivers with acceptable quality and without any adapter boxes or modification to the subscriber's NTSC receiver. Anything else is simply not compatibility.

The last thing we need is to be put in the position of having to provide adapter boxes so existing subscribers can continue to view programming.

The single universal standard

In the best of all worlds, a single universal ATV standard would reduce consumer confusion and increase efficiencies. Lower prices and faster adaptation of ATV would result. It would provide a level playing field for all competitors. Price, service and quality of programming would be the instruments of competition. The example of the free market approach to AM stereo clearly displays the problems of multiple standards.

Unfortunately we do not live in the best of all worlds. In our world there are real, physical differences between video delivery methods. Video has changed a lot since the simple days when black-and-white TV was introduced. Then the consumers' only choice was off-air reception. Compatibility then meant only that all broadcasters used the same technical standards so the consumer could get by with only one receiver. When color was introduced, cable was an insignificant part of the video scene. Compatibility again meant that all broadcasters used the same technical standards. But "compatibility" gained an additional meaning: The old black-and-white receivers had to be served by the same signal that put color pictures on new sets.

Today the situation is much more complex. The consumer not only receives signals off-air but also subscribes to cable, rents tapes and discs and maybe has a DBS dish receiving FM video. Furthermore, one hears of the phone company wanting to provide digital video signals over fiber. Since these delivery means are diverse in their fundamental technology, a single universal standard is impossible. VSB/AM, FM satellite, digital fiber and tape and disc recording are just too different in their basic technologies to come under a single universal standard.

The regulatory situation is also much more complex. While the FCC has rigid control over some of the video transmission means, it has virtually no control over others. For example, no one asked the FCC for permission to introduce Super-VHS. Likewise, no one needs to ask for permission to introduce a prerecorded ATV format. Unless this is changed in ways that seem highly unlikely at present, a single universal standard is simply impossible!

Signal robustness

The broadcasters' signal is important to cable subscribers; they expect it. When broadcasters begin transmitting ATV signals, cable subscribers will insist on receiving those signals over their cable connection.

Cable's concern over the broadcaster's signal is primarily over robustness. The cable system processes the signal many times before it reaches the subscriber. In doing so, the signal may become bruised. If the broadcasters achieve ATV in the present 6 MHz, they will have to squeeze even more information into the existing bandwidth. This will most likely reduce the robustness of the signal and make it more subject to damage. The cable industry must work with the proponents of systems for use in broadcast to minimize this hazard.

While there is a lot of hype over ATV and particularly HDTV, we must be realistic in our expectations. The consumer electronics industry has decades of experience with the manner in which new technologies are adopted. In essence, there is a long period of very slow growth while prices are high and programming in the new format is scarce. This usually lasts from five to eight years. Then, rather suddenly, things come together. An attractive price point is reached, programming becomes available, and the new product becomes the "in thing." It becomes socially unacceptable to be without it. Growth is massive. The penetration curve goes almost straight up. Then overcapacity in the industry and intense competition cause prices to plummet. The rapid growth phase is probably eight to 10 years away.

This doesn't mean that cable should ignore ATV. Quite the contrary, it will take those eight to 10 years to be truly ready for ATV. If we turn our attention away, those years will be gone before we know it and there won't be adequate time to prepare. Our competitive position will be weakened.

Fiber plays a facilitating and a threatening role. Fiber in a cable system significantly eases the problems of bandwidth and signal quality. However, fiber in the telco plant becomes the method by which the telcos reach video capability. We certainly can't stop the telco implementation of fiber to the home. We must instead maximize the opportunities fiber presents us as cable operators.

Digital delivery of video is the telco goal. Digital video is near perfect. This does not mean cable must deliver digital video, just digital quality video. Perhaps there is a digital delivery method in cable's future. It is too early to tell at this point. But we'd better carefully watch our telco competitors so we have adequate warning.

An effective competitor

ATV will be a source of concern, effort and excitement for at least a decade. We have our work cut out for us. If cable actively pursues solutions, it can be a very effective competitor in the ATV arena.

HDTV: Boom or bust?

By Vito Brugliera
Vice President, Marketing and Product Planning
Zenith Cable Products Division, Zenith Electronics Corp

The trend toward improved television pictures has been gaining momentum over the past several years. Buzzwords such as "improved definition TV" (IDTV) and "enhanced definition TV" (EDTV) have been applied to improvements in the NTSC standard. These improvements have raised the hope of not only providing consumers with better quality TV pictures but of pumping new blood into the domestic consumer electronics industry.

Technologically, the biggest improvement is expected to come from the advanced TV (ATV) category high-definition TV (HDTV), a new consumer-oriented service that promises:

- Improved picture resolution, perhaps twice that achieved by the current NTSC transmission system.
- Improved audio comparable to the compact disc.
- Wider aspect ratios, from 4:3 to 16:9.

These enhancements to our existing system create opportunities for many different segments: consumers, retailers, manufacturers, programmers, broadcasters and cable operators.

Consumers can enjoy enhanced viewing pleasure and greater choice. Retailers can expect increased incremental sales of new TV receivers—many with larger viewing screens and features—and higher selling prices and margins. Manufacturers can look forward to increased sales volumes and potential profits of new products differentiated from "commodity" televisions of today.

For programmers, a market will open for products that take advantage of the new technology and format. Satellite and terrestrial broadcasters can expect to profit from the technology. The scarcity of spectrum within current channel allocations could allow direct broadcast satellite (DBS) services to profit from a need for increased bandwidth required for increased information content not compatible with our 6 MHz channel allocations. Terrestrial broadcasters, with new programming, could look for an increase in viewers with the advent of new services and programming. Cable operators, for similar reasons, could look forward to renewed viewer interest and increased revenue.

Too good to be true?

All of this sounds too good to be true. Obviously there is a potential downside. In addition to the opportunities, there are considerable risks: cost, obsolescence of existing equipment, consumer reluctance, terrestrial broadcast spectrum and incompatibility with cable plant and hardware.

Cost, especially with a new technology, presents a barrier. There are many costs to consider. One would be that of supplying the transmission infrastructure: new studios, TV transmitters and towers. The cost of the new receivers also should be factored. HDTV is a natural catalyst for larger pictures. Projection TV receivers are expensive—up to $3,000. New, larger, wide-aspect picture tubes require an enormous investment. This investment presents a definite challenge for an industry that still suffers from price erosion and lack of profits. To overcome the resistance to big investments, the TV industry also will have to convince the public that receivers, perhaps costing as much as $3,000 initially, are worth the investment. Consumers who can often buy 20-inch color receivers with remote for $300 may need considerable convincing.

Along with cost, there is obsolescence. What do we do about the 160 million TV receivers, many with a decade or more of life remaining? TV stations look forward to writing off huge capital investments and new capital outlays. That is a challenge in an environment where takeovers and buyouts have created huge debt. Currently profitable program libraries may have to be valued down because of diminished earnings potential against the new format.

All of this represents cost that will ultimately have to be borne by consumers. Any consumer reluctance, especially at the beginning, could diminish the perceived value and make consumers reluctant to buy a product that may be five to 10 times higher in cost.

Terrestrial broadcasters have a scarce commodity that exists solely for their use: 6 MHz of bandwidth for each channel allocation. Despite what seems an enormous availability of channels, there is actually a severe shortage. The transmission characteristics of NTSC signals in a given area require "taboos" in the VHF and UHF portions of the spectrum to prevent co-channel, adjacent channel and image interference. Put bluntly, there is no additional spectrum available. Thus, if HDTV systems require bandwidth beyond 6 MHz (as some proposed systems do), this can only come from existing allocations. Terrestrial broadcasters will have a real problem. They will not easily give up valuable spectrum.

Cable faces the risk that new technologies will not perform well in a cable environment. Channels are scarce in cable as well, and spectrum will not be free. An even more important issue hinges on whether the signal will be robust enough to survive continuous channel allocations, ingress, microreflections and attainable signal-to-noise constraints.

Time to explore

This overview of opportunities, risks and issues summarizes the HDTV phenomenon before us. We sometimes become absorbed in the details of competing technologies without considerating some of their ramifications. One must always remember that performance, spectrum use and co-existence taken together are the constraints. What is required is time enough to explore all the proposed systems and make sure we are not swayed by exciting simulations and prototype hardware.

Putting HDTV to the test

By Willem A. Mostert
Manager of Engineering, Distribution Products, Magnavox CATV Systems Co

The cable TV industry has system specifications for typical parameters involved in multichannel wideband transmission over its systems. The criteria for carrier-to-noise (C/N), composite triple beat (CTB), cross-modulation (X-MOD), return loss, group delay and their effects on picture quality and distortion perceptibility for standard NTSC signals are well understood and used in system design. We need to understand how our parameters will affect picture quality once high-definition television is introduced. Can conventional CATV systems adapt to HDTV transmission? What should be the design criteria to ensure high quality picture transmission of HDTV?

In order to get an insight into HDTV picture quality over a CATV system, a series of comparative tests was performed between HDTV and NTSC signals transmitted over a fully loaded 60-channel system. For these tests the Philips High-Definition NTSC (HDNTSC) was added to such a system. HDNTSC is the signal developed and optimized for terrestrial broadcast and CATV applications by North American Philips Corp. It is fully compatible with NTSC (Figure 1) and can be directly derived from HDMAC-60, a satellite HDTV transmission signal also developed by Philips.

Simply defined, HDTV is a TV picture that has: a wide aspect ratio of 16:9 (as opposed to the NTSC ratio of 4:3), at least four times greater spatial resolution than NTSC and compact disc-quality digital stereo sound.

HDNTSC is a total system concept (Figure 2) from studio and transmission media to consumer products (TV sets and VCRs). It is fully NTSC-compatible; i.e., an HDTV set can receive a standard NTSC signal and an NTSC set can receive the HDTV signal (with NTSC quality). There are no effects on the picture quality of the NTSC section of the HDTV signal when received on a standard NTSC receiver. The HDNTSC system is CATV-friendly and designed with satellite transmission, ter-

Figure 1: HDTV/NTSC compatibility

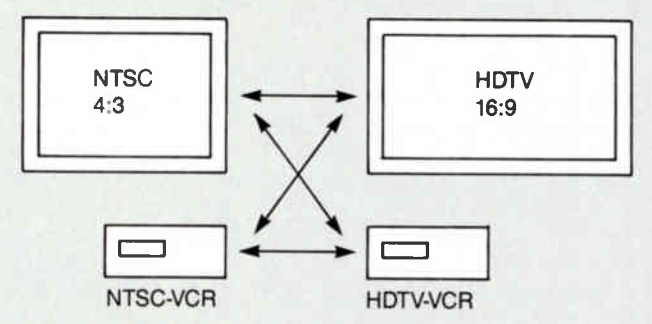
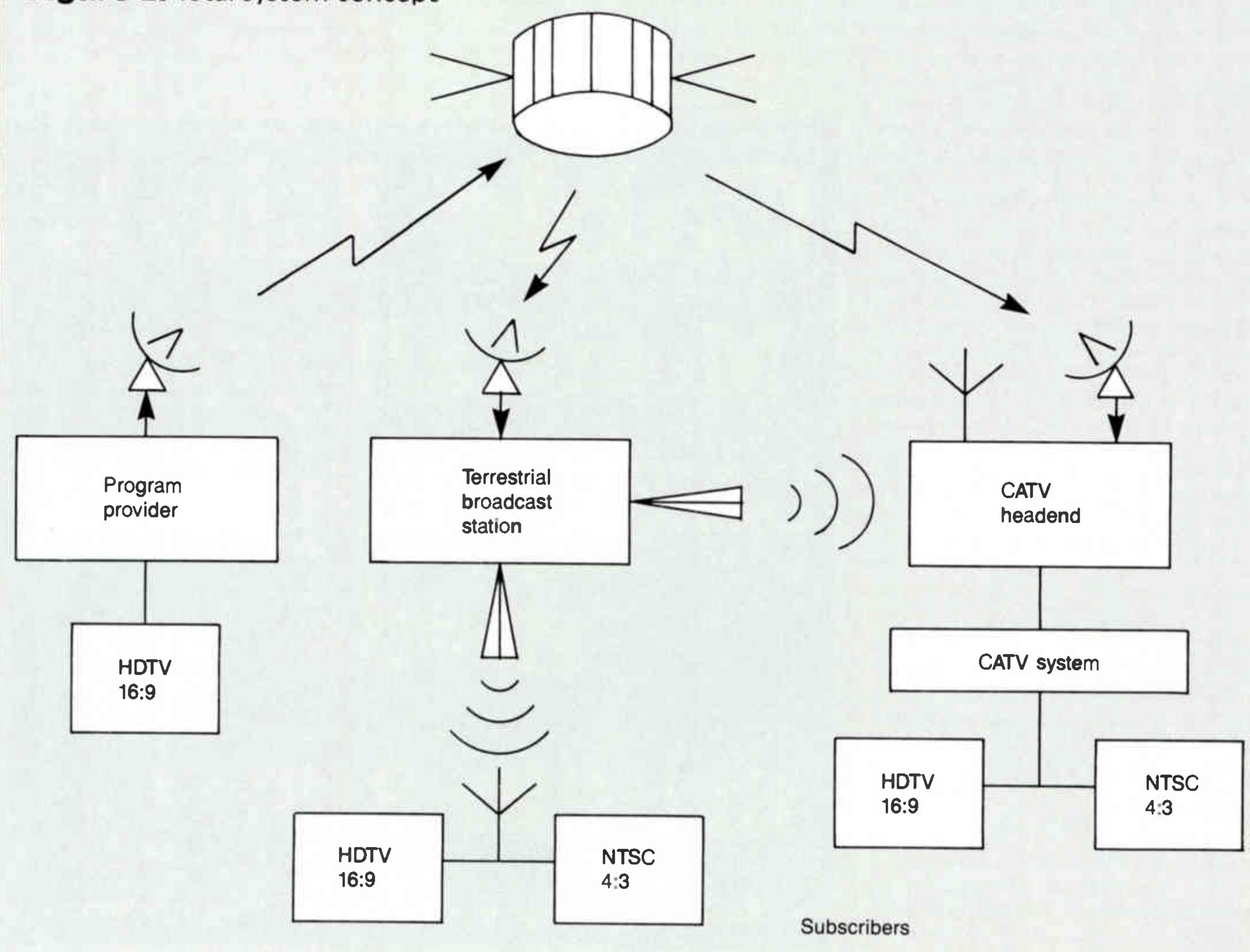


Figure 2: Total system concept



restrial broadcast and CATV transmission in mind, the media that have to be able to carry HDTV.

CATV test setup

The HDTV tests were performed with the HDNTSC first-generation format connected to the CATV system in the Magnavox Mobile Training Center. As shown in Figure 3, the source signal—525 lines, progressively scanned, 59.94 field rate and 16:9 aspect ratio—was fed into the HDNTSC encoder input. The output of the encoder was then transmitted over a pair of coaxial cables to the van at the headend input.

Both the main and augmentation channels of HDNTSC were modulated on standard RF carriers, which randomly could be located anywhere in the spectrum and mixed with additional NTSC channels to form a 60-channel (450 MHz) CATV headend output.

Those signals were sent through a cable system with eight mainstations, 22 dB spaced; a bridger; two line extenders, 27 dB spaced; and three feederline tap strings totaling 24 subscriber eight-way taps. The channels at the subscriber drop cable output were sent to tunable demodulators.

