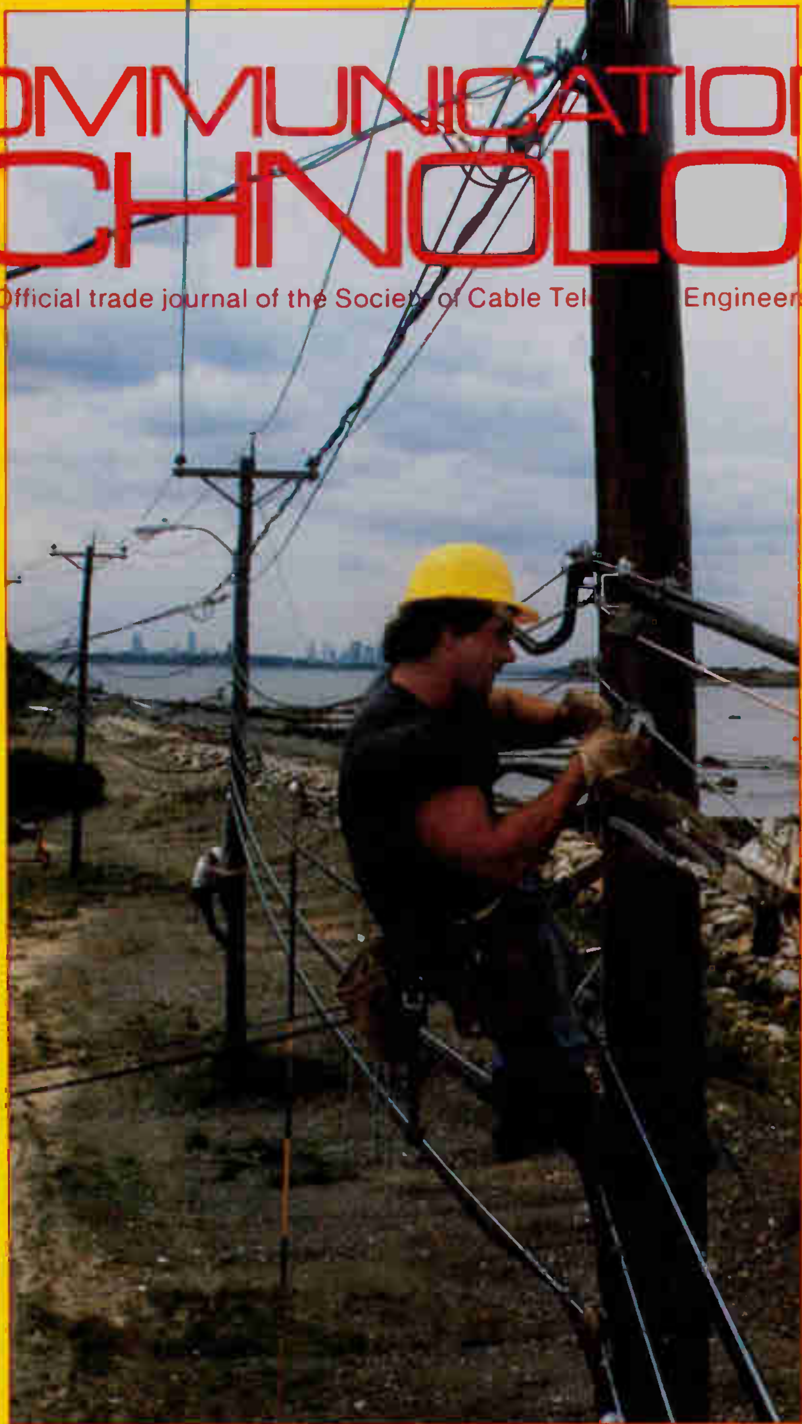
COMMUNICATIONS TECHNOLOGY

Official trade journal of the Society of Cable Television Engineers



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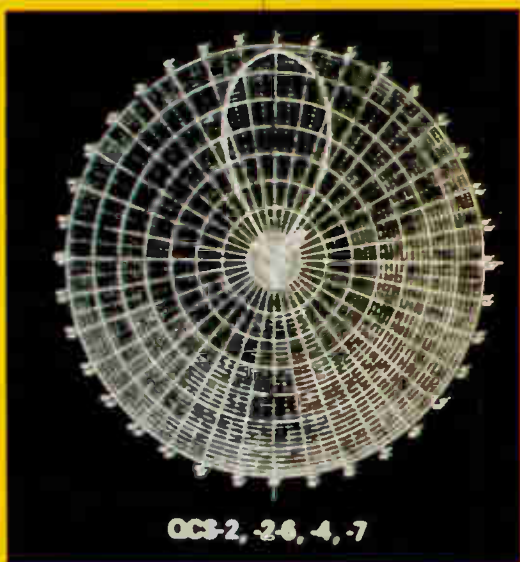

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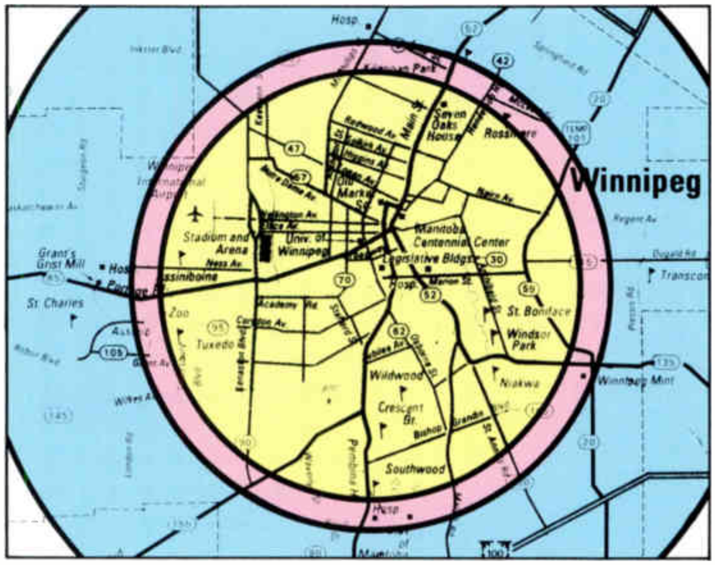

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Communications Technology is published monthly by Communications Technology Publications Corp., 7600 E. Arapahoe Rd., Suite 305, Englewood, Colo 80112—or—P O Box 3208, Englewood, Colo 80155 August 1984 Volume 1, Number 6

Baseband or RF? Tough question. But Jerrold gives you an answer you'll be able to live with comfortably tomorrow, no matter which you choose today.