The baseband HDNTSC main and augmentation signals plus the RF NTSC main channel were sent to the HDNTSC decoder and NTSC receiver, respectively, for picture quality tests. These tests were per-

Figure 3: Test setup

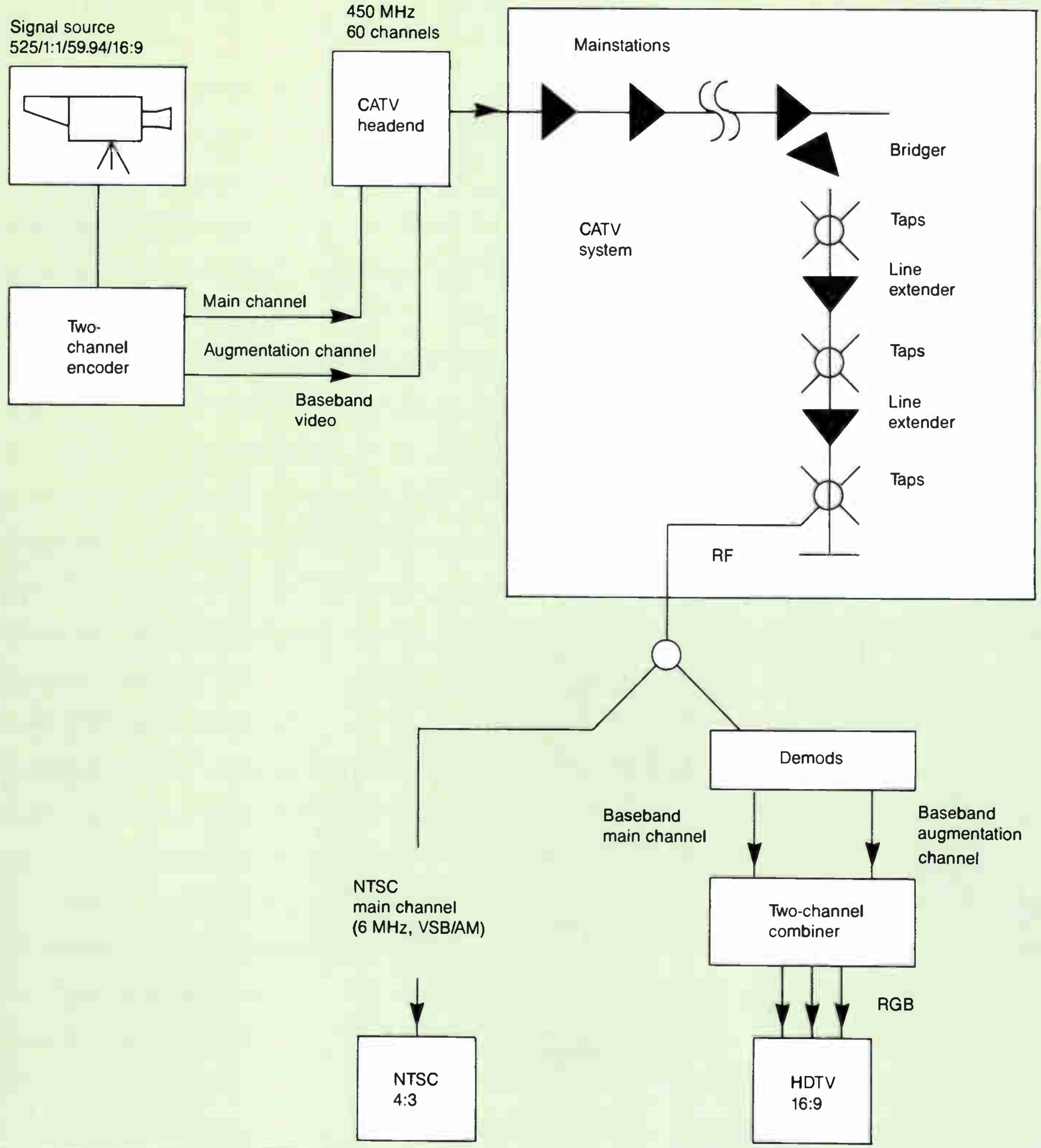


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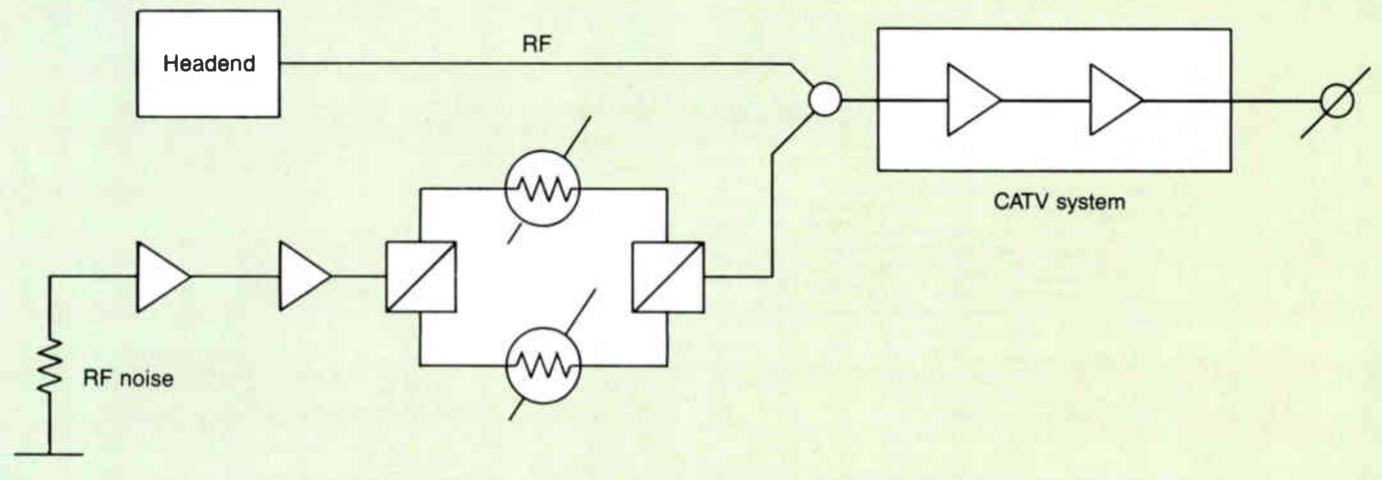
Figure 4: C/N test setup



formed by creating and varying the different CATV system distortion parameters the signal levels in the system were changed. Some special test setups were used for ghosting and group delay evaluation. The RF signal quality was measured for both HDTV and NTSC pictures to quantify differences in distortion perceptibility between HDNTSC and NTSC.

The viewing audience of four to five people monitored and compared HDTV and NTSC picture qualities throughout the series of tests. Over a period of 10 days, the following parameters were observed: C/N, CTB, X-MOD, group/chroma delay, reflections, modulator/demodulator matching and channel locations.

C/N test (Figure 4) was performed by selectively varying wideband system noise in the HDTV and NTSC channels under test. This way, the noise in main and augmentation channels could be monitored simultaneously and individually.

The CTB tests (Figure 5) were performed with all modulated carriers and by creating multichannel CTB in the channels under test, using high signal levels in the CATV system. The channels under test were sent around the CATV system in order to eliminate simultaneous X-MOD distortion. CTB levels could be selectively varied after filtering out the CTB for the channels under test. The CTB in the main and augmentation channels therefore could be monitored when simultaneously or individually present.

Figure 5: CTB test setup

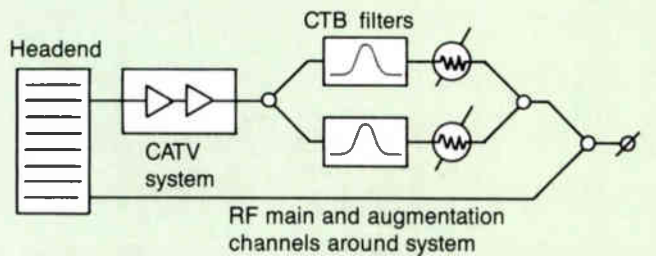
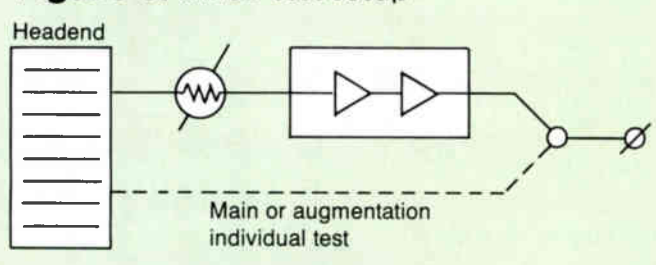


Figure 6: X-MOD test setup



Cross-modulation, monitored with all channels modulated, was tested by varying the signal levels throughout the system (Figure 6). By selectively switching off some of the headend channels, the CTB components were kept below the level of perceptibility in order to monitor X-MOD only. This way X-MOD could be monitored with it simultaneously present in main and augmentation channels. To monitor X-MOD in main or augmentation channels only, either channel was sent around the CATV system to remain distortion-free.

Two types of reflection tests were performed. First, the system was used to look at effects of *periodicity in tap location* in the feeder leg. All 24 taps in the feeder legs were equally spaced at 100 feet, building up reflections through periodicity in spacing. HDTV and NTSC signals through the system were observed for effects on picture quality. A second test (Figure 7) was done for effect on picture quality of *ghosting caused by reflections.* A reflection visible in the pictures as a ghost was created and could be varied in levels for picture quality comparison.

Different types of group delays were observed with the HDTV signals. *In-channel chroma delay* in main or augmentation channel occurred when Ch. 2 was used with its own group delay caused by the amplifier diplex filters, with addition of specially designed filters for additional chroma delay added to the CATV system. *Differential propagation delay* or group delay between main and augmentation channels was caused by different propagation speed of these channels over cable due to diplex filters or over the air caused by different propagation conditions for different channel frequencies. Here, the test setup of the reflection test was used, as well as the diplex filter test system.

Results of tests

Carrier-to-noise: HDTV is about 3 dB more sensitive to noise than NTSC when noise is applied to both main and augmentation channels simultaneously. HDTV and NTSC are equally sensitive to noise when it is applied to only the main or the augmentation channel.

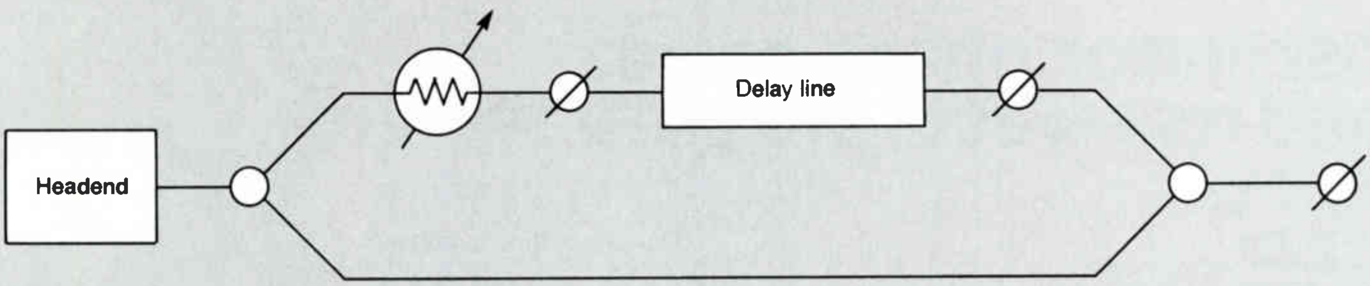
Composite triple beat: HDTV and NTSC are equally sensitive to CTB when it is applied to both main and augmentation channels simultaneously. HDTV is approximately 3 dB less sensitive to CTB than NTSC when CTB is applied to only the main or the augmentation channel.

Cross-modulation: HDTV is approximately 3 dB more sensitive to X-MOD than NTSC when X-MOD is applied to main and augmentation channels simultaneously or individually. (It is noteworthy that X-MOD was less perceptible than CTB under the same conditions.)

Reflections: Although the equal tap spacing in the feeder leg caused considerable peak-to-valley changes (by several dB), it had no effect on picture quality of either HDTV or NTSC. Reflections causing ghosts in the pictures had an equal effect on perceptibility of picture quality of HDTV and NTSC signals when applied to main and augmentation channels simultaneously or individually.

Group delay: In-channel (Ch. 2) chroma delay of up to 400 nanoseconds caused no noticeable color shift to be observed in either

Figure 7: Reflection test setup



HDTV or NTSC picture quality. Propagation time differential between main and augmentation channels from very small values as caused by diplex filter group delays to very large values of up to 20 microseconds had no effect on the HDTV picture quality, due to the correction servo mechanism in the receiver.

Modulator/demod matching: Standard modulators and demods were used for the tests. For good side-panel matching in the HDTV picture it appeared that the two modulator/demod sets have to be matched close to equal performance for optimum results.

Channel location: Throughout the various tests, different main and augmentation channel locations were used. By design, the system was indifferent to the location of the two channels, provided modulator/demod matching between main and augmentation channels was done properly.

Discussion of test results

The test results were positive, meeting the HDNTSC design objectives of a CATV-friendly HDTV system. The C/N test indicated that with the present generation HDNTSC and equal noise in main and augmentation channels, a 3 dB better C/N is required at the subscriber's HDTV receiver, compared to NTSC. This by itself is no surprise, since more bandwidth is used and, therefore, more noise power is present in the picture content. However, the test with noise in the main channel only indicates the possibility of a lower than 3 dB differential with a future improved version of the augmentation channel.

Since the C/N performance of a CATV system is mainly dependent on its trunk cascade, a better C/N would require a raise in trunk levels with consideration for trunk distortions. However, one has to take into account all the noise sources involved in the transmission link (e.g., satellite receivers, microwave links, headend, the CATV system and converters) as with any properly specified CATV system.

The CTB tests indicate an equal performance vs. NTSC with CTB in both main and augmentation channels, and approximately 3 dB better when in main or augmentation channels individually. This can be explained as follows:

1) The main channel processing before display involves vertical line interpolation, which acts like a vertical low-pass filter, reducing low-frequency noise and distortion. The test with CTB in the main channel only shows 3 dB improvement in picture quality perception.
2) The augmentation channel with CTB, when added to a "clean" main channel signal, causes averaging of the perceptibility on the display. The test indicates a 3 dB improvement of perception.
3) With CTB in both main and augmentation channels, both effects together eliminate the individual improvement, resulting in a picture quality perception equal to NTSC.

The X-MOD tests might indicate better system X-MOD requirements. However, today's systems have head room in X-MOD performance vs. limits of perceptibility in picture quality. This in particular is true when multichannel X-MOD is derived from multiple non-synchronized picture sync sources.

Finally, the modulators at the headend have to be matched. Likewise, at the receiver side, the two demods or tuners have to be matched, which is true by definition in a two-channel HDTV receiver.

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Acknowledgments: The author would like to express sincere appreciation for the cooperation of both Magnavox CATV Systems and Philips Laboratories in the preparation and exercise of the HDTV/CATV tests and for the day-to-day support during the tests. Special thanks go out to Doug Molloy, Philips Laboratories, and Tim Carvis, Magnavox CATV Systems.

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Oscillator phase noise and its effects in a CATV system

By Rezin Pidgeon
Principal Engineer, Scientific-Atlanta

And Dan Pike
Vice President of Engineering, Prime Cable

In recent years, experienced CATV engineers spoke of an effect they had begun to observe in which TV pictures appeared to the trained eye to have more noise than standard traditional measurements indicated. In mid-1987 an ad hoc group consisting of representatives of the National Cable Television Association, cable operators and equipment manufacturers organized to examine the issue. A short time later this group (called Group 1) was incorporated by the NCTA Engineering Committee into its HDTV Subcommittee and charged with the investigation and documentation of signal transfer characteristics in cable systems with particular emphasis on parameters useful in forecasting the transparency of a cable system to various HDTV proposals. Improved quality of present CATV service is also an expected result. This article, together with a paper by Gerald Robinson[1], form the first published results of the Group 1 investigations.

It was determined that the first efforts of the group should be devoted to rigorous investigation of phase noise effects throughout the entire network, including satellite links and through final detection.

Background theory

A general expression for oscillator phase noise as derived by D. B. Leeson[2] is:

$$L(fm) = \frac{1}{2}\left[1 + \frac{fo^2}{fm^2}\,\frac{1}{4Q^2}\right]\frac{kTF}{P} \qquad \textbf{(1)}$$

where:

L(fm) = the ratio of single-sideband noise power in a 1 Hz bandwidth (centered fm Hertz from the carrier) to the carrier power,
fm = frequency offset from the carrier (modulating frequency),
fo = carrier frequency,
Q = loaded Q of oscillator resonator,
F = noise factor of active drive,
k = Boltzmann's constant,
T = temperature in degrees Kelvin and
P = available carrier power in watts.

Equation 1 predicts the spectral distribution due to intrinsic noise in the active device and assumes the AM (amplitude modulation) contribution is negligible, as it is in a well-designed oscillator. Low-frequency phase noise which is usually predominately power supply-related, is not included, nor is low-frequency flicker noise. Furthermore, in CATV equipment, oscillators of concern are often incorporated in a synthesizer phase lock loop, which modifies the close-in spectrum.

As a result, the close-in spectrum is determined by the particular circuit design and cannot be predicted in a general way. Low-frequency phase modulation is often caused primarily by insufficient filtering or isolation of the oscillator power supply. The result is frequency modulation at 60 Hz and harmonics of 60 Hz. The clamping action of TV sets tends to suppress the effects of this low-frequency FM, and sets may respond quite differently to this low-frequency disturbance. The effect of high-frequency noise is quite different, and the analysis here will be limited to high-frequency noise, that is, noise modulation approximately 10 kHz or higher.

From Equation 1, the spectral density (noise power/Hz) is proportional to $1/fm^2$ up to the point at which it "breaks flat" (fm = fo/2Q). We will consider oscillator phase noise to be that which has a noise power spectrum proportional to $1/fm^2$; i.e., a 6 dB per octave decrease with offset frequency. Eventually the oscillator phase noise falls below the noise floor of the system. The noise floor of the system is limited by the carrier-to-noise (C/N) ratio of the distribution system, but the earth station, headend equipment, set-top converters, etc., are also contributors. The system noise floor is caused by amplified thermal noise and is referred to as *thermal noise*. It contains equal amounts of AM and PM (phase modulated) noise, and upper and lower sidebands are uncorrelated. Here we will consider system noise to be comprised of oscillator phase noise plus thermal noise. From Equation 1, that part we call oscillator phase noise is:

Figure 1: Nyquist filter response

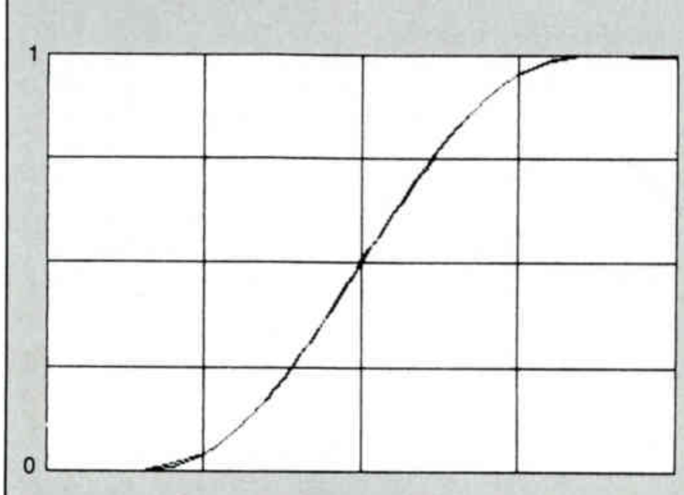
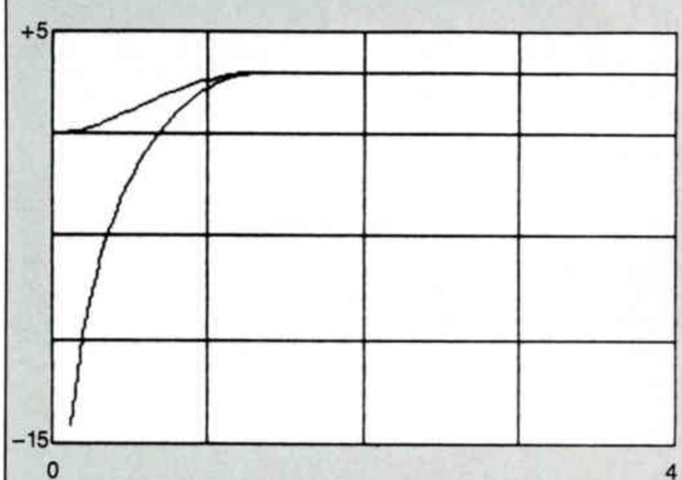
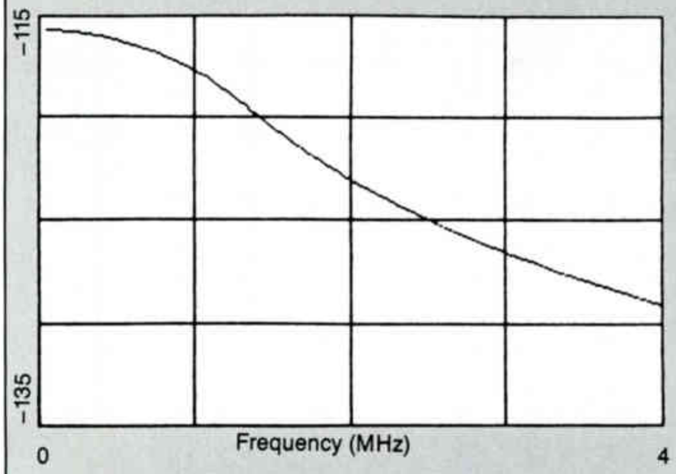


Figure 2: AM demodulation of RF noise



Ordinate is C/No ÷ S/No in dB for thermal noise and phase noise

Figure 3: Baseband noise spectra for phase noise = 1/(fmQe)²



$$L(fm) = 1/(fmQe)^2 \quad (2)$$

where:
Qe = a constant ("effective Q"), which defines the spectral purity of the oscillator.

The equations that follow give phase noise, frequency noise and video signal-to-noise ratio (SNR) as a function of the parameter Qe. The term L(fm) is the reciprocal of the more commonly used term C/No, where C is carrier power and No is noise power in a 1 Hz bandwidth. We will use the notation C/N_p for the ratio of carrier-to-phase-noise, and C/N_t for the carrier-to-thermal-noise ratio. For noise given in a 1 Hz bandwidth, the notation is:

$$C/No_p = \text{Carrier/phase noise/Hz} \quad (3)$$

$$C/No_t = \text{Carrier/thermal noise/Hz} \quad (4)$$

Qe expressed in dB is 20log(Qe). Qe can be obtained directly from the oscillator spectrum measured with a spectrum analyzer by:

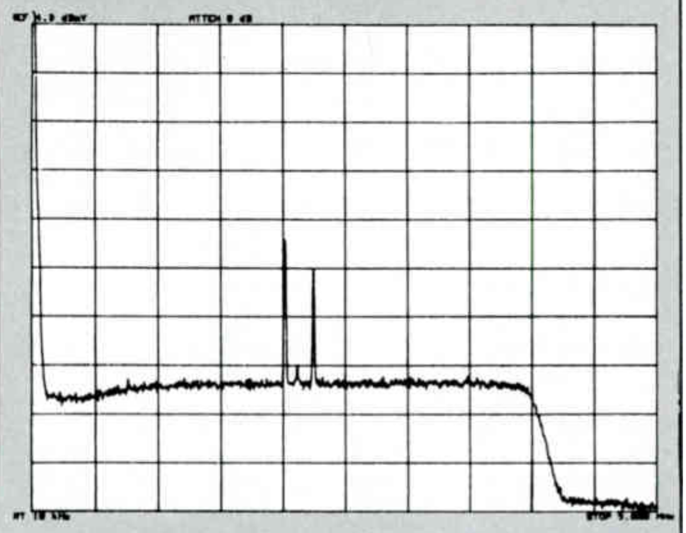
$$Qe = C/N_p - 1.7 - 20\log(fm) + 10\log(B)\ \text{dB} \quad (5)$$

where:
C/N = the carrier/phase noise sideband ratio in dB
B = the analyzer bandwidth and
1.7 = the usual analyzer correction factor applied to noise measurements[3].

For example, if an oscillator spectrum measures 56 dB below carrier in a 1 kHz bandwidth 20 kHz from the carrier, then Qe = −1.7 dB.

In analyzing the effects of oscillator phase noise in an NTSC system, it is helpful to convert phase noise to frequency noise since it is FM noise that is directly converted to AM noise by the Nyquist filter in the TV receiver. For the analysis, it is convenient to make use of the principle that random noise can be approximated by a large number of sinusoidal components all approximately equally spaced and of arbitrary phase[4]. Thus, the oscillator spectrum can be considered to consist of a carrier plus sinusoidal components 1 Hz apart. The ratio of the power of each component to the carrier power is, therefore, L(fm) — refer to the definition of L(fm). The ratio of the RMS voltage of each component to the RMS voltage of the carrier is $\sqrt{L(fm)}$. The peak phase deviation of the oscillator at a frequency fm is equal to the sum of the upper and lower sideband phasors, or $2\sqrt{L(fm)}$. The RMS phase deviation θn for a 1 Hz bandwidth is:

Figure 4: Fixed frequency modulator baseband noise spectrum



Start: 10 kHz Stop: 5 MHz BW: 10 kHz
Ref.: 4.3 dBmV 5 dB/div.

$$\theta n(fm) = \sqrt{2L(fm)} \quad \text{RMS radians/Hz} \quad (6)$$

Instantaneous frequency in radians/sec. is the time derivative of phase ($\omega = d\theta/dt$). Thus, for the sinusoidal peak phase deviation of $2\sqrt{L(fm)}$, the peak frequency deviation is $2fm\sqrt{L(fm)}$. The RMS frequency deviation due to phase noise in a 1 Hz bandwidth fm Hertz from the carrier is:

$$\Delta f(fm) = fm\sqrt{2L(fm)} \quad \text{RMS Hz} \quad (7)$$

$$= \sqrt{2}/Qe$$

Thus, the spectral density of frequency noise is constant (white) for $1/fm^2$ spectral phase noise.

The slope of a TV Nyquist filter extends over a nominal range of ± 750 kHz centered around the picture carrier. First, assume the Nyquist slope is linear over that bandwidth. A deviation of 750 kHz in this case would theoretically produce 100 percent AM at the output of the Nyquist filter. As a result, the AM depth of modulation is equal to $1/(750\times10^3)$ times the frequency deviation, which from Equation 7 is:

$$An(fm) = \frac{fm\sqrt{2L(fm)}}{750 \times 10^3} \quad fm < 750\ \text{kHz} \quad (8)$$

$$= \sqrt{2}/(750\times10^3) \times Qe$$

An(fm) is specifically the ratio of the RMS noise component that is in phase with the carrier to the RMS carrier voltage. Likewise, $\theta n(fm)$ (Equation 6) is the ratio of the quadrature RMS component to the RMS carrier.

Now consider the effects of phase noise for frequencies where the response of the Nyquist filter is flat; i.e., the single-sideband region. The amplitude response of the Nyquist filter should be down 6 dB at the carrier frequency relative to the response at single-sideband frequencies. As a result, the relative single-sideband noise power is four times greater than at the input to the Nyquist filter; the noise power ratio at the output is 4L(fm). For single-sideband noise, the AM and PM spectral components are equal in power; each is one-half the total spectral power. The AM component of noise power is 2L(fm); the RMS noise voltage ratio is

$$An(fm) = \frac{\sqrt{2L(fm)}}{\sqrt{2}} \quad fm > 750 \text{ kHz} \tag{9}$$

$$= C/No_p$$

In this region the noise spectrum at the filter output has the same shape as the input noise spectrum, and the ratio of carrier-to-noise power density is degraded 3 dB.

Now consider the effects of the Nyquist filter on white thermal noise. For thermal noise, sidebands are uncorrelated and, as for single-sideband phase noise, half the power is in the AM component and half in the PM component. The effect of the Nyquist filter can be calculated by power addition of AM sideband components at the output of the filter. With the assumption of a linear Nyquist filter, sidebands add to produce a baseband noise spectra that increases quadratically 3 dB to 750 kHz[5]. Above 750 kHz, the output of the receiver filter is single-sideband, and the result is the same for phase noise.

Application of theory

The assumption of a simple linear characteristic for the receiver Nyquist filter is useful, but, of course, real receiver filters are not linear. To more accurately calculate noise resulting from slope detection in the Nyquist filter and to better correlate the theory with measured data, this analysis is based on the response of the Nyquist filter in the Tektronix 1450-1 television demodulator used in the video SNR and baseband spectra measurements. A plot of the Nyquist filter response is given in Figure 1. Also superimposed is 1/2 cycle of a sinusoid function and, as seen, it is a very good approximation of the actual filter function. With this characteristic and the previous equations, good accuracy has been achieved in relating baseband measurements—video noise spectra and weighted and unweighted SNR—to the carrier phase noise spectra and thermal noise.

Figure 2 is a plot of the AM noise spectra at the output of the Nyquist filter caused by thermal and phase noise. Thermal noise produces a video noise spectrum that increases from DC to the upper limit of the Nyquist filter and is constant above that. For frequencies near carrier frequency, the AM (in phase) component is the same at the output of the filter as at the input since upper and lower sidebands are nearly equal. The thermal noise plot shows simply the effect of the Nyquist filter on AM noise.

Figure 3 shows the PM-to-AM conversion of oscillator phase noise. In the frequency range of the Nyquist filter there is some noise rolloff; for a linear Nyquist filter the response would be flat. Above the cutoff of the Nyquist filter the baseband noise rolloff is the same as at RF. Oscillator phase noise contributes primarily to low-frequency video noise in the frequency range of perhaps a few hundred kilohertz to a megahertz or more.

Oscillator phase noise can be recognized and distinguished from video noise in an examination of the video baseband spectra. For high oscillator phase noise, the noise seen when viewing a TV set is recognizable as low-frequency noise and appears different from broadband noise. Data is given in a later section that illustrates these points.

The objective of this article is to relate RF C/N measurements to video SNR and baseband noise spectra. Weighted SNR is the ratio expressed in dB of the total luminance signal (100 IRE units) to the weighted RMS noise level. Note, however, that noise due to phase noise is different from thermal noise in that it is directly proportional to the carrier level. If the carrier were to drop to zero percent modulation, there would be no phase noise contribution, of course. Thermal noise is the same (for constant receiver gain) regardless of carrier modulation. Furthermore, note that noise is more noticeable in dark TV scenes of perhaps 10 to 20 IRE. In our experiments, SNR was determined by measuring weighted baseband noise with the carrier unmodulated in accordance with EIA Standard RS250B. Signal generators capable of being phase-modulated were used to generate the video carrier, and the amount of noise caused by phase noise was determined by turning the phase modulation on and off. Phase SNR is the ratio of the signal for 100 percent modulation (1.143 V for 1 V/100 IRE) divided by the RMS phase noise voltage.

Phase noise can be measured also on a waveform monitor using the Tektronix 147 test signal generator or by the *NTC Report No. 7* approximation technique. With these procedures the amount of phase noise measured will depend on the level of the waveform pedestal at which noise is measured. If noise is measured at a level of 20 IRE, these procedures theoretically give the same results and agree with the measurement and definition of phase SNR.

For the Nyquist filter data the theoretical AM baseband spectral density is plotted in Figure 3 for Qe = 1. Video SNR can be obtained by a noise power integration of Figure 3. The weighted SNR is obtained by multiplying the spectral density in Figure 2 by the noise weighting function. For this data and in our tests, the weighting filter given in CCIR Report 637-1, Equation 4, for System M (prior to the introduction of the unified network) was used. This network is in general use for NTSC system measurements. Performing the noise power integration to 4.2 MHz gives SNR due to phase noise:

$$\text{SNR unweighted} = 54.2 + Qe \text{ dB} \tag{10}$$

$$\text{SNR weighted} = 57.7 + Qe \text{ dB} \tag{11}$$

In a similar manner, the unweighted and weighted video SNR due to thermal noise is obtained. SNR due to thermal noise:

$$\text{SNR unweighted} = C/N - 6.9 \text{ dB} \tag{12}$$

$$\text{SNR weighted} = C/N - .5 \text{ dB} \tag{13}$$

From Equations 5 and 11 one obtains a fortuitous and very neat identity. By measuring phase noise at 20 kHz offset from the carrier in a 1 kHz bandwidth,

$$\text{SNR weighted} \approx C/Np \text{ dB} \tag{14}$$

where:
C/Np is the carrier-to-noise ratio.

This is a simple and possibly very useful measurement for predicting degradation caused by phase noise.

The amount of phase noise relative to that produced by thermal noise in the system can be calculated from Equations 11 and 13 and the definitions of Qe and C/N. Given that the phase noise spectrum crosses the thermal noise spectrum (measured in the same resolution bandwidth) at a frequency F, then, for equal contribution of each to the weighted SNR F is equal to 1.53 MHz. Thus, if the phase noise spectrum crosses the thermal noise spectrum below 1.53 MHz, thermal noise predominates; if it crosses above 1.53 MHz, phase noise predominates.

These equations assume the oscillator spectrum decreases 6 dB/octave, and one should observe the spectrum on a narrow and wide span to see if that is the case. Also, the spectrum in the range of 10 to 20 kHz can indicate higher phase modulation in that range than actually is present. Low-frequency high-deviation PM can cause high order Bessel sidebands to extend above 10 kHz and cause phase noise to appear high.

Video demodulator types and response to phase noise

The effect of phase noise on NTSC video depends on the type demodulator employed in the TV receiver or TV demodulator. Demodulators may be classified as envelope detectors, such as diode rectifiers, or product demodulators[6,7,8]. Envelope detectors respond to large quadrature modulation and distortion of the amplitude modulated signal can occur. However, the envelope detector is immune to the relative small amount of phase noise considered here. This can clearly be seen when one considers that oscillator phase noise produces low deviation FM that in this case may be a deviation of perhaps a few hundred Hertz or even a few kilohertz. Deviation that low would not be detected by a broadband envelope detector except for detection by FM-to-AM conversion in the Nyquist filter.

Product demodulators or coherent demodulators in principle detect an AM signal by recovering the carrier from the modulated signal and multiplying the RF signal by the recovered carrier (hence the name "product" demodulator). A mixer (ring diode-type or integrated circuit mixer)

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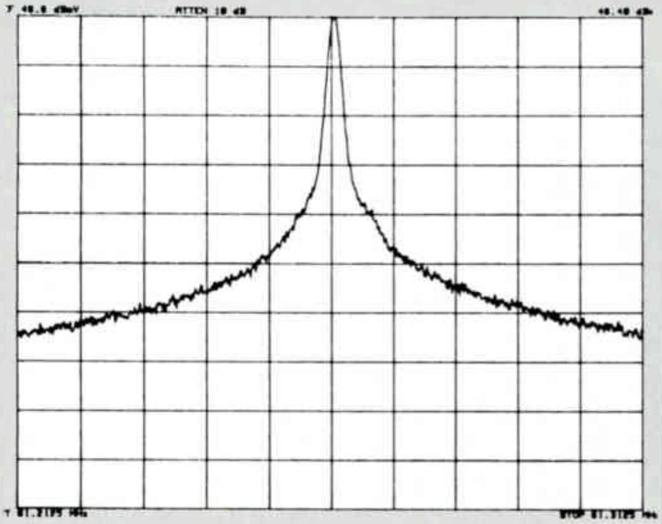
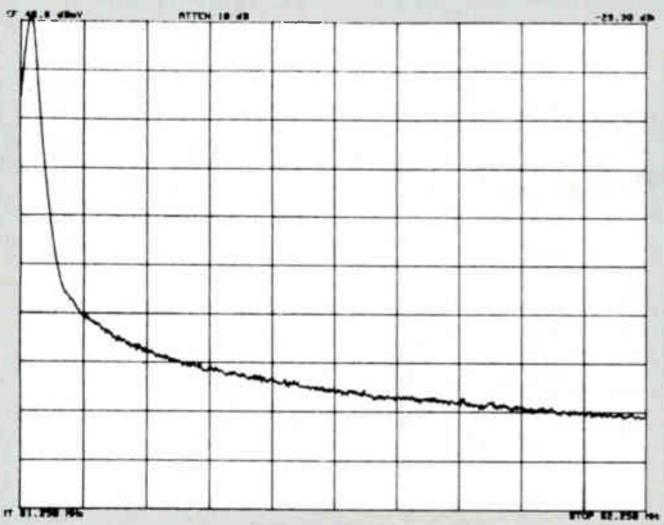
Figure 5a: Agile frequency modulator RF noise spectrum



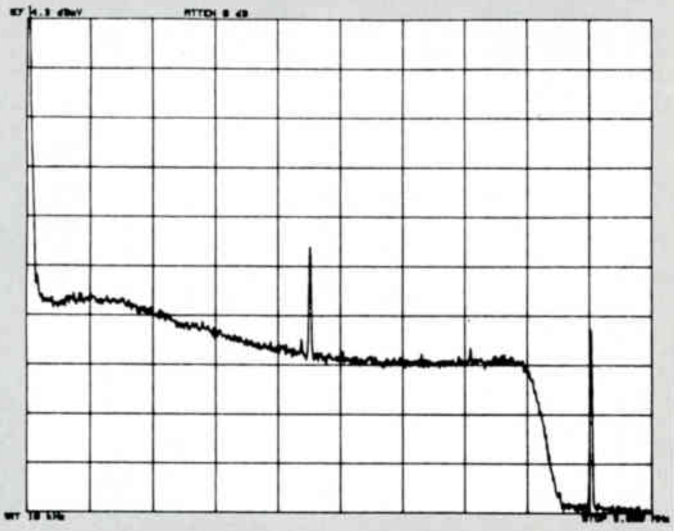
Center freq.: 61.25 MHz Span: 100 kHz
BW: 1 kHz 10 dB/div.