You see, our new STARCOM* V Advanced Baseband Converter and STARCOM* 450 RF Converter are compatible and can be used interchangeably within your system. So you can give subscribers a choice of cable services and operating conveniences.

Both converters bring you exceptional value, with these important features in common:

- ☐ Potting of sensitive circuits—prevents tampering.
- ☐ Dynamic trimode scrambling—prevents signal theft by changing scrambling modes on a pseudo random basis.
- ☐ Upgradeability to two-way IPPV.
- ☐ 256 tags, 2 million addresses.
- ☐ A/B switch option.
- ☐ Built-in self test—for easier servicing.
- ☐ Programmable time-out.
- ☐ Optional cordless remote control.
- ☐ Direct channel entry and AFT.

Now here's a brief overview of the other features of each converter.

The STARCOM V.

The STARCOM V 550MHz Addressable Baseband Converter offers 82- or 164-channel capacity, selectable by an internal switch. With both video and audio scrambling. And more downloading parameters than any other converter. Here's a sampling:

- ☐ Flexible barker channel location—changeable at any time. Even different barker channels for different subscribers.
- ☐ Programmable output channel—cable operators can simplify inventory by stocking only one model for all systems.
- ☐ Custom channel assignment—lets you maintain off-air channel numbers.
- ☐ System ID code—prevents converter from being used on another system.

Subscriber features are equally notable. Some of the principal ones: volume control on the remote control; last channel recall; favorite channel scan; electronic parental control by both channel and rating.

There's a lot more you should know about, of course. See our STARCOM V brochure.

The STARCOM 450.

The STARCOM 450 Addressable RF 450-MHz Converter, as noted, has many of the same operator and subscriber features as the STARCOM V. It's state-of-the-art all the way. The fact is, the STARCOM 450 is probably the best buy in its class.

Check out these other important features:

- ☐ 66-channel capacity—internal A/B switching for expansion to 132 channels.
- ☐ Easy-to-use keyboard, on both the remote and on the converter, itself.
- ☐ Parental control.

Our STARCOM 450 brochure will give you complete information on this versatile, high performance converter.

Where to go from here.

Baseband or RF? The decision can be easy enough, if you decide on Jerrold. Because you not only get an open-ended choice, you get the technical support and after-the-sale backup of the major supplier in the industry.

For literature on the STARCOM V and STARCOM 450, you have only to call or write. Jerrold Division, General Instrument Corporation, 2200 Byberry Road, Hatboro, PA 19040. (215) 674-4800.

Jerrold.
First in cable TV.

GENERAL INSTRUMENT

Jerrold advances the state of the art: Baseband and RF converters you can use in the same cable system.

Rebuilding with a gameplan in mind

CATV construction is no longer simply a muscles and endurance occupation. The need for increased channel capacity, addressability, off-premise security systems and other system design requirements demand that construction personnel become knowledgeable about state-of-the-art technology. More often than not, chief technicians and engineers are found in the field rather than in the office.

The need for advanced technical training becomes more obvious when we examine the CATV construction that lies on the horizon. Systems that remain to be built are, for the most part, the large city systems such as Chicago, Milwaukee, Philadelphia, Saint Louis and Washington. These are the systems that must provide many of the "blue sky" technologies that were bargained for during franchise negotiations.

Unfortunately, technology has arrived far in advance of adequate technical training for construction personnel. Simply getting the new urban systems turned on will be a challenge. Ensuring that all the advanced system design requirements work promises to tax even the most proficient technicians.

There are also upgrades and rebuilds. Reasons for upgrading and rebuilding vary. Many first generation systems are up for renewal. Also, an increase in channel capacity can increase subscriber revenues. Or, the system may be in a do-or-die situation.

In a continuing effort to provide important technical information to the industry, this issue of *Communication Technology* focuses on various aspects of the rebuild/upgrade situation.

"Increasing channel capacity," by GE's Paul Brooks, provides a step-by-step evaluation of the distribution system. Phil Webber details the use of a variety of cable locators in his article, "Locating underground utilities." In "The art of rebuild," Tom Polis discusses three options for upgrading. As well, module change outs are covered by Fred Rogers. These and other articles promise to help close the technical gap between engineering and construction departments and personnel.

Any new products?

The recent National Cable Television Association show did not offer the bounty

of new products that engineers and new product editors love to see at trade shows. There are, however, good reasons for this: Since most of the hoopla concerning franchising has died down, so has the need for neat new gimmicks to sell to the unwired cities. Also, the economic climate for manufactures has leveled off considerably. In any event, it is a good bet that the upcoming Eastern Show in Atlanta will showcase a variety of new products. If not, the Christmas season is just around the corner with the Western Show!