Figure 5b: RF spectrum



Span: 1 MHz BW: 10 kHz 10 dB/div.

Figure 5c: Baseband noise spectrum



Start: 10 kHz Stop: 5 MHz BW: 10 kHz
Ref.: 4.3 dBmV 5 dB/div.

is effectively a multiplier for this purpose. Product demodulators are realized in different implementations and respond differently to the presence of PM on the desired AM signal. In TV applications, product demodulators also are known as synchronous and quasi-synchronous demodulators. Furthermore, envelope detectors, as in the Tektronix 1450 TV demod, can be realized as product demods. Generally, the synchronous detector recovers the carrier by phase locking a local oscillator to the carrier of the TV signal. The bandwidth of the phase lock loop is low, approximately 50 Hz for the Tektronix 1450 demod and Scientific-Atlanta 6250 demod, and the oscillator may be a crystal oscillator. Certainly, this type of synchronous detector cannot handle a large amount of phase noise, particularly 60 Hz power supply noise and low-frequency jitter. The advantage of the synchronous demod is its good linearity and immunity to quadrature distortion provided incidental phase modulation is low.

Quasi-synchronous demods and envelope detectors realized as quasi-synchronous recover a carrier by filtering and limiting the TV IF (intermediate frequency) signal and applying it as the reference (local oscillator) for the IF signal mixer. Since the filtering occurs at IF, the filter bandwidth is relatively wide: 50 kHz for the Tektronix demod and about 200-300 kHz or more currently for TV receivers. Within this frequency range, the recovered carrier tracks the signal carrier and the system behaves as an envelope detector. However, in recovering the carrier, if the filter bandwidth is too small and phase noise is high, the detector itself will convert phase noise to AM noise. Theoretically, the output of a product demod is proportional to the cosine of the angle between the recovered carrier and the carrier of the input signal. For a small tracking error (small phase error), the cosine of the angle is approximately 1 and negligible error is caused by the detector. If the tracking error is large, the detected signal is modulated by the cosine of the tracking error. Thus, inability of the recovered carrier to track phase noise results in additional PM-to-AM conversion in the detector itself. This should not be a problem except for very narrowband tracking loops and excessive low-frequency phase noise. By integrating the mean square phase noise spectra from frequency f_1 to infinity, the total RMS phase noise is obtained:

$$\Phi = \frac{1}{f_1} \sqrt{\frac{2}{Qe}} \quad \text{radians RMS} \qquad \textbf{(15)}$$

For example, for phase noise that would result in weighted SNR of 46 dB, from Equation 12, Qe is −11.7 dB, or a factor of 0.26. The total phase noise in the spectrum above f_1 = 10 kHz is only .016° RMS. This small amount of high-frequency phase noise should not be detrimental to the quasi-synchronous demodulator.

Perceptibility tests

Tests have been conducted to investigate the effects of phase noise on TV reception and determine the threshold of perceptibility. In tests reported by Giorgio Allora-Abbondi[9] and Robb Balsdon[10], a Hewlett-Packard 8660B synthesized signal generator was frequency-modulated by the broadband noise source of a Tektronix 147 test signal generator and the synthesizer output was substituted for the output converter LO in an S-A 6530 TV modulator. The bandwidth for noise modulation was limited by the synthesizer to about 250-500 kHz. In these and other tests, phase noise was measured by measuring carrier sideband noise level in dBc at 20 kHz offset from the carrier and in a 1 kHz bandwidth. Balsdon reported that phase noise became perceptible at a noise level

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Figure 6a: Set-top converter

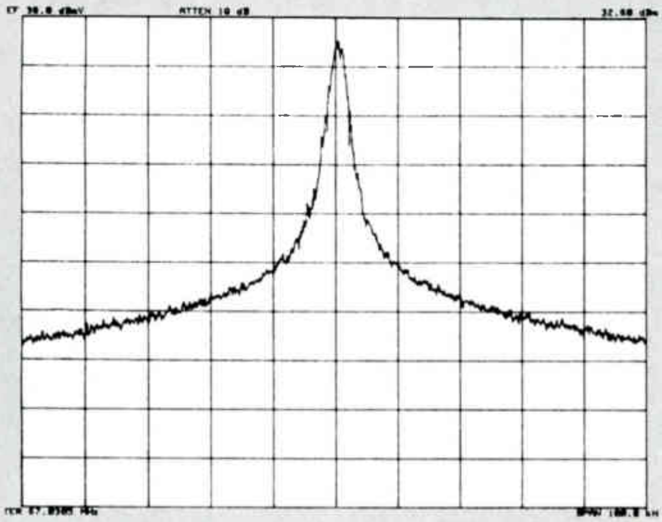
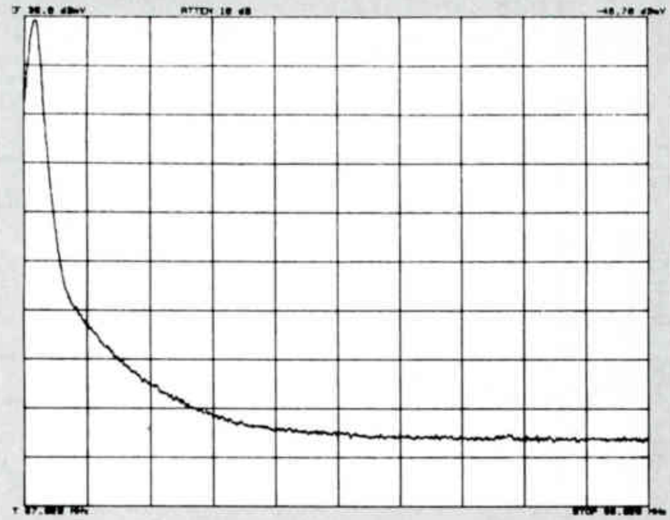


Figure 6b: RF spectrum



of about −53 dBc on three TV sets, and at −54 dBc when using an S-A 6250 TV demod in the envelope detector mode. When operating in the synchronous detector mode, phase noise became perceptible at a much lower level, −67 dBc, due to the narrow bandwidth of the synchronous demodulator (approximately 50 Hz) and its inability to track the low-frequency noise.

In tests by Allora-Abbondi the perceptibility threshold was found to be −52 to −56.5 dBc with −53 dBc typical for envelope detectors. With Tektronix and S-A synchronous demodulators, susceptibility to phase noise was much greater: −57 to less than −64 dBc. Performance in the synchronous mode was best with the fast detector time constant due to better tracking between the reference oscillator and the incoming signal. With no phase noise added, weighted SNR of the system was 54 dB.

The tests that follow were conducted at S-A with participation by members of the Group 1 committee. In tests similar to those previously mentioned and using an HP 8640 signal generator as the noise-modulated source, the perceptibility threshold was found to be at a phase noise level of −56 dBc. Levels were set for optimum performance; without phase noise weighted SNR measured 66 dB. At the phase noise threshold, weighted phase SNR measured 60 dB.

In another test, an oscillator with 4 MHz modulation bandwidth capability was frequency-modulated by the Tektronix 147 noise source and substituted for the S-A 6350 video modulator output converter LO. With this oscillator the background SNR was 64 dB. Phase noise and weighted SNR measured −62 dBc and 60 dB, respectively, at the perceptibility threshold. Phase noise at 20 kHz offset from the carrier was 6 dB lower than with the HP 8640 source due to the narrower modulation bandwidth of the HP 8640, approximately 250 kHz, but the resulting SNRs were the same.

Thermal noise was added from a broadband RF source and the perceptibility test repeated for thermal noise only. Weighted SNR measured 58 dB for the same degree of perceptibility. This is within 2 dB of the SNRs measured for wideband and band-limited phase noise. We believe that weighted SNR gives a good quantification of system performance regardless of whether noise is thermal or phase in origin.

Thermal noise was increased to give a weighted SNR of 46 dB. Under this condition, phase noise measured −50 dBc at threshold. Weighted SNR due to phase noise (measured with thermal noise off) measured 50.7 dB.

For the S-A tests, test patterns were very closely scrutinized to see any noise effects. Tests also were made with program video obtained from a satellite feed. The HP 8640 signal generator was noise-modulated and used for these tests. Video SNR from the satellite feed measured approximately 53 dB. For moving program video phase noise became visible generally in highly saturated areas at a phase noise level of −47.6 dBc (at 20 kHz offset from the carrier and in a 1 kHz bandwidth, as before).

Phase noise appears a little different from thermal noise in test patterns and video. Thermal noise appears as fine grain noise; phase noise has more of a streaked, low-frequency characteristic that is to be expected from general knowledge of the baseband spectrum. In the S-A tests, plots were made of the baseband video spectra (with the Tektronix 1450 demodulator operated in manual gain mode to ensure that the gain is the same with unmodulated carrier as for normal video). Phase noise was easily distinguished from thermal noise by its shape. Phase noise showed a rolloff with frequency, whereas thermal noise showed a slight rise from DC to approximately 1 MHz and was flat from there to 4 MHz.

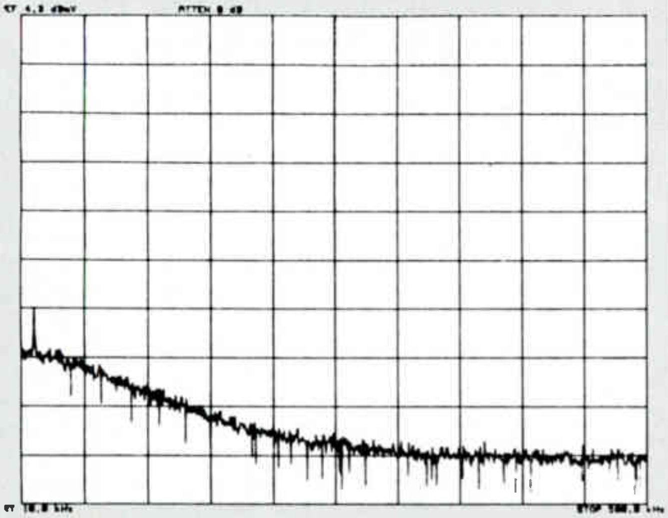
Representative data

Figure 4 is data for a fixed-frequency (Ch. 5) video modulator. Oscillators in this modulator are crystal oscillators and, of course, phase noise is very low. The baseband plot is characteristic of a system white noise limited: No phase noise is evident. Spurious responses in the baseband plot are evident, but these are low enough so as not to materially affect the results. Calculated unweighted phase noise is more than 10 dB below measured noise.

Figure 5 is data for an agile modulator. This modulator shows results of oscillator phase noise that is somewhat high. The oscillator spectrum has the classical 6 dB/octave rolloff up to approximately 2 MHz where it approaches the noise floor of the modulator. Above that frequency, baseband noise is determined by thermal noise; below approximately 2 MHz baseband noise is predominately phase noise in origin.

Figure 6 is data for a set-top converter. The input level was set relatively high — 16 dBmV — but not excessive for a single channel in order to achieve maximum dynamic range for the spectrum plots and SNR. Also, the converter output was amplified ahead of the spectrum analyzer for the same reason. Notice that for the 100 kHz RF span, the carrier is several dB below the reference line. The carrier was actually set to the reference line in a wide IF bandwidth (30 kHz), and because of low-frequency FM, the carrier appears low when plotted with an IF bandwidth of 1 kHz. At baseband, there is a definite contribution from phase noise below 1 MHz. For no phase noise, there should be a dip in the baseband spectrum below 1 MHz. As shown in the 1 MHz RF span, the oscillator spectrum falls off more rapidly than 6 dB/octave, and ap-

Figure 6c: Baseband noise spectrum



Start: 10 kHz Stop: 500 kHz BW: 1 kHz
Ref.: 4.3 dBmV 5 dB/div.

Figure 6d: Baseband noise spectrum

Start: 10 kHz Stop: 5 MHz BW: 10 kHz
Ref.: 4.3 dBmV 5 dB/div.

parently is below the noise floor of the converter by 500 kHz. This causes a sharper rolloff in the baseband spectrum to 500 kHz as compared with that shown in Figure 3.

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Aerial Safety
Instructor Certification Program

The SCTE, in its continuing role to provide technical training to the CATV industry and in conjunction with the recently announced Installer Certification Program, is about to embark on a new project: an Instructor Certification Program for pole climbing, ladder climbing and bucket truck safety.

In other words, this program will certify instructors, who will in turn certify installers and technicians within their respective systems or local SCTE chapters. One of the first tasks of the committee is to decide how this program will be presented to the industry...and what better way than to ask the industry.

Here are some of the preliminaries: The program needs to be presented in a location where practice poles, ladders and bucket trucks are available. Also, a committee member or an appointed member of the SCTE must be available for the actual certification of the instructor.

Listed as follows are some of the committee's ideas. Please rate each by circling the appropriate number (0 is the least favorable, 10 is most). Also, there are a few general questions regarding the program, requests for assistance, and places to write your opinions.

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I. Program presentation possibilities:

1. Centralized location, such as having all participants travel to the ATC Training Center in Denver; an SCTE certifier will be available.

0 1 2 3 4 5 6 7 8 9 10

2. Local chapters and meeting groups—cable systems or other utilities provide a location; an SCTE certifier will travel to the location.

0 1 2 3 4 5 6 7 8 9 10

3. Regional training centers are designated throughout the country; an SCTE certifier will be available nearby.

0 1 2 3 4 5 6 7 8 9 10

4. Do you have, or know of such a center available for SCTE's use? (Please give name of company, address, phone number and contact person.)

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Other ideas: ______________________________

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II. Presentation medium proposals:

1. Self-study workbook

0 1 2 3 4 5 6 7 8 9 10

2. Self-study workbook/video

0 1 2 3 4 5 6 7 8 9 10

3. Self-study workbook/interactive video

0 1 2 3 4 5 6 7 8 9 10

4. Lectures, demonstrations and practice

0 1 2 3 4 5 6 7 8 9 10

5. Other: ______________________________

____

III. Requirements for entrance to the program:

1. Enrollment exam to enter the Instructor Certification Program, based on written and/or field exams, and supervisors' recommendations.

0 1 2 3 4 5 6 7 8 9 10

IV. Requirements for instructor certification:

1. Final written exam

0 1 2 3 4 5 6 7 8 9 10

2. Final field exam

0 1 2 3 4 5 6 7 8 9 10

3. Hands-on, in the field training Hours ________
4. Training on OSHA, ANSI, NEC, NESC and regulatory issues Hours ________
5. Years in the CATV industry Years ________
6. Years actively climbing Years ________
7. Additional requirements ______________________________

____

____

V. Cost

A certain amount of cost is associated with the administration of a program such as this one. What would you be willing to pay to be certified or have one of your employees certified? $ ________

Additional comments ______________________________

____

____

____

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Part I: Light measurement

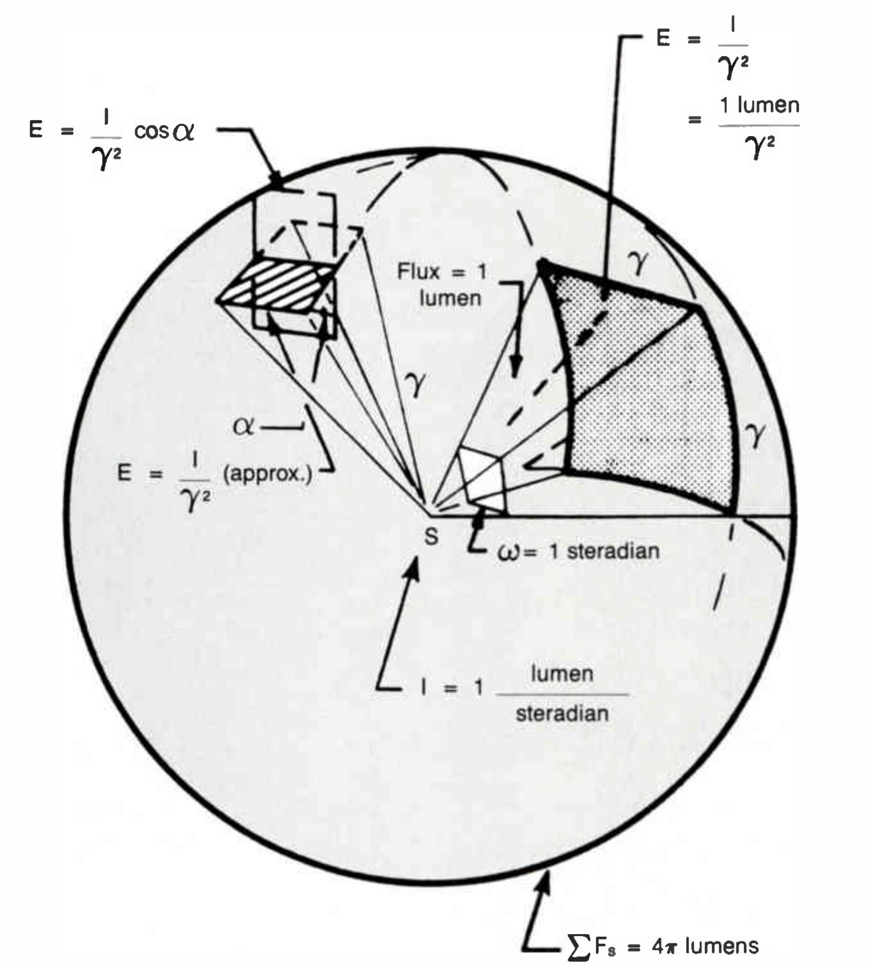
For years the necessity for a complete understanding of light for the production of good TV scenes has been a "given." As the importance of fiber optics in communications increases, the corollary importance of light and its measurement in that field follows. Over the many years of the study of light, a jungle of often bewildering technology developed. The lack of uniqueness, in addition to everyday connotations of much visual terminology, often confuses the reader not familiar with the subject.

It is further confusing because light measurement has two different generic approaches. From a physicist's viewpoint light is radiant energy and thus can be measured in watts—radiometry. Over the course of time, the measurement of light as we see it and photograph with it, for use by human observers, has produced light measurement units (lumens) in photometry. The formulas for various radiometric quantities are analogous to the ones for the corresponding photometric quantities. If watts are substituted for lumens, the units (in the international MKS unit system) in the radiometric quantities are the same as those of the corresponding photometric quantities.

Customarily, photometric measurements are used in general illumination and photography (film and TV), whereas radiometric measurements are widely used in scientific applications, e.g., microwave/satellite RF, fiber optics, etc.

By Lawrence W. Lockwood
President, TeleResources
East Coast Correspondent

Figure 1: Relationships of flux (F), intensity (I), and illuminance (E) about a point source equivalent to one international candle, emitting equally in all directions



There is a great deal of confusion among many people about the correct use of terminology when dealing with light. This is due to two main reasons:

1) The major cause of confusion is that we have all used terms for light in everyday language throughout our lives. Many of these terms used in this manner are treated casually and used interchangeably; i.e., brightness and intensity. When used in a scientific manner they cannot be so treated but must be used in *only* the specific manner that each is defined.

2) The second cause of confusion, unfortunately, is that the scientific terminology is itself not rigorous (due to the historical growth of the study of light) and often the same term is used to refer to different quantities, and conversely different terms are used to refer to the same quantity.

Nature and measurement of light

Light is radiant energy that arouses visual sensations. The sensation of brightness is not a linear function of the amount of radiant energy received by the eye. Therefore, light is commonly measured by photometry, in which the eye itself is used as the sensing device, and the observer compares its brightness with that of a known standard. Photometric units are arbitrarily based on the international candle, which formerly was an actual candle and now is an incandescent filament of carefully maintained specification.

Chief concepts and units are as follows:

a) *luminous flux*, analogous to rate of transfer of energy (or quantity of illumination) measured in lumens (a point source of one international candle emits 4π lumens in all directions).
b) *intensity*, the flux per solid angle from a point source, measured in candles.
c) *illuminance*, the flux striking a surface, measured in lumens per unit of area.
d) *luminous emittance*, the flux emitted in all directions from each unit of an area source (including reflecting and transmitting sources), measured in lumens per unit of area.
e) *luminance* (brightness), the luminous emittance of reflectance in one direction from an area source, measured in lumens per unit of area per steradian or in lamberts or millilamberts.

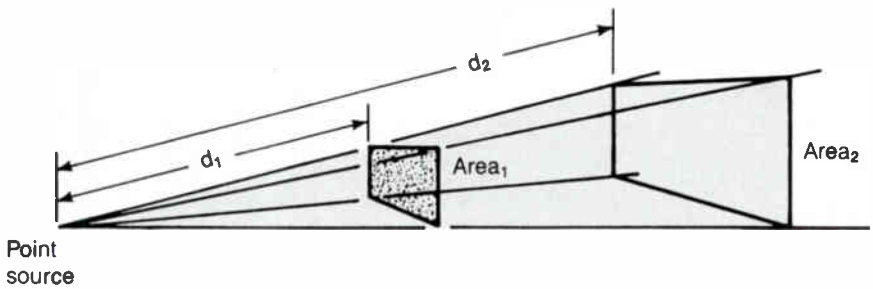
Radiant flux is the amount of radiant energy striking a surface per unit time, which is generally specified in terms of watts.

The eye is not a photographic plate; the intensity of a visual sensation depends not on the total amount of light transferred to the eye over a period of time, but on the rate of transfer beyond a critical minimum duration. Therefore, magnitudes of light in photometry are given in terms of luminous flux (F), the time rate of flow of light.

Luminous flux is radiant flux weighted according to the response of the visual system.

The unit of lumimous energy is termed the *lumen*. The lumen is a measure of the brightness-producing capacity of a radiant source. Under

Figure 2: Law of inverse squares



$$\frac{\text{Luminous flux received per unit area}_1}{\text{Luminous flux received per unit area}_2} = \frac{d_2^2}{d_1^2}$$

$$\frac{\text{Area}_1}{\text{Area}_2} = \frac{d_1^2}{d_2^2}$$

therefore:

$$\frac{\text{E at area}_1}{\text{E at area}_2} = \frac{\text{flux per unit area}_1}{\text{flux per unit area}_2} = \frac{d_2^2}{d_1^2}$$

normal viewing conditions two sources of equal luminous flux will be judged equally bright. However, perceived brightness and luminous flux are not, in general, simply related. It is useful, therefore, to discuss the difference between brightness and luminous flux.

It is important to note what has *not* been accomplished in the determination of luminous flux. First, quantitative statements predicting the amount of perceived brightness differences between two sources cannot be made from a knowledge of their corresponding luminous fluxes. For instance, in general a two-lumen source will not appear twice as bright—that is, will not be judged as twice as bright—as a one-lumen source.

Second, two sources of the same luminous flux may not, in fact, appear equally bright unless certain conditions are satisfied. The most important of the conditions is that the two sources under comparison must be focused on retinal areas of equal sensitivity and that the adaptation level of each area must be the same (adaptation level refers to the sensitivity of the eye and is related to the history of light exposure).

An exception to these conditions can be easily demonstrated. Close one eye for five or 10 minutes in a brightly illuminated room. Then alternate between your two eyes. The scene appears brighter with the dark adapted eye than it does with the eye that was kept open.

Another example of an exception is to surround an area of constant luminous flux with an area of variable flux. The central area will darken as the surrounding flux is increased. Thus, a difference in brightness can occur between two sources of equal luminous flux. Luminous flux is obtained from a weighting function based on a standard observing condition (hence, sometimes termed "objective"); whereas brightness is obtained from judgments of an observer in a given situation (hence, sometimes termed "subjective") and is a complex function of the illumination history and other factors, as well as of the luminous flux present at a given time.

Luminous flux is a useful measure for the specification of lighting levels. If the visual response (perceived brightness) of an observer is desired in a given situation, then factors other than luminous flux may need to be considered.

Brightness as a function of adaptation level and other conditions has been studied, but the determination of brightness in an arbitrary viewing situation remains a difficult problem. The distinction between brightness and luminous flux is often confused both in everyday use and in the technical and scientific literature. The term

"Over the many years of the study of light, a jungle of often bewildering technology developed."

brightness is most commonly used incorrectly where a luminous flux measure is appropriate.

Photometric measures and units

Several kinds of measures are derived from the basic definition of luminous flux. In principle, these measures are analogous to radiometric quantities, the only difference being that luminous flux replaces radiant flux. In practice, however, various systems of photometric quantities are in use. Furthermore, several photometric

Figure 3: Area of emitting surface (E) as viewed along perpendicular (B) and along (A) at angle α from perpendicular

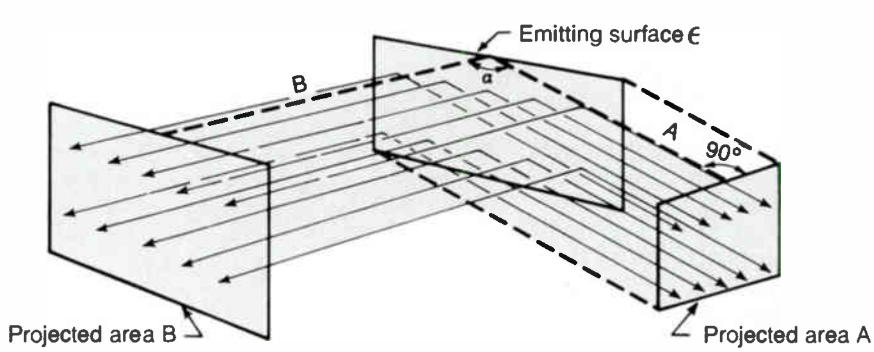


Figure 4: Reflection or emission according to cosine law

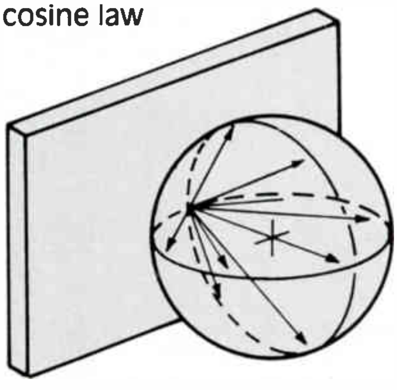
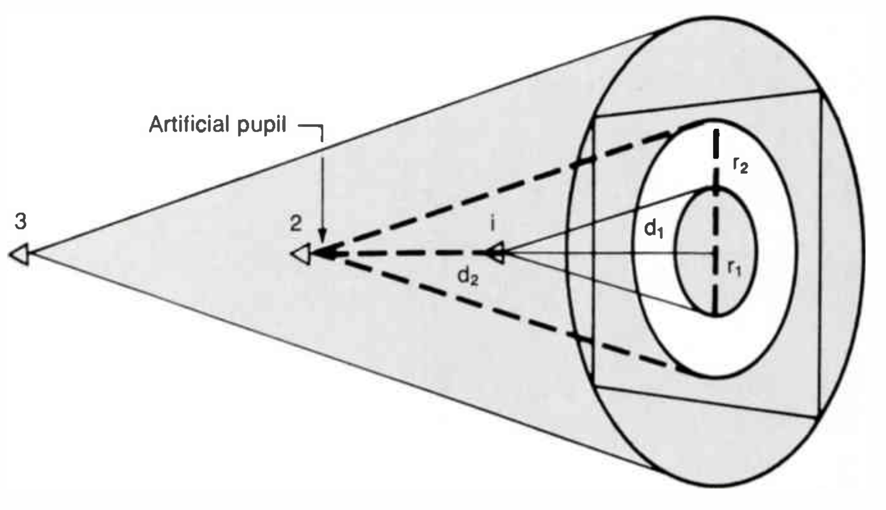


Figure 5: How the luminance of an area source is independent of distance up to a certain limit imposed by the size of the source



units may exist for each quantity, including metric and non-metric. The choice of a particular unit or photometric system in a given application has largely depended on the idiosyncracies of the particular investigator. Much confusion has resulted.

A set of metric units has been accepted as standard by the International Commission on Illumination (CIE). The relationships among the different units and possible sources of confusion will be described.

Photometric units are derived from an arbitrary standard, the international candle. It was originally an actual sperm candle weighing 1/6 pound and burning at the rate of 120 grains of wax an hour. Now the primary standard is platinum at its melting point viewed through a small opening in an oven, which serves as a black body. The secondary standards are electric incandescent filaments maintained at the U.S. National Bureau of Standards.

In photometry, two kinds of light sources are important: a *point source* and an *area source*.

A point source is by definition infinitesimal, but a source of finite size may be considered a point source if it is small or distant enough so that the geometry of light emitted from it approaches that of light emitted from a point source. An area source is by definition a source of finite size. In practice, it may be considered any source large enough so that the luminous flux emitted per unit of area is important. Note that when the word *source* is used, it need not be the ultimate source of light. The reflection of a distant light in the windshield may itself be considered a point source; a cloud transmitting and diffusing the light of the sun or a runway reflecting it may be considered an area source. In fact, anything that can be seen is a source of light, because vision is (except in rare instances) stimulated only by light entering the eye.

The sum of all the light being emitted from a point source may be expressed geometrically as a solid. If light is emitted equally in all directions, the solid becomes a sphere. The geometrical relationships of light are shown in Figure 1. The basic unit of flux is the *lumen*. By definition, one lumen is equal to $\frac{1}{4}\pi$ times the total flux emitted by a point source equal to one international candle. (Since the visual investigator is usually concerned with the flux in a given direction rather than total flux, and since there is a total of 4π steradians of solid angle (ω) about a point, one lumen is defined as $\frac{1}{4}\pi$ total flux rather than total flux to facilitate mathematical manipulations.)

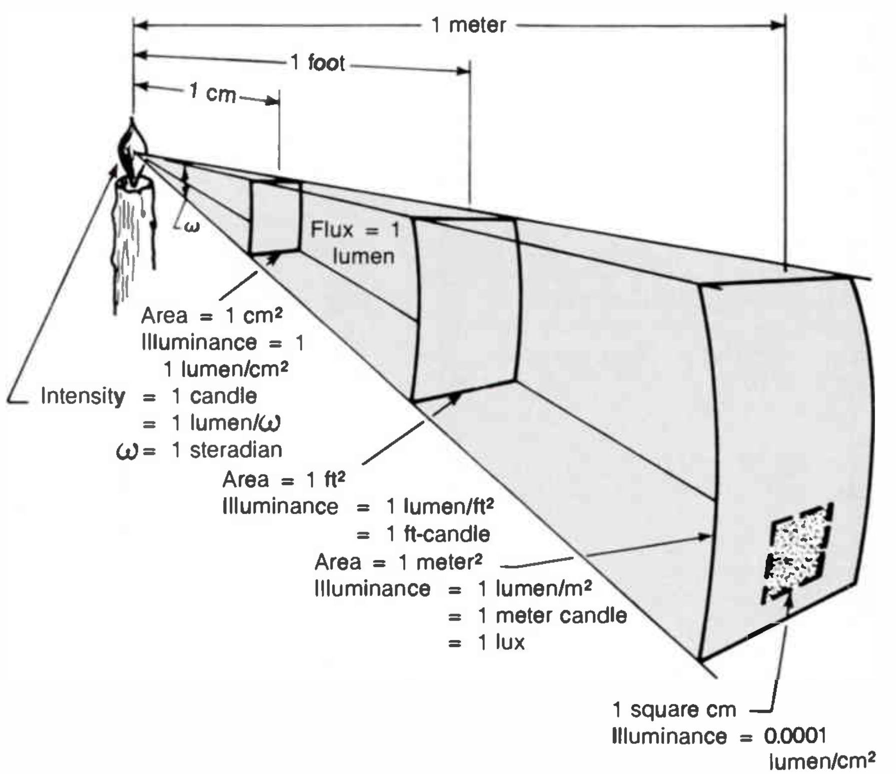
Luminous intensity (I) is analogous to radiant intensity and is the amount of luminous energy emitted from a point source per unit solid angle; i.e.;

$$I = \frac{d\Phi}{d\omega}$$

where:

Φ = luminous flux and ω is solid angle. One steradian is the solid angle subtended at the center of a sphere by an area of arbitrary shape on the surface of the sphere, equal to the square of the radius of the sphere. Since the total area of a spherical surface is $4\pi r^2$, the total solid angle about a point is 4π steradians. In general, if ω represents the solid angle subtended at a point by an area A on the surface of a sphere of radius r, then ω (in steradians) is equal to the area A

Figure 6: Relationships between intensity units of source and illuminance units on surfaces at various distances



divided by the square of the radius r, i.e.:

$$\omega = A/r^2$$

The unit of luminous intensity is the candle (cd), which is equal to one lumen/steradian. A point source equal to one international candle has an average intensity of one lumen per steradian.

Illumination or *illuminance* (E) is the amount of luminous energy incident on a surface from a distant source. Several units for illumination are used with the most common being the foot-candle, which equals one lumen/ft^2. (Note that the term foot-candle is a misnomer, as the hyphen in scientific terminology is generally used to refer to a multiplicative quantity such as erg-sec.; in the case of a foot-candle no such relationship is intended.) The internationally approved unit is the lux (lx), which equals one lumen/meter^2. Illumination is formally defined as:

$$E = \frac{d\Phi}{dA}$$

where:

Φ = luminous flux and
A = surface area

When the source of light is a point source, the illuminance on the surface is related to the intensity of the source by the law of inverse squares; that is, the area of a surface subtending a given solid angle increases with the square of its distance from the source (Figure 2). The concentration of flux falling on the surface must therefore *decrease* in proportion to the square of the distance. (If the surface is the retina of the eye, the intensity of visual stimulation also will decrease with the square of the distance.) If the surface is the surface of a sphere whose center is a point source and whose radius is r, then each steradian of angle is subtended by an area r^2; the illuminance (E) on the surface is found by

$$E = \frac{I}{r^2}$$

This relationship holds true only under conditions assuming that there is no absorption, reflection or refraction of light between the source and the surface (Figure 2). The same relationship holds approximately true for a flat surface normal to the direction of light from a point source, provided that the surface subtends a small solid angle, so that its area approaches that of the spherical segment it subtends. If such a surface is tilted in respect to the direction of light, it can easily be shown that

$$E = \frac{I}{r^2} \cos \alpha$$

where:
α is the angle of tilt from the vertical (Figure 1).

Luminance emittance and luminance

Luminance is a somewhat confusing term, in part because of the existence of two measures. One measure refers to the total flux emitted by a surface (*luminous emittance*); the other in-

Table 1: Table of equivalences for commonly used photometric units

Intensity (I)	1 lumen/steradian = 1 candle = 1 candle power
Illuminance (E)	lumens/cm^2
	1 lumen/m^2 = 1 meter candle = 1 lux
	1 lumen/ft^2 = 1 foot-candle (ft-c)
Luminous emittance (L)	lumens/cm^2
	lumens/m^2
	lumens/ft^2
Luminance (B)	lumens/steradian/m^2 (or cm^2)
	lamberts (L) = millilamberts (mL) $\times 10^3$ =
	microlamberts (μL) $\times 10^6$ for a perfectly diffusing surface,
	1 lambert = $1/\pi$ candles/cm^2
	footlambert (ft-L) = 1.076 mL

volves the directional reflectance characteristics of a surface (*luminance*). In general, *luminance* and *luminance emittance* apply to area sources that cannot be treated as point sources.