Toni I. Barnett

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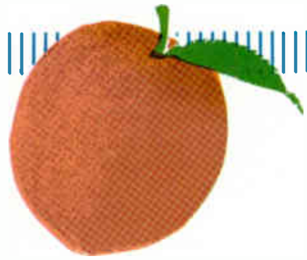


Eastern Show features special technical program

ATLANTA—The Southern Cable Television Association is offering a special registration program for system technicians and engineers for the 1984 Eastern Show. Every cable system that has registered at least one person for the full convention (Sept. 6-8) will be able to purchase Saturday daily registrations for technicians for $10.

Under the direction of Harold Null, vice president of engineering for Storer Communications, the sessions are geared to yield useful information for the system engineer and technician. Panelists and topics include: W.C. Margiotta, product marketing manager, special programs, for Hughes Aircraft Co., speaking on "Data Transmission Via Cable, Microwave and Satellite"; Allan Kushner, vice president of Times Fiber, speaking on "Addressability On and Off Premises"; Michael Hayashi, sales engineer manager for Pioneer, speaking on "Signal Security"; Richard Thayer, vice president of cable television engineering for Times Fiber, speaking on "Utilizing Existing Cable in Upgrades and Rebuilds"; Rex Porter, vice president of sales and marketing for Gilbert Engineering, and John Carlsen, manager of strategic marketing-CATV at Raychem Corp., speaking on "Connectors and Repair Kits for Cable"; Jay Staiger, product manager-amplifier for Magnavox, speaking on "RF Amplifiers, Feedforward and Power Doubling"; and Larry Richards, manager of technical services for Magnavox, speaking on "Proper Testing of System Components, Before and After Installation."

Each technician or engineer registered under the special registration offer will be entitled to attend the Saturday session on "Proper Testing of System Components" and have full access to the trade show floor.

GTE, Citicorp close sale/leaseback plan

MCLEAN, Va.—GTE Spacenet announced the closing of a sale and leaseback transaction with Citicorp Multilease (SEF) Inc. for approximately $250 million. The transaction includes all 24 transponders on the recently launched Spacenet I satellite.

"GTE Spacenet entered into the sale/leaseback because it offered a method of financing the satellite at an attractive cost," said Charles Lee, senior vice president for finance of GTE. "This transaction completes a significant portion of GTE's 1984 financing program," Lee added.

During the lease term, GTE Spacenet will retain full operational control of the satellite and there will be no impact on the provision of service to customers who have contracted with GTE Spacenet.

Spacenet I was launched on May 22, 1984, by Arianespace, the private space transport company based in France. The satellite reached its assigned orbital location at 120° West Longitude on June 6. After successfully completing on-orbit testing it began operational service on June 28.

Four additional GTE satellites—two Spacenets and two Gstars—are scheduled to be launched during 1984-85. The satellites are manufactured by RCA Astro-Electronics. Spacenet I is monitored and controlled from the GTE Spacenet satellite control center in McLean, Va.

Zenith joins IIT to study two-way cable

GLENVIEW, Ill.—Zenith Electronics Corp. and Illinois Institute of Technology (IIT) announced a joint research effort on two-way cable television systems. The research is aimed at arriving at a protocol, or standard, for two-way interactive cable systems that could draw upon cable's enormous unused potential, according to James Faust, president of Zenith's cable products division. "With more than 30 million American cable TV subscribers, there is a tremendous network of potential customers for interactive transactional services," Faust said.

Faust noted that various protocols are under development, but there is not yet a defined set of rules for such two-way interactive cable systems. Possible new applications for cable include communications between personal computers as well as accessing interactive services. Graham Campbell, a professor of computer science at IIT, is directing the research project. Eventually the communication network protocol could lead to packet switched voice services and full-color electronic home shopping with sound.

Under the agreement, Illinois Institute of Technology's computer science department is designing and building a test facility at its Chicago campus. The facility will be functioning by the end of 1984 and will remain in operation for a year. Zenith will provide the necessary hardware.

Consisting of hundreds of microprocessors, the facility will permit "the real-time testing of various protocols," said Campbell. "Each microprocessor will be simulating the activity of a person in a home who is trying to retrieve and transmit information."

SSS acquires interest in VideoStar

TULSA, Okla.—Satellite Syndicated Systems Inc. announced that it has acquired a minority interest in VideoStar Connections Inc. SSS has purchased 9 percent convertible, redeemable preferred stock, which will be converted into as much as 14 percent of VideoStar's common stock.

Now in its fifth year of operation, VideoStar offers videoconferencing as well as satellite networking services using a combination of fixed and transportable earth stations. VideoStar also owns and operates earth stations at more than 150 premium hotel properties across the United States comprising the company's Tele-Meeting™ Network.

S-A opens new warehouse, employees reject union

ATLANTA—Scientific-Atlanta Inc. announced the opening of Cablemart/San Francisco, its third cable television product warehouse. Other Cablemart facilities are located in Atlanta and Dallas.

Cablemart provides 24-hour order processing on all in-stock Scientific-Atlanta CATV products, including headend electronics, distribution electronics, satellite earth station antennas, video receivers and related accessories.

Customers may place orders by calling (800) 332-5787 or in California (408) 993-8350 collect, 24 hours a day. Cablemart catalogues are available by writing to Scientific-Atlanta Inc., 1701 Junction Court, Suite 100, San Jose, Calif. 95112.

On Friday, June 29, employees of Scientific-Atlanta voted not to join the International Brotherhood of Electrical Workers (IBEW) in a union representation election. The vote was 1,207 for the company and 490 for the union.

According to S-A President John Levergood, the IBEW had spent almost two years trying to organize the company.

RMS appoints H.E.C. as Caribbean distributor

BRONX, N.Y.—Due to the continued growth of the cable TV industry in the Caribbean and in an effort to enhance its service to this region, RMS Electronics Inc. announced the appointment of H.E.C. Enterprise (Puerto Rico) Inc. as the exclusive distributor of RMS and Poleline Corp. products. H.E.C. Enterprise will service Puerto Rico, as well as the entire Caribbean area, Central and South America.