When a surface transmits or reflects light, that surface may be considered an area source of light (except in the special case of a perfectly reflecting or transmitting surface receiving light from a point source). Luminous emittance (L) is the name for flux emitted per unit of area of an area source and, like illuminance, it is measured in lumens per unit area. If the luminous emittance consists entirely of reflected light, then

$$\text{Reflectance} = \frac{L}{E}$$

If the luminous emittance consists entirely of transmitted light, then

$$\text{Transmittance} = \frac{L}{E}$$

However, the brightness of an area source, as viewed from any given point, depends on the angle from which it is viewed and on the luminous flux emitted from each point on the surface per unit of solid angle.

Consider first a plane surface that emits light equally in all directions. If this surface were viewed from an angle, it would appear brighter than if viewed from straight ahead. The reason for this is indicated in Figure 3. All the flux emitted from the surface in any given direction must pass through an area equal to the projected area of the emitting surface. The greater the angle, the smaller the projected area; and since the same total flux is emitted in every direction, the flux will be more concentrated—and the surface will appear brighter—in inverse proportion to the size of the projected area. The size of the projected area, and hence the brightness, is proportional to the cosine of the viewing angle—the angle between a line perpendicular to the emitting surface and the observer's line of sight.

In Figure 3, projected area B, being straight out from the emitting surface, is equal to it in area. Area A is smaller; Area A = Area B × cosα. Flux per unit area at A = flux per unit area at B/cosα, assuming flux is emitted equally in all directions. However, a diffusing surface usually emits or reflects the maximum amount of luminous flux straight outward, and the amount decreases as the angle from the perpendicular increases. If this decrease is exactly proportional to the cosine of the angle with the perpendicular, as illustrated by the vector diagram (Figure 4), it will just cancel out the increase in brightness due to the light's being concentrated in a smaller projected area. Such a surface will appear equally bright from any angle. It is said to follow the cosine law, and to be perfectly diffusing. Energy is transmitted in each direction at rate proportional to cosine of the angle with the perpendicular; vectors form a sphere.

Luminance (B) is defined as intensity per unit of projected area from an area source. The unit is the lambert. The visual sensation of brightness is thus a function of the luminance of the source. Luminance is measured in lumens per steradian per square centimeter (or other unit of area), or more commonly in terms of a special unit called the *lambert* (L). For a perfectly diffusing surface, one lambert = $1/\pi$ lumens per steradian per cm^2. Where the surface is not perfectly diffusing, its luminance as viewed from a given direction may still be expressed in terms of lamberts, by comparing it with a perfectly diffusing surface of known luminance. Since the lambert is an inconveniently large unit for most purposes, luminance is more often measured in millilamberts, mL (lamberts × 10^{-3}); in microlamberts, μL (lamberts × 10^{-6}); in micromillilamberts, μmL (lamberts × 10^{-9}); or in micromicrolamberts, $\mu\mu$L (lamberts × 10^{-12}).

An important property of a perfectly diffusing area source is that within a limiting distance that depends on the size of the source, the luminance does not vary with the distance of the eye. It will be remembered that the flux reaching the eye from a point source decreases with the square of the distance of the eye from the source. The same decrease takes place in the flux emitted by any point on an area source. This decrease is offset by the increase in the area from which the eye receives flux as it gets farther away. The situation is illustrated in Figure 5, where you will note the presence of an artificial pupil that serves to limit the visual field. What this means is that the apparent brightness of an area source does not vary with distance to the eye for these conditions.

(Continued on page 106)

Technical training with joint seminars

By Ron Hranac
President, Society of Cable Television Engineers

Technical seminars co-sponsored by the SCTE and one of its local chapters have been an annual occurrence until this year. 1988 marks the first time that *two* such seminars bring SCTE's training message to the field. Looking back over the past few years, a wealth of technical training has been provided through such joint efforts. In 1985, the Rocky Mountain Chapter teamed up with national headquarters to put on a very successful signal leakage program; in 1986, the Florida Chapter co-hosted a seminar on automated CATV system testing. 1987 was the Chattahoochee Chapter's turn, with a technical management development seminar held in Atlanta.

The most successful joint seminar to date has to be the fiber-optics program co-sponsored by the Florida Chapter in January of this year. Anticipating about 150 attendees, Richard Kirn and his group were quite surprised when 412 people showed up in Orlando to learn about fiber!

Hoping to continue this trend, the Rocky Mountain Chapter has once again joined forces with national: On Oct. 28, 29 and 30, Denver will be the location of 1988's second joint seminar. "HDTV and beyond" is a technical conference that will cover the nuts and bolts of high-definition television. (For an agenda, see this month's "News.")

HDTV has the potential of being as important to TV picture quality as the introduction of color TV was to black-and-white several years ago. Television in North America now uses 525 lines to form the pictures we watch. HDTV images contain up to 1,125 lines and approach the quality of 35mm motion pictures.

At this seminar you will be able to learn the history of HDTV's development, how it works, and see it in operation. Breakout sessions are planned that will include live demonstrations of various HDTV formats and transmission through simulated cable plant and satellite links. Attendees will receive handouts from all the sessions and workshops in a three-ring binder.

If you've wanted to learn about HDTV, this seminar is the place to be. Advance registration forms have already been sent to SCTE's membership. If you did not receive that package, a registration form is provided below. As well, BCT/E exams will be administered during the seminar, so you'll have an opportunity to work toward certification!

Advance Registration Form for "HDTV and Beyond"

(Please print or type)

Please read instructions prior to completion.

Name: ____________________

First or Nickname for Badge: ____________________

System or Firm Name ____________________

Title: ____________________

Address: ____________________

City, State, ZIP: ____________________

Telephone: ____________________

If you are a national member of the SCTE, SMPTE or SBE please indicate.

☐ SCTE Member # ____________________

☐ SMPTE Member # ____________________

☐ SBE Member # ____________________

Spouse (if registering) ____________________
(Rates listed below)

Registration Fees

☐ I plan to take the BCT/E certification exams on Sunday, Oct. 30 from 1-4 p.m. (Note: Exam fees will be collected on-site.)

Advance Registration

____ Member SCTE, SMPTE or SBE	$150
____ Non-member	$190
____ Member Saturday only	$ 50
____ Non-member Saturday only	$ 75
____ Spouse—anytime	$ 50

On-Site Registration

____ Member SCTE, SMPTE or SBE	$195
____ Non-member	$235
____ Member Saturday only	$ 95
____ Non-member Saturday only	$120
____ Spouse—anytime	$ 50

Non-member full registration includes one-year SCTE membership.

Instructions (Please read carefully)

1) Use separate form for each registrant (photocopies accepted).
2) Advance registration ends Friday, Oct. 13.
3) Advance registration forms and hotel request must be received by the RMSCTE office prior to Oct. 13. Those who have not registered on or before Oct. 13 must do so on-site.
4) Registration forms should be returned to:
   Society of Cable Television Engineers
   Rocky Mountain Chapter
   P.O. Box 5317
   Englewood, Colo. 80155
5) *Payment must accompany advance registration form to be a valid registration.*

Method of Payment

_____ Check (Check must be made payable to RMSCTE.)

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____

Card Number: ____________________

Expiration Date: ____________________

I hereby authorize RMSCTE to charge my registration fees to my above indicated credit card. Date: ____________________

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Reader Service Number 51.

Outage management

This is the second installment of a three-part series on minimizing service interruptions. Part III will discuss real-time management and tracking of outages.

By Roy Ehman
Director of Engineering, Jones Intercable Inc

Last time, we covered some possible causes of outages, such as self-induced interruptions, poor installation practices, inadequate batteries and vandalism. Several other causes we'll discuss are electrical storms, ice, power problems and equipment failures.

Electrical storms (lightning):

Fortunately, lightning strikes directly to the plant are very rare indeed, due to the invariable presence of other conductors above the space that take the hit. On occasion, the lightning strikes the 13 kV high-voltage line and flashes over the lightning protectors to the neutral, cable TV, telephone and ground (Figure 1).

This creates an ionized conducting path that the 13 kV AC immediately follows and tries to find its way back to the substation or power station through whatever path it can. Many power companies keep accurate and detailed records of the number of strikes, breaks and fault currents and their paths. It is not uncommon for as much as 10,000 amperes of AC fault current to flow back to the substation. This current could be sustained for as long as 160 milliseconds before the substation breaker could stop the flow.

Even a 1 ohm ground, which can be achieved by coupling up ground rods and driving them 24 to 32 feet into the ground until water is contacted, is not adequate to lead away such large currents. Typically, those 10,000 amperes of fault current would split approximately equally between the neutral and the strand and cable. In the case of strand and cable, the division is also approximately equal, leaving us with approximately 2,000 amperes flowing through the cable sheath. No wonder amplifiers and fuses blow under these conditions. Note that the problem goes directly to the coax, bypassing the 60 V ferroresonant supply and all its isolating and regulating qualities.

Some of the ways tried in the past to overcome this particular problem are as follows:

1) Drive *unbonded* grounds at separate poles. This provides a divider network that drains off some of the energy under fault conditions, but there are limits. For example, 1 ohm grounds do not completely solve the problem. Also, it should be noted that this technique can create life-threatening potentials between conductors on the pole during a fault situation.
2) Bridge the amplifiers with at least AWG #6 copper wire. This should shunt the approximate 1,000 or so amperes flowing in the strand and cable during fault conditions and prevent a potential from developing across the entire assembly, including input and output connectors.
3) Increase fuse ratings incrementally. This is especially true where the equipment is sufficiently robust, such as the secondary of ferroresonant-type, 60 V power supplies that are short circuit-proof and almost "indestructible."

"Portable standby generators are a must for keeping the first few important power supplies nearest the headend going during a prolonged outage."

4) Attack surge, spike and overvoltage problems at the center conductor. The safe, legal and uncontentious way to overcome power-related problems where the damage occurs is by using a fast-responding, rugged, transient protector.

One such device is Alpha Technologies' "Amp-Clamp," which is simply a 450 MHz power inserter with voltage-sensing thyristors (SCRs)[1]. It has been tested through the IEEE 587 surge voltage compliance test (6,000 volts at 200 amperes) and IEEE 587 Part B (6,000 volts at 3,000 amperes). Metal oxide varistors (MOVs) are undesirable in this type of service for repeated shunting away of large currents because of the "tunneling" phenomenon that MOVs exhibit, leading to their ultimate self-destruction.

SCRs are much more effective than zeners because the latter have to dissipate considerably higher wattages, and the I^2R dissipation becomes too much. Compare Figure 2 with Figures 3 and 4 where the drop across the SCR, when conducting, is only about 0.3 volts. The crowbar will shunt 35 amperes continuously or 500 amperes for 1/2 AC cycle, or 1,000 amperes for 1 microsecond. Field testing during the summers of 1986 and 1987 in Virginia and Arkansas has been highly successful and eliminated recurrences of plant demolitions due to lightning-induced currents and surging power or severe transients from a high-voltage power company switching station.

During the device protective cycle, the coax center conductor is virtually shunted to sheath ground. This shorts out the power supply for each half-cycle that the overloads or transients

Figure 1: Lightning strike directly to the plant

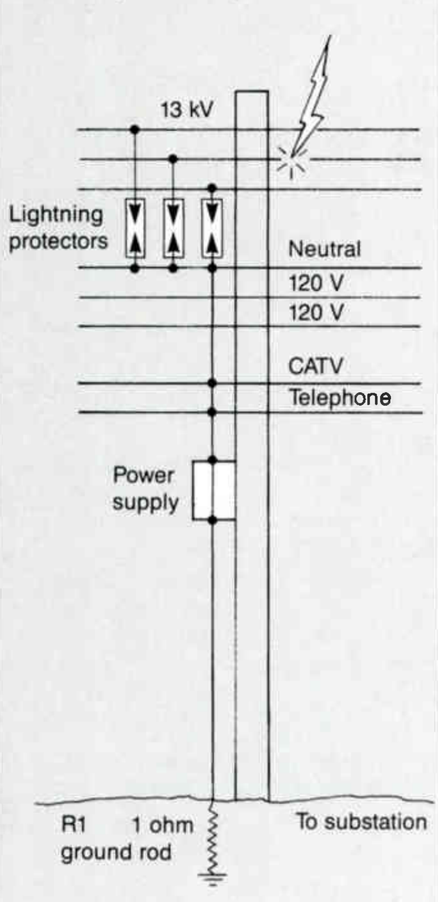


Figure 2: I^2R losses in zener-type clamping circuit

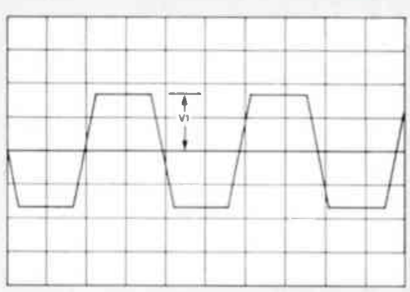
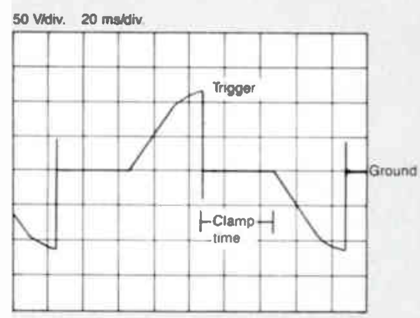


Figure 3



are present. A 15 ampere ferroresonant transformer limits at about 20 amperes and can maintain this condition indefinitely even while the transistors are working on standby. During an AC surge or sustained AC voltage from whatever cause, the power will be "chopped" as shown in Figure 3 and a regulating action much like the dimmer on a lighting circuit will take place and plant operation will continue.

In the case of steep high-level spikes when the voltage reaches 104 to 110 V peak, the spike will be halted in less than 60 ns and taken to ground. No power will be delivered to the plant during the remainder of the AC half-cycle; in the absence of further high-level peaks full operation restores in the next half-cycle.

Line amplifiers typically stay up for as much as 100 ms due to their internal capacitors and in many cases the amplifiers (and your customers) may never be aware of the potential disasters that have been averted. Figure 4 shows a 400 V transient caught at 100 V and taken to ground. (This is an actual scope picture.)

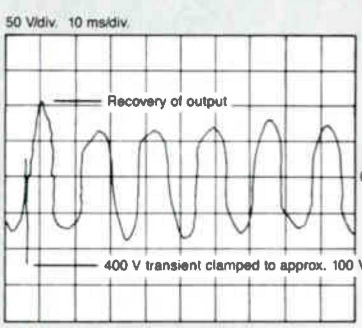
Ice:

Heavy ice loading under certain adverse conditions can stretch or break the strand and cable. If there is an awareness of the problem and it is not too extensive the ice can be dislodged by tapping the strand or strand and cable with a layup stick.

Power problems:

Blackouts are handled by properly maintained standby power supplies as are brownouts. The term "surges" means excessive AC voltage for prolonged periods of time such as 100 ms to two or three seconds at a time. This often occurs in rural power systems where synchronism and regulation are lost and can often be observed when the house lights go bright and then go out. This is very damaging to plant equipment and is combated in two ways. First, the previously mentioned crowbar will clamp the 60 VAC on the center conductor to a safe value and regulate it in much the same manner as the dimmer on a domestic light control circuit (Figure 4). Second, at least one kind of power supply, when sensing high primary voltage beyond which the ferroresonant transformer can regulate, cuts over to the standby mode and delivers the correct voltage to the plant.

Figure 4



Portable standby generators are a must for keeping the first few important power supplies nearest the headend going during a prolonged outage. This not only keeps these amplifiers operational but ensures that any customers downstream who may still have power will be able to continue receiving service. Be sure the generators have adequate fuel tanks that will let the unit run unattended for 10 to 12 hours without tying up personnel all night running around looking for gasoline.

If left unattended they should be chained to a pole. Even so, there have been cases where chain cutters were used to steal no less than three brand new units in one night.

Equipment failure:

Catastrophic equipment failure is becoming more and more rare. It is interesting to note that the failure is often caused by lightning and dirty power. This happens in an indirect manner when the equipment actually survives the surges, spikes and other transients but is injured and slowly deteriorates until it "unexplainably" dies, causing a surprise outage.

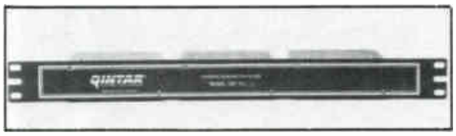
Reference

[1]Roy Ehman (Jones Intercable) and Tom Osterman (Alpha Technologies), "Improved outage control using a new and unique transient eliminator," *1988 NCTA Technical Papers.*

Fiber cleaver

The FK11 fiber cleaver from York Technology uses an electronically tuned, ultrasonic vibrating diamond blade that carries out up to 20,000 cleaves. The unit can be adjusted for a range of diameters for both single- and multimode fiber with cleaves typically under 0.5 degrees. According to the company, the use of this blade reduces fiber damage due to compressive stresses from anvil use and eliminates contamination of the cleaved end.

For additional information, contact York Technology, 210 N. Glenoaks Blvd., Suite C, Burbank, Calif. 91502, (818) 955-8927; or circle #137 on the reader service card.



Channel elimination

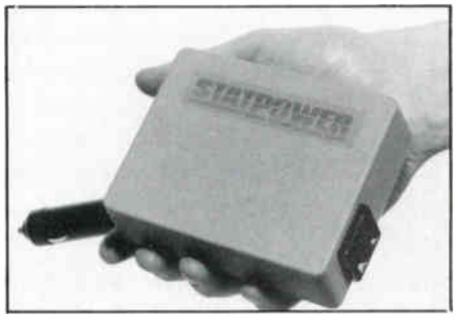
Qintar's Model CEF channel elimination filter offers a signal attenuation of −50 dB minimum to −55 dB typical at the video carrier with adjacent channel loss of −4 dB maximum. This single channel bandstop filter is designed to eliminate a full 6 MHz wide television channel in a fully loaded system and allow for reinsertion of any program the user desires.

For more information, contact Qintar, P.O. Box 8060, Moorpark, Calif. 93020-8060, (800) 252-7889; or circle #135 on the reader service card.

F connector

Augat/LRC Electronics' Snap-N-Seal F connector is triple-sealed and requires no crimping. According to the company, 360° compression on the cable jacket ensures a complete radial seal, eliminating moisture migration path and problems encountered with rubber boots due to inconsistency of port lengths on mating equipment.

For additional details, contact LRC Electronics, 901 South Ave., Box 111, Horseheads, N.Y. 14845, (607) 739-3844; or circle #140 on the reader service card.



Power inverter

Statpower Technologies introduced its 12 VDC to 115 VAC Pocket Power Inverter, which takes up 19 cubic inches and weighs 14 ounces. Producing 200 watts of peak power and 100 watts of constant power, the unit can be used to operate standard AC powered electronic test equipment including oscilloscopes, spectrum analyzers and chart recorders.

Other features are high-frequency design, silent operation, high starting surge and regulated output. Specifications include 10-15 VDC input voltage, 115 VAC ±5 percent at 60 Hz ±1 percent output voltage, peak output of 200 watts and continuous output of 100 watts.

For further information, contact Statpower Technologies, 170-717 Simundson Dr., Point Roberts, Wash. 98281, (604) 420-1585; or circle #125 on the reader service card.

Power protector

PolyPhaser's Power Mains shunting-type protector is designed to protect facilities from major surges at the entrance mains. The IS-PM240-1P is independent of AC current usage and is for 240 VAC single-phase applications and protects each 120 VAC to ground. The turn-on voltage is ±200 V peak with a response time of 28 ns. Circuit breakers are for added protection and a relay will relax if power is lost or a circuit breaker is popped. The relay contacts can be used for local or remote alarms.

For more details, contact PolyPhaser Corp., 1425 Industrial Way, P.O. Box 1237, Gardnerville, Nev. 89410-1237, (800) 325-7170; or circle #138 on the reader service card.

FO transmission

According to PCO Inc., its PCO-5010 portable fiber-optic video/audio transmission system allows for studio-quality live transmissions from remote or temporary sites. Using analog frequency modulation, the unit transmits NTSC video and stereo audio over single-mode or multimode fiber at either 1,300 or 1,550 nm. It transmits from either a laser or LED transmitter.

For additional details, contact PCO Inc., 20200 Sunburst St., Chatsworth, Calif. 91311, (818) 700-1233; or circle #133 on the reader service card.

Software upgrade

ComNet Engineering upgraded its Broadband System Engineering to Version 3.2, a computer-aided engineering software package that designs RF broadband cable networks for the LAN and CATV industries. This software designs any kind of split and dual cable from 1 to 600 MHz, automatically selects taps by minimum drop level, changes cable sizes anytime and deletes, inserts or replaces designed components followed by an automatic recalculation of the RF paths. It also features a highly interactive user screen interface, speed key commands and help screen.

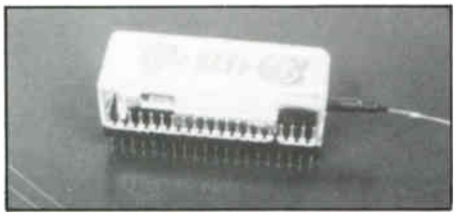
Version 3.2 comes pre-configured with CommScope, Jerrold, C-COR, Scientific-Atlanta, Eagle, RMS, Trilogy and Magnavox manufacturer files in its data base. It can be used in any IBM or compatible personal computer using MS-DOS 2.0 or higher, 256 K, single floppy (two-floppy drive is desirable, hard disk preferred), EGA/CGA/mono and most standard printers.

For additional information, contact ComNet Engineering Co., 3310 Western Dr., Austin, Texas 78745, (512) 892-2085; or circle #128 on the reader service card.

Tilt compensator

Multiplex Technology is offering the TC200 tilt compensator, a passive device that compensates for the imbalance in attenuation and restores signal balance by attenuating the lower frequencies. It readjusts signal strength, biasing attenuation effects in favor of the higher frequencies. According to the company, this unit is low cost and works with any amplifier.

For more information, contact Multiplex Technology, 251 Imperial Highway, Fullerton, Calif. 92635, (714) 680-5848; or circle #134 on the reader service card.



Multiplexers

Physical Optics Corp. announced the availability of its family of three- and four-channel HoloStar wavelength division multiplexers (WDMs). The WDM is a passive optical component that combines or separates multiple wavelengths of light from a single fiber to increase LAN bandwidths. The unit's volume hologram technology is said to be insensitive to the polarization of incoming or resulting optical signals, ensuring low insertion loss, better imaging and greater immunity to radiation-induced loss.

For more information, contact Physical Optics Corp., 2545 W. 237th St., Suite B, Torrance, Calif. 90505, (213) 530-1416; or circle #131 on the reader service card.

Line extender

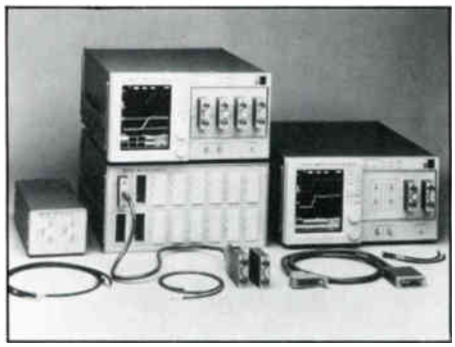
According to C-COR Electronics, its E-517 line extender utilizes fourth-generation hybrid devices that provide an increase in performance of 4 dB in both composite triple beat and cross modulation over amplifiers using third-generation hybrid chips. It is fully compatible with the PHD line of extenders and existing ancillary products and covered by a three-year warranty.

For further details, contact C-COR Electronics, 60 Decibel Rd., State College, Pa. 16801, (814) 238-2461; or circle # 139 on the reader service card.

Pressure testing

General Machine Products' GMP E pressure testing liquid is designed to detect leaks in a wide variety of pressurized cables. When applied to the outer surface of the cable the liquid creates a stable bubble over any leaks and is safe for use with all cable types, according to the company. It can be used at temperatures as low as 10°F (– 12°C) and is available in ready-to-use solution in pint bottles and concentrate in gallon jugs.

For more details, contact General Machine Products Co., 3111 Old Lincoln Hwy., Trevose, Pa. 19047-4996, (215) 357-5500; or circle #129 on the reader service card.



Digital o-scope

Tektronix's 11800 Series of expandable, 20 GHz digital sampling oscilloscopes sample high-speed signals 200,000 times a second and feature 20 GHz trigger bandwidth capability. They also feature differential time domain reflectometry measurement techniques, histogram-based jitter and noise measurement, and eye diagram analysis.

For more details, contact Tektronix, P.O. Box 500, Beaverton, Ore. 97077, (503) 627-1844; or circle #124 on the reader service card.

Switcher

AM Communications' RTS-1 is a plug-in module for use in Jerrold JN or JX Series dual-cable trunk amplifiers. It is controlled by AM's TMC-8051 amplifier status monitor module and provides the capability to control signal flow for the inbound cable.

The signal path can be turned on, off or attenuated 6 dB under control of the LANguard system software. The LED indicators on the module show the current state of the switch. The module uses RF relays and the circuit is designed to fail safe so loss of control results in a default on state.

For additional information, contact AM Communications, 1900 AM Dr., P.O. Box 505, Quakertown, Pa 18951, (215) 536-1354; or circle #120 on the reader service card.

Tracking software

The Vehicle Information Center (VIC) from Long Systems is said to be the first full-feature software to track vehicle fleets written especially for cable systems. VIC tracks four categories of data—vehicles, drivers, maintenance and accidents. Its program design is modular and it works on all 100 percent IBM compatible computers.

For more details, contact Long Systems, 9666 Businesspark Ave., Suite 105, San Diego, Calif. 92131, (619) 530-1926; or circle #126 on the reader service card.

Lettering machine

According to ADS/Linex, the Model 301 Scriber lettering machine features an advanced menu-driven system enabling the user to access and/or change working parameters quickly and easily. Some of its functions include 20 K memory, full test programmability, centering, mirroring, underscore, overscore and auto kerning.

For more information, contact ADS/Linex, 3130 Gateway Dr., Suite 400, Norcross, Ga. 30071, (404) 448-0977; or circle #123 on the reader service card.

Power supply

The type MUPSA mini uninterruptible power system from Philtek Electronics is self-contained with a continuous, regulated, sine wave output. The unit is a union of three basic subassemblies: a rectifier/battery charger, maintenance-free gelled electrolyte storage battery and solid-state DC to AC inverter. It is available in 300, 500 and 750 VA and operation is automatic.

For more information, contact Philtek, 2200 Queen St., Unit 11, Bellingham, Wash. 98226, (206) 647-1553; or circle #121 on the reader service card.

Airborne diplexer

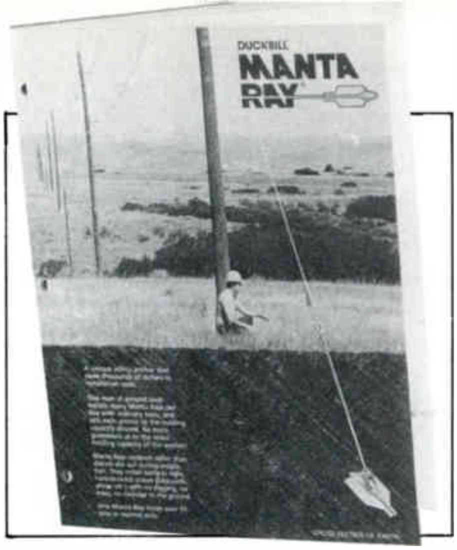
The Model 6127 diplexer from Microwave Filter Co. can be used at a microwave antenna to combine two transmitters into one antenna output. Low-band is 1,426-1,463 MHz, high-band is 1,510-1,546 MHz, passband loss is 3 dB maximum with mutual isolation of 50 dB. It also features 50 ohm impedance, BNC connectors, 15 watt average power handling and 75 watts peak power per channel.

For additional details, contact Microwave Filter Co., 6743 Kinne St., East Syracuse, N.Y. 13057, (315) 437-3953; or circle #122 on the reader service card.

100 MHz o-scope

Hewlett-Packard's HP 54501A 100 MHz digitizing oscilloscope has four channels, 5 mV sensitivity and eight-bit vertical resolution. It also features 10 megasample per second digitizing rate, autoscale, and advanced logic and TV/video triggering. The unit is fully HP-IB programmable with instant hardcopy output, automatic measurements, measurement limit test and dual time base windowing.

For more details, contact Hewlett-Packard, P.O. Box 10301, Palo Alto, Calif. 94303-0890, (800) 752-0900; or circle #136 on the reader service card.



Brochure

A brochure about Manta Ray utility anchors is now available from Foresight Products. This brochure contains complete installation instructions illustrated in color and photos and descriptions of the equipment needed to install the anchors. Also included are illustrated descriptions of methods of anchoring poles in extremely hard soils, methods for temporary guying of utility poles and complete specifications of the entire anchor line.

For further information, contact Foresight Products, 6430 E. 49th Dr., Commerce City, Colo. 80037, (800) 325-5360; or circle #130 on the reader service card.

Catalog

Marconi Instruments issued a 327-page catalog covering its entire product line. It outlines operating features and specifications for equipment such as spectrum analyzers, oscillators, sweep generators, RF test equipment, power meters and signal generators.

The catalog also includes a review of application notes and technical publications offered by the company as well as reprints of various articles written by engineers from Marconi.

For more information, contact Marconi Instruments, 3 Pearl Court, Allendale, N.J. 07401, (201) 934-9050; or circle #141 on the reader service card.

Correspondent's Report

(Continued from page 96)

Surfaces other than planes may be perfectly diffusing. The moon's surface is perfectly diffusing, or almost; it appears as bright at the edge, where the line of sight is tangential to its surface, as at the center, where it is viewed "head-on."

Very few surfaces are good approximations to a lambert surface, although many diffuse surfaces are reasonable approximations (flat paint, velvet, blotting paper). Most photometers measure luminance (candle per unit projected area) rather than luminous emittance (lumen per unit area), even though they may be calibrated in the latter system. Thus, when a measurement of luminance at a given angle is taken on a nondiffuse surface and expressed in lamberts, one cannot predict what the luminance will be for a different angle. In that case, the interpretation of the lambert value is that it is the luminous emittance that would be obtained for a diffuse surface with the indicated luminance as stated previously.

One further unit is used in some visual research to express stimulus intensities in terms of illuminance produced on the retina of the eye by a source. The eye responds to the flux that actually reaches the retina; this flux is controlled by (among other things) the amount the pupil is open. A unit, called the *troland*, takes into account both the luminance of the source and the pupillary opening; one troland is the visual stimulation produced by a luminance of one lumen per steradian per square meter when the entrance pupil has an area of one square millimeter. Artificial pupils can be constructed for laboratory experiments, and the results expressed in trolands.

Other photometric units

Table 1 lists other photometric units often found in the results of visual research and compares them with the units defined in the foregoing paragraphs. Figure 6 shows the relationships of some of these units to each other and to a point source.

The second installment of this three-part series will discuss conversion factors for photometric units and basic design principles of photometers.

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Meyers

Robert Meyers was appointed vice president of corporate communications for **Scientific-Atlanta.** Before joining S-A, he was director of international public affairs of Allied-Signal. Contact: 1 Technology Pkwy., Box 105600, Atlanta, Ga. 30348, (404) 441-4000.

Catel Telecommunications named **Richard Green** vice president of sales and marketing. He was previously with Granger Associates as vice president of field sales. Contact: 4050 Technology Place, Fremont, Calif. 94537-5122, (415) 659-8988.

Midwest CATV added four new sales representatives to its staff. **Robert Kirby** will open up new territory in New England. He was formerly with CATV Supply in Woburn, Mass.

Tom Baldwin will represent the Northeast distribution center. He was previously with TVC Supply in Hershey, Pa.

Greg Lemon will cover the Ohio territory. Before this, he was in the company's engineering department.

Wayne White was hired as a telemarketing sales representative in the Eastern region office. He was formerly with 3M. Contact: P.O. Box 271, Charleston, W. Va. 25321, (304) 343-8874.

Richard Lundy was appointed vice president of engineering for **C-COR Electronics.** Before joining the company, he was program manager for GTE Government Systems Corp.

John Pawling was named manager of the Field Services division. He was previously vice president and general manager of Temtek Inc.

David Badoud was appointed Western regional account executive. Most recently, he was national market manager at the Videonet Division of Oak Industries. Contact: 60 Decibel Rd., State College, Pa. 16801, (814) 238-2461.

Cable Link recently announced three promotions. **Bill Holehouse** was named vice president of sales, **Quinn Williams** is vice president of production and **Charles Hanchett** was appointed vice president of engineering. Contact: 280 Cozzins St., Columbus, Ohio 43215, (614) 221-3131.

TeleSciences Transmission Systems (formerly Avantek Transmission Systems) named **George Woodruff** vice president of marketing and sales. Before joining the company, he was vice president of marketing for Harris Corp.'s Farinon Division. Contact: 48761 Kato Rd., Fremont, Calif. 94538, (415) 498-1510.

Hirschfield

The **California Cable Television Association** named **C.J. Hirschfield** vice president of industry affairs. She was most recently director of marketing for Pacific Video Resources. Contact: 4341 Piedmont Ave., P.O. Box 11080, Oakland, Calif. 94611, (415) 428-2225.

CALENDAR

October

Oct. 4-6: Atlantic Show, Convention Hall, Atlantic City, N.J. Contact (609) 848-1000.

Oct. 5: SCTE Rocky Mountain Chapter seminar on professionalism and management. Contact Steve Johnson, (303) 799-1200.

Oct. 5-8: Hawaii Cable Television Association annual convention, Sheraton Kauai Hotel, Kauai, Hawaii. Contact Kit Beuret, (808) 834-4159.

Oct. 6: SCTE Gateway Chapter technical seminar. Contact Darrell Diel, (314) 576-4446.

Oct. 11: SCTE Central Illinois Chapter technical seminar on data networking and review session for BCT/E Category V, Sheraton Inn, Normal, Ill. Contact Tony Lasher, (217) 784-5518.

Oct. 11: SCTE Chattahoochee Chapter technical seminar on connectors, Perimeter North Inn, Atlanta. Contact Dick Amell, (404) 394-8837.

Oct. 12: SCTE Oklahoma Chapter technical seminar. Contact Herman Holland, (405) 353-2250.

Oct. 12-14: Magnavox CATV training seminar, Kansas City, Kan. Contact Amy Costello, (800) 448-5171.

Oct. 12-14: World Teleport Association general assembly conference and exhibition, Congress Center East, Cologne, Germany. Contact Holly Kobran, (202) 333-7400.

Oct. 13: SCTE Central California Meeting Group technical seminar on methods of corrections/distortions. Contact Andrew Valles, (209) 453-7791; or Dick Jackson, (209) 384-2626.

Oct. 14-16: West Virginia Television Association fall meeting, Greenbrier Resort, White Sulphur Springs, W. Va. Contact Linda Arnold, (304) 345-2917.