H.E.C. Enterprise is headed by Hector Rivera Siaca. Siaca is well known in the local construction industry, operating under the name of Rivera Construction.

H.E.C. Enterprise also is involved in the data communications industry. Its Data Sales &

Service division operates on the island of Puerto Rico, but is exploring opportunities and clients on the Mainland.

H.E.C. Enterprise's mailing address is: P.O. Box 10075, Caparra Station, Puerto Rico 00922. The street address is: C-13 5th St., Parkside, Guaynabo, Puerto Rico 00922. Telephone: (809) 781-8590 or 792-9879.

Anixter-Canada carries Mycrodyne product line

SKOKIE, Ill.—Anixter Communications-Canada has been appointed exclusive Canadian stocking distributor for Microdyne Corp.'s entire product portfolio.

Microdyne manufactures earth stations and electronic equipment for the cable television and broadcast industries worldwide. Anixter Communications-Canada will stock the entire product line and distribute equipment from its 14 locations throughout Canada.

Magnavox, Gilbert sign distribution pact

MANLIUS, N.Y.—Magnavox CATV Systems Inc. and Gilbert Engineering have reached an agreement in principle for the distribution of the Gilbert line of CATV connectors. These connectors will be manufactured by Gilbert in its Phoenix, Ariz., facility and will be sold through Magnavox's worldwide sales network under the Gilbert name.

Avantek to build new semiconductor facility

SANTA CLARA, Calif.—Avantek Inc. announced plans for a new 90,000 square foot microwave semiconductor manufacturing plant to be constructed on a 9-acre site in the city of Newark (Alameda County), Calif. Upon completion of the new facility, scheduled for August 1985, Avantek's current microwave semiconductor plant in Santa Clara will be used for R&D purposes. The total investment in the new facility, exclusive of equipment, will be approximately $10 million.

When fully occupied, the building will house up to 700 assemblers, technicians, engineers and management personnel, working in two shifts.

Tele-Media new-builds to use C-COR electronics

STATE COLLEGE, Pa.—C-COR Electronics Inc. announced that Tele-Media Corp. will use C-COR distribution electronics and systems design in its 1300 miles of new plant to be built in northeastern Connecticut. Total value of the commitment is placed at approximately $1.5 million. Deliveries, which began this spring, will continue for a three- to four-year period.

The 400 MHz trunk, distribution and extender amplifiers and 550 MHz main line passives will be installed to give the systems 52-channel capability. Portions of the systems will be active, two-way. C-COR's mini-trunk amplifiers will be used in low density, rural areas to perform the same functions as full-sized trunk amplifiers at less cost. The systems also will be using several hundred standby power supplies, manufactured by C-COR.

Cable TV Industries moves headquarters

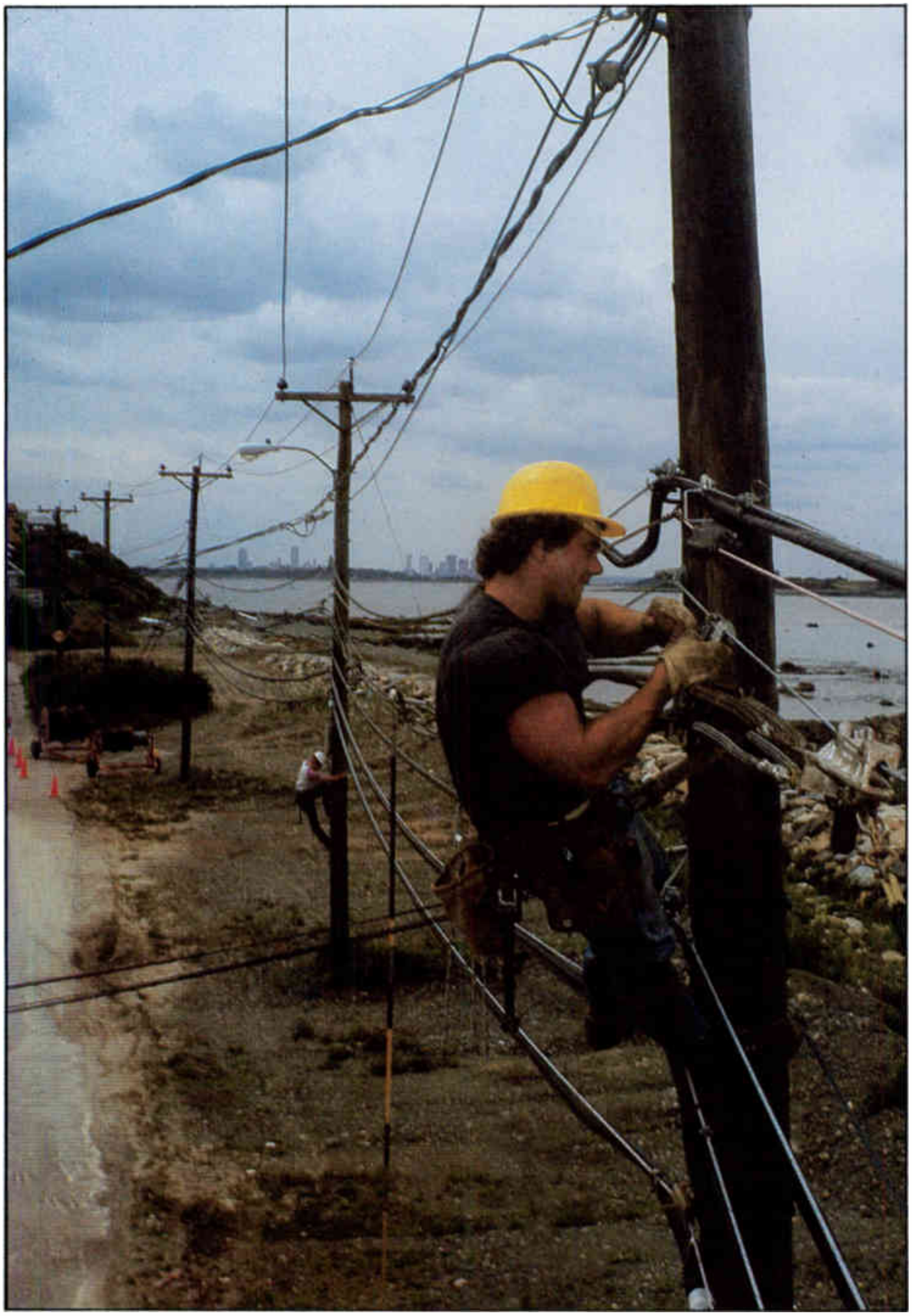
LOS ANGELES—Cable TV Industries moved its national headquarters last month to West Los Angeles. Company purchasing and marketing departments, along with corporate officers, have relocated to the new headquarters.

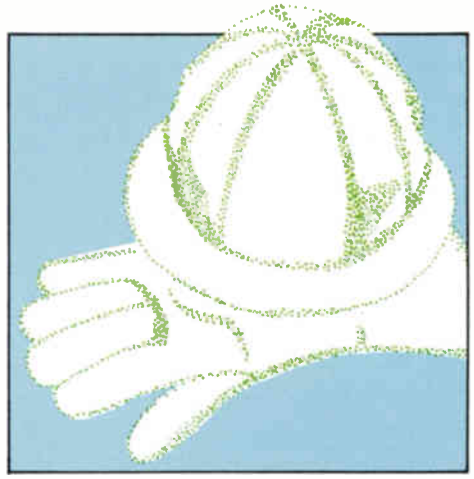
The new office is located at 10801 National Blvd., Suite 606, Los Angeles. The respective phone numbers for the purchasing and marketing departments are (213) 202-2761 and 202-2746.

Coaxial Communications completes systems proof

LAGUNA NIGUEL, Calif.—Coaxial Communications Co. has completed the final balance and systems sweep of several Los Angeles area Group W new-builds, according to Mark Clancey, Coaxial's director of operations.

The balance and sweep functions were performed on over 600 miles of dual subscriber plant, and included proof of performance tests for various institutional networks.





'In the real world . . . technical elegance will take a back seat to (the) practicalities'

The art of rebuild

By Thomas J. Polis
Executive Vice President, Communications Construction Division, RT/Katek Communications Group

As the franchise issued for a cable system approaches its renewal date, great pressures are placed on the operator to enhance his service package to the subscribers. A great deal of this pressure comes from the recent franchise application process, wherein the new technology of expanded bandwidth equipment has permitted capacities of up to 60 channels per cable.

While planning a new-build system in a new market the incremental cost per channel added represents only marginal increases in the capital investment for the expected increase in revenue. The analysis can be substantially different for an existing market upgrade.

Financial analysis

The first logical step in considering a system upgrade is that of the financal impact which will be brought to bear by the operations. Both the income and capital expenditure areas must be considered—thus close coordination between the marketing and engineering departments is essential. In the real world it is the marketing analysis that will drive the engineering analysis, as the capital expenditures will be directly dependent on the increase in income resulting from the combination of rate increases and additional income revenue generated from new services. In other words, technical elegance will take a back seat to real world practicalities.

If you have not completed a detailed marketplace analysis and projection prior to consideration of the upgrade approach you are entering the "Twilight Zone" and could be suspended forever in the darkness of fiscal problems.

Three approaches

The most apparent limitations to additional service offerings from the technical consideration is that of bandwidth availability in the distribution and drop system. As well, the current system architecture, which determines the system distortion characteristics, must be considered.

The two classic approaches to expand bandwidth are: 1) raise the existing plant and build a complete new system; and 2) increase gain by electronics change out and drive the increased losses. Option 1 can represent a capital investment of 3:1 over that of option 2, but is often selected because it is easy to implement, is least disruptive to the ongoing operaton and yields the highest possible bandwidth improvement.

A third option is to consider the use of the interlace two-for-one channel approach offered by General Electric. This approach requires investments in the headend and the subscriber converter. The major consideration here is that one becomes locked to a singular technology produced by a single source and that system improvements may still be required for proper operation.

Prior to selecting one of these options it is absolutely necessary to perform a detailed technical analysis of the existing system.

Step 1: As-built maps

Before any viable technical analysis can begin it is important to know what exists in the current system. The critical items that must be included are:

- Existing cable routings.
- Existing non-cable bearing strand.
- Existing electronic, passive and tap placement.
- Existing and potential subscriber passings.
- Confirmation of footages.
- Cable, passive, tap and electronics types or series.
- Power supply locations.
- Connector types or series used.
- Operational levels.
- Apartment inside plant configuration.

It is advisable, but not required, to perform a subscriber audit at the same time.

Step 2: Condition analysis

An inspection of the physical plant must be performed to discover deficiencies that may lead to a short remaining life. Separation of non-repairable items such as general strand plant corrosion from isolated repairable items such as broken lashing wire, cracked cable sections and damaged or missing hardware should be performed. All items should be noted on the as-built maps.

Step 3: Technical analysis

Now that the discovery stage is completed it will be necessary to analyze the extent of the changes that will be required to upgrade—without complete rebuild—to the desired bandwidth.

This analysis will require both field testing and theoretical elements, and should be performed on a critical path basis taking each element as a go, no-go point:

1) Will the current active equipment spacings permit bandwidth expansion with market available equipment gains and performance?

2) Is the cable that is in place structurally sound and does it follow the square root of frequency function in terms of loss over the proposed bandwidth?