Oct. 15-19: Society of Motion Picture and Television Engineers technical conference and equipment exhibition, Jacob K. Javits Convention Center, New York. Contact Anne Cocchia, (914) 761-1100.

Oct. 16-18: Wireless Cable Association annual conference and equipment expo, Hyatt Regency, Crystal City, Va. Contact (202) 343-4253.

Oct. 18: CaLan sweep seminar, Holiday Inn, Ontario, Calif. Contact Mary Chudoba, (717) 828-2356.

Oct. 18-19: SCTE Heart of America Chapter technical seminar. Contact Wendell Woody, (816) 474-4289.

Oct. 18-20: Mid-America Show, Hilton Plaza Inn, Kansas City, Mo. Contact Rob Marshall, (913) 841-9241.

Oct. 18-20: Magnavox CATV training seminar, Charlotte, N.C. Contact Amy Costello, (800) 448-5171.

Oct. 18-20: C-COR Electronics technical seminar, Worcester, Mass. Contact Shelley Parker, (800) 233-2267.

Oct. 19: SCTE Delaware Valley Chapter technical seminar on fiber optics, Williamson Restaurant, Horsham, Pa. Contact Diana Riley, (717) 764-1436.

Oct. 20: SCTE Greater Chicago Chapter technical seminar on new broadband technologies. Contact William Gutknecht, (312) 690-3500.

Oct. 21: CaLan sweep seminar, Alameda County Fairgrounds, Pleasanton, Calif. Contact Mary Chudoba, (717) 828-2356.

Oct. 22: SCTE Razorback Chapter technical seminar. Contact Jim Dickerson, (501) 777-4684.

Oct. 24: CaLan sweep seminar, Red Lion Inn at the Quay, Vancouver, Wash. Contact Mary Chudoba, (717) 828-2356.

Planning ahead

Dec. 7-9: Western Show, Convention Center, Anaheim, Calif.

Feb. 22-24: Texas Show, Convention Center, San Antonio, Texas.

May 21-24: NCTA Show, Convention Center, Dallas.

June 15-18: Cable-Tec Expo '89, Orange County Convention Center, Orlando, Fla.

Aug. 27-29: Eastern Show, Atlanta Merchandise Mart, Atlanta.

Sept. 19-21: Great Lakes Show, Columbus, Ohio.

AD INDEX

Fiber-optics glossary

By Hal Williams
Jones Intercable Inc.

This is the first installment of a three-part series defining important terms in fiber optics, arranged in alphabetical order.

A

absorption — Conversion of radiant energy into other energy forms by passage through matter.
acceptance angle — The maximum angle within which radiant energy will be accepted by an element, such as an optical fiber or detector.
acceptance cone — A cone defined by an angle equal to twice the acceptance angle.
ambient light — Light present in the immediate environment.
angle of incidence — The angle formed between a ray of light striking a surface and the normal to that surface at the point of incidence.
angle of reflection — The angle formed between the normal to a surface and the reflected ray. This angle lies in the same plane as the angle of incidence and is equal to it.
angle of refraction — The angle formed between a refracted ray and the normal to the surface. This angle lies in the same plane as the angle of incidence.
angstrom—May be abbreviated A, Å or AU (angstrom unit). A unit of very short wavelength (1A = 1 × 10^{-10} meters).
angular misalignment loss — The optical loss caused by angular deviation from the optimum alignment of source to optical waveguide, waveguide to waveguide or waveguide to detector.
anode — The element of an electron tube or semiconductor device toward which the primary electron stream flows. It is at a positive potential with respect to the corresponding negative electrode, called the *cathode*.
APD — Abbreviation for *avalanche photodiode*.
attenuation (optical) — The radiant power loss per unit of length. The sum of absorption and scattering.
avalance photodiode (APD) — A photodiode designed to take advantage of avalanche multiplication of photocurrent. Note: As the reverse-bias voltage approaches the breakdown voltage, hole-electron pairs created by absorbed photons acquire sufficient energy to create additional hole-electron pairs when they collide with ions; thus a multiplication (signal gain) is achieved.
axial ray — A ray propagating along the longitudinal axis of a fiber with no internal reflection or refraction.

B

backscattering — The scattering of light into a direction generally reverse to the original one.
bandwidth — The range of frequencies (wavelength) over which a device is designed to operate within specified limits. Also, the difference between the specified frequencies.
beam — 1) (light) The path traced by a small section of an advancing wavefront, which is comprised of an infinite number of light rays. 2) (electron) A concentrated stream of particles that is unidirectional.
beam diameter — The distance between two diametrically opposed points at which the irradiance is a specified fraction of the beam's peak irradiance; most commonly applied to beams that are circular or nearly circular in cross section. Synonym: *beamwidth*.
beam divergence — 1) For beams that are circular or nearly circular in cross section, the angle subtended by the far-field beam diameter. 2) For beams that are not circular or nearly circular in cross section, the far-field angle subtended by two diametrically opposed points in a plane perpendicular to the optical axis, at which points the irradiance is a specified fraction of the beam's peak irradiance. Generally, only the maximum and minimum divergencies (corresponding to the major and minor diameters of the far-field irradiance) need to be specified.
beamsplitter — A device for dividing an optical beam into two or more separate beams; often a partially reflecting mirror.
beamwidth — Synonym for *beam diameter*.
bit — An electrical or light pulse whose presence or absence indicates data.
black body — A totally absorbing body (one that reflects no radiation). In thermal equilibrium, a black body absorbs and radiates at the same rate; the radiation will just equal absorption when thermal equilibrium is maintained.
brightness — A perceptual term denoting the apparent amount of light perceived. Closely related to luminous intensity.

C

candela — International unit of luminous intensity. A point source of one candela intensity radiates one lumen into a solid angle of one steradian.
candle power — The luminous intensity of light source expressed in candelas.
cathode — The element of an electron tube or semiconductor device from which the primary electron stream flows. It is at a negative potential with respect to the corresponding positive electrode, called the *anode*.
chromatic — Having the property of color.
CIE — *Commission Internationale de l'Eclairage*, International Commission on Illumination.
cladding — A sheathing or covering, usually of glass or plastic, fused to the core of higher index material.
coherent — Characterized by a fixed phase relationship between points on an electromagnetic wave.
coherent radiation — Radiation in which the wave trains are in phase with each other.
collimated radiation — A simulation of the kind of radiation coming from an infinitely distant object in which the rays are parallel to each other.
collimation — The process by which a divergent or convergent beam of radiation is converted into a beam with the minimum divergence possible for that system (ideally, a parallel bundle of rays).
color — The perceptible feature of visible light that is directly related to wavelength. Because of this feature, the eye experiences a unique sensation for each wavelength in the visible spectrum; thus, light at the high-frequency end of the spectrum "looks violet," and light at the low-frequency end of the spectrum "looks red."
core — The center dielectric in an optical fiber whose index of refraction is greater than that of its surrounding medium, usually a cladding.
core center — A point on the fiber axis.
coupling lens — A device used to efficiently couple optical power between low numerical aperture optical fibers.
coupling loss (expressed in decibels, dBs) — The amount of power in the fiber-optic link lost at discrete junctions such as source-to-fiber, fiber-to-fiber or fiber-to-detector.
critical angle — 1) The angle made by the reflected ray in an optical waveguide when the ray enters the core at the maximum half-angle of the acceptance cone or maximum acceptance angle. 2) The smallest angle of incidence within a fiber that will result in total reflection.

D

dark current — The output current that a photodiode produces in the absence of light.
decibel — The standard unit used to express the ratio of two power levels. It is used in electronics to express either a gain or loss in power between the input and output devices. The amount of change in power level, expressed in decibels, is equal to 10 times the common logarithm of the ratio of the two powers.
destructive interference — The interaction of superimposed light rays that results in a combined intensity that is less than the sum of the individual intensities before they were superimposed.
detectivity — The reciprocal of noise equivalent power (NEP).
detector — A device that provides an electrical output that is a useful measure of the radiation upon the device.
diffuse reflection — Reflection accompanied by diffusion or scatter to the extent that there is no excessive specular reflection.
diffusion — The multipoint reflection of light from a rough or unpolished surface, or the transmission of light through a translucent substance. Both processes produce a spreading of the light rays and this imparts a "softness" to the light.
diode — A two-electrode device with an anode and a cathode that passes current in only one direction. It may be an electron tube or semiconductor device.
discrete — An individual circuit component, complete in itself, such as a resistor, capacitor, transistor or diode. It is used as a separate and replaceable circuit element.
dispersion — Describes the chromatic or wavelength dependence of a parameter as opposed to the temporal dependence, referred to as *distortion.* It is used, for example, to describe the process by which an electromagnetic signal is distorted because the various wavelength components of that signal have different propagation characteristics. The term also is used to describe the relationship between refractive index and wavelength. Signal distortion in an optical waveguide is caused by several dispersive mechanisms: waveguide, material and profile dispersions.
distortion — A change of signal waveform shape. In a multimode fiber, the signal can suffer degradation from multimode distortion. In addition, several dispersive mechanisms can cause signal distortion in an optical waveguide: waveguide, material and profile dispersions.
duty cycle — A measure of the effect of a pulsed input to a device. Expressed as a percentage of "on time" as compared to the total time.

E

electromagnetic spectrum — The total range of wavelengths, extending from the shortest to the longest that can be generated. This range extends practically from zero to infinity and includes visible light.
electron — A substance particle that possesses a unit negative charge and orbits the atomic nucleus.
emergent ray — A light ray leaving a medium.
etching — The engraving of a surface by acid, acid fumes or a tool.
exitance — Flux leaving a surface per unit area.
extrinsic joint loss — That portion of joint loss that is not intrinsic to the fibers (i.e., loss caused by imperfect jointing). See also *angular misalignment loss, gap loss, intrinsic joint loss* and *lateral offset loss.*

F

FET photodetector — A photodetector employing photogeneration of carriers in the channel region of an FET structure to provide photodetection with current gain.
fiber buffer — A material that may be used to protect an optical fiber waveguide from physical damage, providing mechanical isolation and/or protection.
fiber bundle — An assembly of unbuffered optical fibers. Usually used as a single transmission channel, as opposed to multifiber cables, which contain optically and mechanically isolated fibers, each of which provides a separate channel. 1) Bundles used only to transmit light, as in optical communications, are flexible and are typically unaligned. 2) Bundles used to transmit optical images may be either flexible or rigid, but must contain aligned fibers.
fiber-optic cable — A subassembly made up of several optical fibers incorporated into an assembly of organic materials arranged for providing the necessary tensile strength, external protection and handling properties comparable to those of equivalent diameter coaxial cables.
fiber optics (FO) — The branch of optical technology concerned with the transmission of radiant power through fibers made of transparent materials such as glass, fused silica or plastic. 1) Telecommunication applications of fiber optics employ flexible fibers. Either a single discrete fiber or a non-spatially aligned fiber bundle may be used for each information channel. Such fibers are often referred to as "optical waveguides" to differentiate from fibers employed in non-communications applications. 2) Various industrial and medical applications employ (typically high-loss) flexible fiber bundles in which individual fibers are spatially aligned, permitting optical relay of an image. An example is the endoscope. 3) Some specialized industrial applications employ rigid (fused) aligned fiber bundles for image transfer. An example is the fiber-optics faceplate used on some high-speed oscilloscopes.
flash lamp — A device that converts a large amount of stored electrical energy into light by a sudden electrical discharge.
flux — The rate of radiant power passing to, from or through a surface (energy per unit time); the number of photons passing through a surface per unit time. Expressed in lumens or watts.
forward voltage (V_F) — Voltage across a semiconductor diode associated with the flow of forward current. The P region is at a positive potential with respect to the N region.
fresnel reflection — Reflection losses that are incurred at the input and output faces of the fiber and are due to the difference in refractive index between the core glass and the immersion medium.
frequency response — The ability of a device (as an optical waveguide fiber) to handle the frequencies applied to it.
fused quartz — Glass made by melting natural quartz crystals; not as pure as vitreous silica. See also vitreous silica.
fused silica — Synonym for *vitreous silica.* See also *fused quartz.*
fusion splice — A splice accomplished by the application of localized heat sufficient to fuse or melt the ends of two lengths of optical fiber, forming a continuous, single fiber.

G

GaAs, GaAsP, GaP — The most commonly used semiconductor emitter materials are gallium arsenide (GaAs), gallium arsenide phosphide (GaAsP) and gallium phosphide (GaP).
gap loss — That optical power loss caused by a space between axially aligned fibers. For waveguide-to-waveguide coupling, it is commonly called "longitudinal offset loss." See also *coupling loss.*
geometric optics — A field of physics that deals with light as if it were composed of rays diverging in various directions from a source. Those rays are bent abruptly by refraction or turned back by reflection into paths determined by established laws.
graded-index fiber — An optical fiber with a refractive index that gets progressively lower away from the center. This characteristic causes the light rays to be continually refocused by refraction in the core. This type of fiber combines high bandwidth capacity with moderately high coupling efficiency.

Cable technology S-curves

By Walter S. Ciciora, Ph.D.
Vice President of Technology
American Television and Communications Corp

Last month we discussed the concepts of the S-curve and of technological limits. These ideas are featured in the book *Innovation, the Attacker's Advantage* by Richard Foster, published by Summit Books. Again, I'd like to recommend it. This month we'll focus in more closely on how these concepts apply to cable TV and its competition.

The S-curve for a whole technology is the composite of S-curves of its components. For example, an S-curve could be drawn for direct broadcast satellite technology. It would be the composite of separate S-curves for uplinks, satellite power supplies, amplifiers, antennas, subscriber receive antennas, flat antennas, low-noise amplifiers, etc. Any advance in a component S-curve translates into progress for the composite S-curve in proportion to the importance that component plays in the whole system. Composite stagnation occurs when all of the significant components have themselves reached their individual points of diminishing return.

In the broad sense, the S-curve also could be used to describe non-technology processes. For example, the number of subscribers obtained from a marketing campaign can be expected to follow an S-curve. Initial efforts to set up the campaign result in very few new subscribers. Then the campaign builds momentum, the results are harvested and everyone is pleased. Finally, most of those who find the campaign's message appealing have heard it and the point of diminishing returns is reached. It's time for a new S-curve, a new campaign concept. Sticking with the old approach will consume resources with few results.

Another S-curve example is the number of leaks found during a CLI reduction project. Initially, while equipment is being acquired and training is taking place, few leaks are being found. Then great progress is experienced as everyone comes up-to-speed on the procedures and proper use of the equipment. Finally, all the easy finds are accomplished. Further results are hard to come by. While these are valid examples of the S-curve, technologists are most interested in applying the ideas to the technology itself.

Cable technology S-curves

An early example of the S-curve in cable TV is the technology for bandwidth expansion. For many years bandwidth was relatively modest with little growth. We then experienced a period in which every cable convention brought news of higher bandwidth technology. The point of diminishing returns was reached and higher bandwidths are no longer news items.

Perhaps the technology area of most interest today is the transmission medium itself. Coaxial cable is a mature product; the dielectric technology and the uniformity of the product have long reached maturity. Likewise, the technology of the amplifiers and the ability to design optimum systems have reached maturity. It would be a mistake to allow our fondness for this technology to drive us to continue putting substantial resources in further development, since much more effort is required to obtain even small improvements. Rather, we need to jump to a new S-curve and invest our efforts in something that still has a large potential for growth and improvement. Of course, that new S-curve involves fiber-optic cable.

The composite S-curve for fiber systems is made up of S-curves for its components, including lasers, light-emitting diodes, receiving diodes and electronics. While the S-curve for the fiber itself is relatively mature, progress is only beginning in transducers. This is especially true of components to be used in vestigial sideband/amplitude modulated (VSB/AM) systems. Even the technology for design of systems using fiber and hybrid approaches is still in the early part of its growth. The message is simply that here is a fertile area to invest resources with the expectation of substantial returns. This is a new composite S-curve for cable TV.

Another technology area that will soon need attention is that of the fundamental method of signal encoding. The technology of VSB/AM encoding of video is relatively mature; there are few improvements left to be harvested. It's time to consider the limits of this technology and whether they are good enough for the future competitive environment. It's time to start thinking of a new S-curve. We need to begin work on digital approaches if we are to obtain the quality we'll need once heavy competition arrives from other technologies.

Competitors' technology S-curves

As you no doubt know by now, I am most concerned about competition from prerecorded video and telcos. Both of these have their own composite S-curves with limits on technological progress.

The consumer electronics technologies that have made the most progress in the last decade are magnetic and optical video recording; they also are still relatively low on their S-curves. These technologies have potential for even more dramatic gains in the next decade. Understanding the S-curve teaches us to be watchful of what is coming from these competitors. For example, 20 MHz baseband HDTV VCRs with near-perfect, studio quality video are on the horizon. Recordable HDTV videodiscs also are struggling to get out of the lab.

The telcos have come to grips with the stagnation in their older S-curves. They well know that twisted copper pairs and analog transmission techniques have progressed about as far as they are going to. Massive efforts are needed to squeeze out even small gains and they understand this is a waste of precious resources. They are now happily pushing technology up S-curves for optical transmission and digital techniques. The combination of these two S-curves enables telcos to be high quality video carriers into the home. They are excited about new services and new twists to old services. Video-on-demand is a target service they hope to achieve with new S-curves.

The role of innovation

Understanding the S-curves of our technology and those of our competitors drives us to look for new S-curves in our business. We can find the new S-curves by being inventive or by innovation. Invention is an unreliable source since it cannot be scheduled or predicted. On the other hand, innovation is much more manageable.

As mentioned last month, innovation is the knitting together of already existing inventions into something of commercial significance. The most innovative and clever application of S-curves is to knit together the inventions created by our competitors into superior systems unique to our business. This minimizes our costs and maximizes our progress. It also is very satisfying to use competitors' results against them.

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