3) Are system passives capable of the extended bandwidth operation? If not, can they be changed without adversely affecting the mechanical properties of the system?

4) Can redesign be accomplished without massive re-routings and cable upgrades?

The drop and apartment

This is the area most frequently neglected when considering a rebuild or retrofit. It is the last and the weakest link of the distribution system. Some of the problems can be corrected in the plant redesign by specifying adequate tap output signals and control of the low-to-high frequency relationships. The mechanical condition and in-home equipment employed also must be considered.

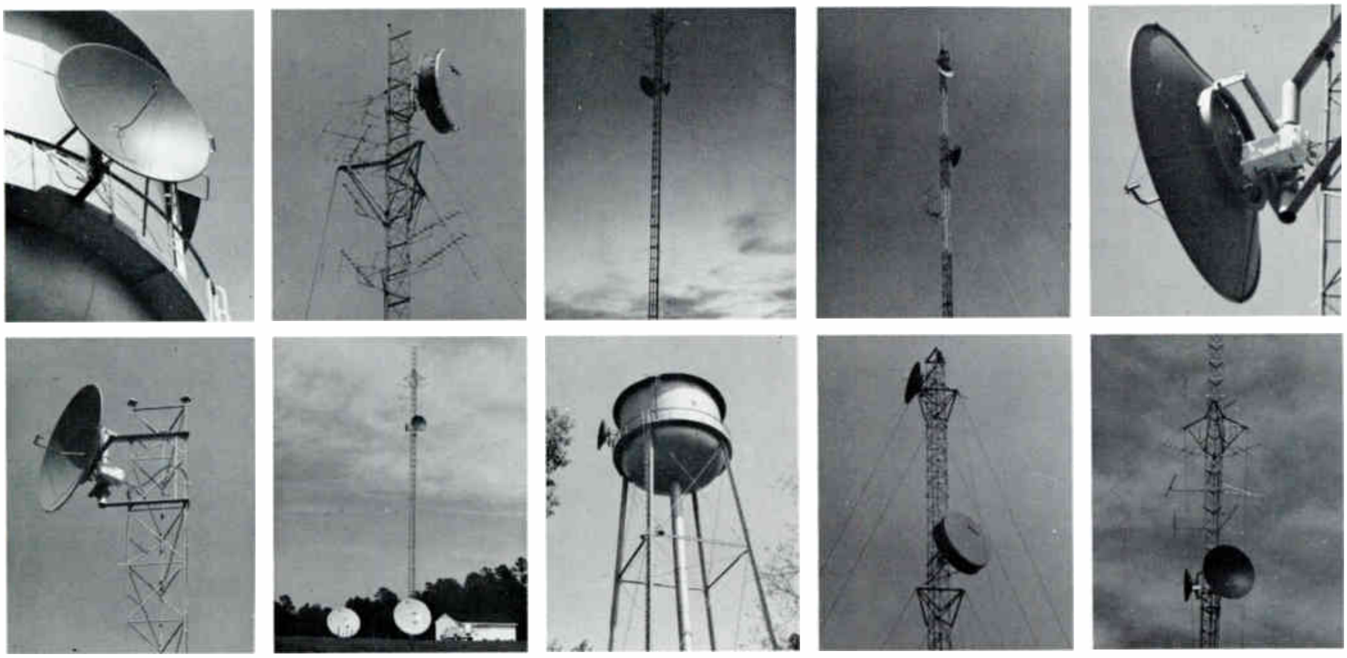
Making the choice

After completion of the detailed analysis of the marketing, financial and system condition, an intelligent decision can be made as to which option will accomplish the desired results. In the event that the complete replacement option is required the steps and controls to be used are the same as that of a new-build plant.

On the other hand, if the decision is made that the retrofit will serve your needs, the process of implementation will be quite different. In a new-build project the critical path analysis will show a great deal of dividing points allowing parallel functions to be performed. While in the retrofit analysis you will find the critical path to be a vertically straight line.

In many systems the possibility of upgrade in lieu of complete rebuild is high. If proper preliminary work is completed the savings could be great. The most frequent problems that are encountered in the upgrade process are a direct result of not having all of the information gathered prior to starting.

If you thought microwaves were too rich for your system...look again!



Micro-Beam™—Performance proven in over a year of trouble-free, revenue producing operation at 9 different sites.

Look at MICROBEAM™

Micro-Beam™ (patent pending) is a new flexible and cost-efficient CARS Band signal delivery system ideally suited for CATV plant expansion.

Micro-Beam™ transmission allows the cable operator to skip on by long cascades. Start with a fresh signal anywhere in the system. Go beyond the limits of subscriber density, geographic, or man-made barriers—without expensive heated/air-conditioned transmitter buildings.

Using just one Micro-Beam™ transmitter (mounted behind the antenna) you can send as many as 52 channels up to 14.5 miles away! And now, with our new Micro-Beam Plus™ systems, you can transmit a full 52 channels up to 10.5 miles, in two different directions. All for less than half the cost of conventional microwave systems.

Micro-Beam™ gives you multi-channel microwave transmission of your entire service from a single outdoor unit which can be located practically anywhere in your plant.

How many new runs are you planning? Take a look at how much it's going to cost you. Then take a look at Micro-Beam™. For more details call, or write:

The "heart" of the Micro-Beam™ system.

channel master satellite systems

Subsidiary of Avnet, Inc., Industry Drive,
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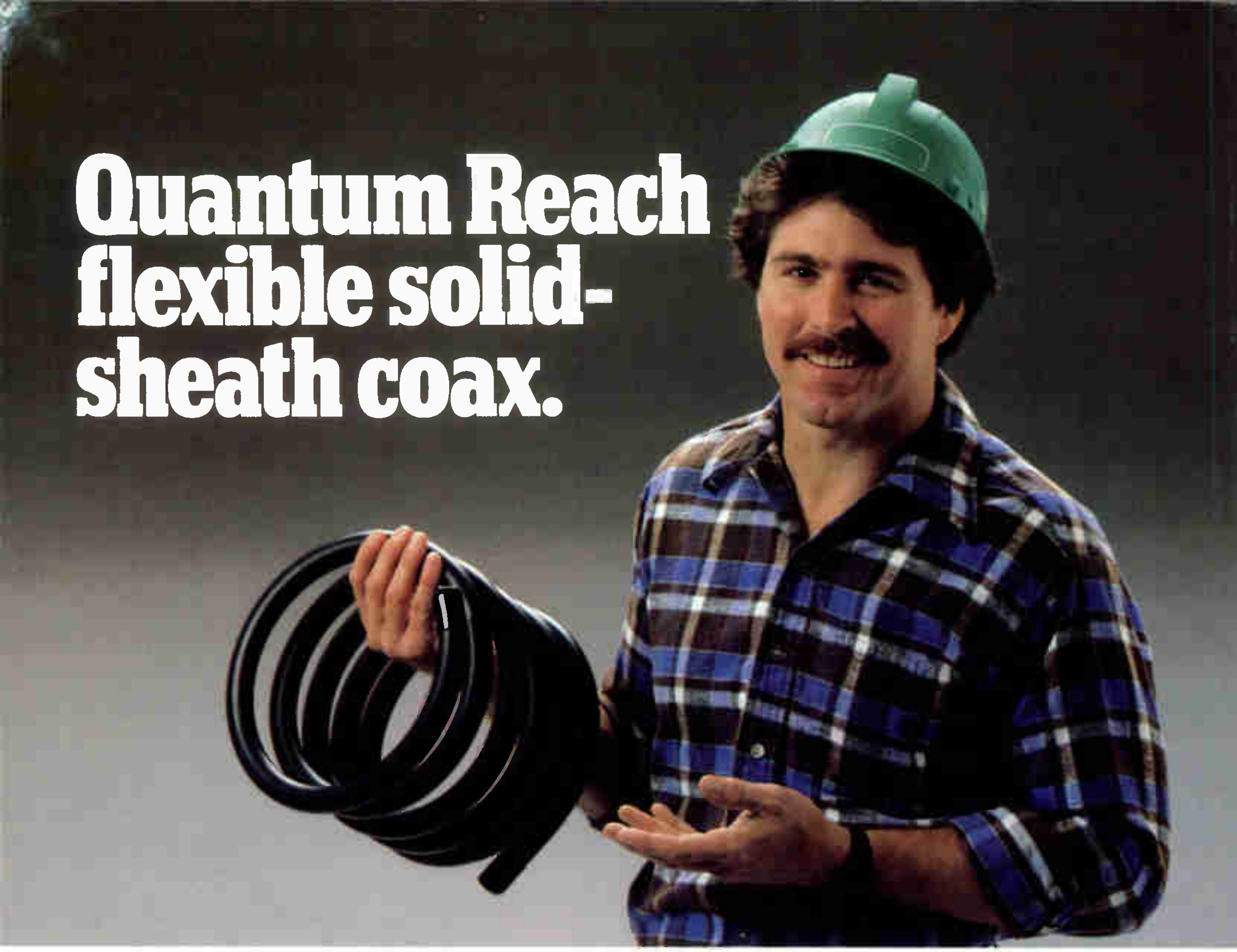


Now you don't have to sacrifice handling performance for lower signal attenuation!

For the first time, there's a coaxial cable that provides both attenuation and handling characteristics of the best of the foam cables. Quantum Reach from M/A-COM — simply the lowest-loss foam cable in the industry, with the best handling performance of any solid-sheath coaxial cable on the market today.

Minimum bend radius of seven inches for the QR 860, five inches for the QR 500. You can install Quantum Reach in tight places with sharp bends quickly and easily.

Lower attenuation and greater flexibility are just two of the reasons why Quantum Reach is a quantum leap ahead in coaxial cable technology.

Take the problem of core pull-out or shrink-back due to thermal cycling over time, for instance. QR's bonded dielectric makes it highly resistant to conductor pull-out.

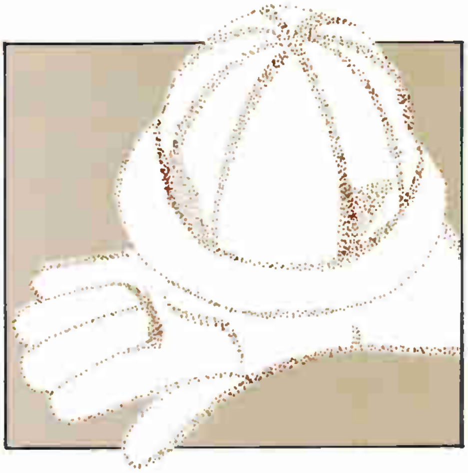
Take durability. QR has an advanced performance, medium-density polyethylene jacket that lasts longer, resisting environmental stress cracks and abrasion. And the lower coefficient of friction means less drag and tension when the cable is being plowed or pulled through multiple bends.

Now there's no reason to compromise between signal quality and handling quality.

With QR, there's no compromise. It's simply the finest coaxial cable available today.

M/A-COM
CABLE HOME GROUP

M/A-COM Cable Home Group COMM/SCOPE Coaxial Cable Products P.O. Box 1729, Hickory, NC 28603 800/438-3331 704-324-2200 Telex: 802-166



Increasing channel capacity

The reasons to increase channel capacity of a CATV system are many—such as franchise requirements, desire to add revenue-producing programming or simple modernization of an outdated and expensive-to-maintain plant. To increase capacity, must all the plant be replaced? If not, then what portion should be retained? To find the answers, we must keep in mind two prime considerations: delivery of a reliable quality product, and keeping required investment and operating costs to a minimum. Other important issues are compliance with franchise and FCC regulations, and service to the community. In this article, the discussion will be limited to the section of the plant between the headend and the subscriber tap port.

By Paul D. Brooks
General Electric Cablevision Corp.

The most expensive portion of a rebuild is cable materials and labor. If existing cable can be used, it will result in significant cost savings. It is also a big advantage to retain existing trunk amplifier locations, so channel capacity can be increased with a minimum of service interruption to the subscriber.

Picture quality, of course, must be maintained at the worst case subscriber. With any type of service upgrade, this is the first consideration. A retrofit is often the most cost-effective way to increase channel carriage while retaining picture quality.

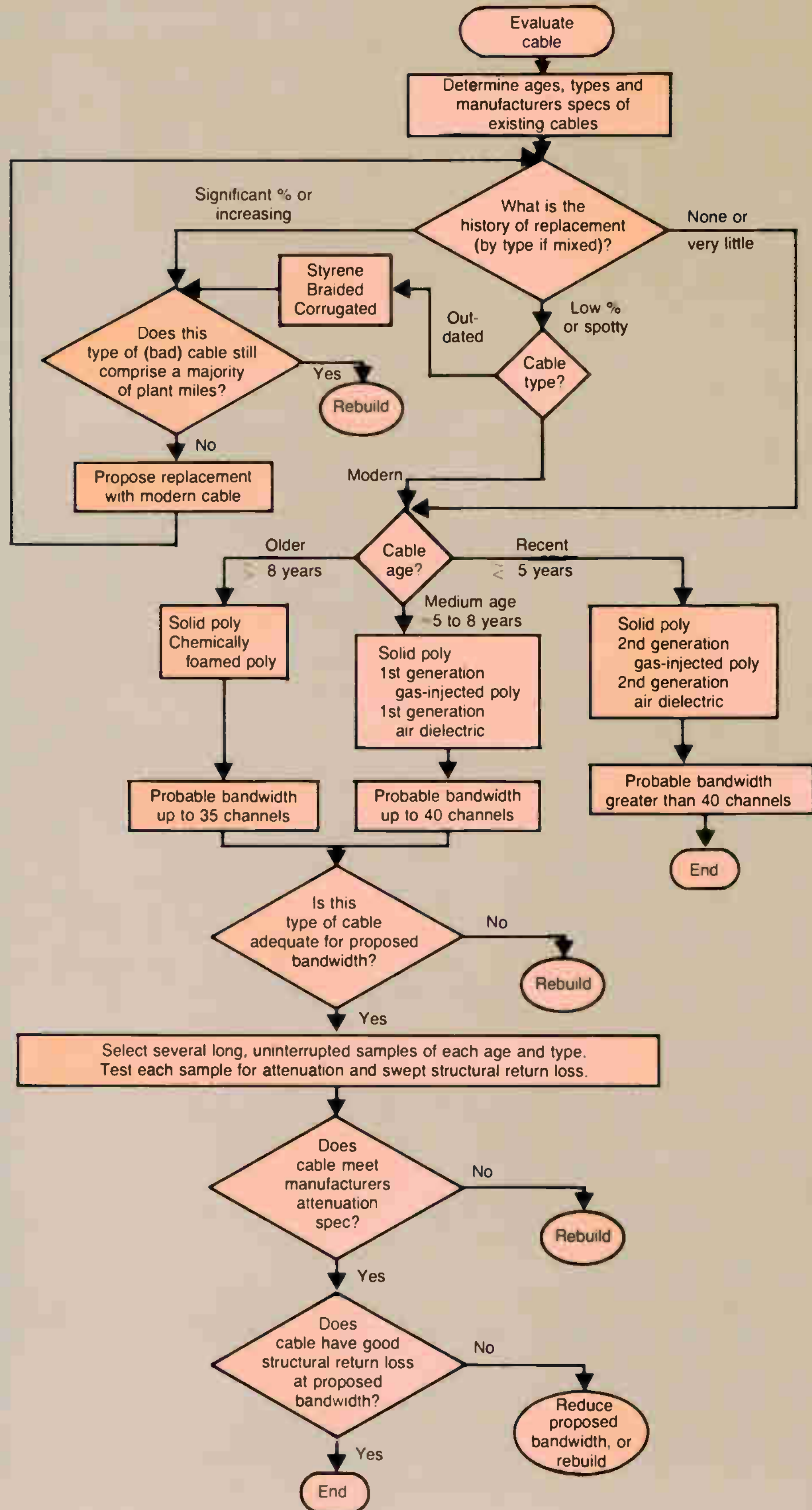
Method of analysis

To determine if some type of retrofit is practical, it is necessary to take a careful look at the plant. This is best accomplished through a separate analysis of four main categories.

1) Cable evaluation: type, age and condition of existing cables need to be examined first because of the large cost impact.

2) Trunk evaluation: distances, cascades and amplifier spacings (these factors will set the limits on performance).

Figure 1: Cable evaluation



3) Distribution evaluation: intimately related to trunk evaluation, this category is important because of cost and ease of maintenance.

4) Existing equipment: often a first priority, usability of existing equipment is best determined after analysis of the previous three items. Figure 1 presents this in logical flow chart form.

Cable evaluation

Using the procedures in Figure 1 will help to answer three main questions: 1) Does existing cable make a retrofit a poor choice? 2) Will existing cable limit usable bandwidth? 3) If cable types and ages are mixed, will some cable need to be replaced?

To evaluate existing cable, first it is necessary to determine the ages, types and the manufacturers specifications. What is the history of replacement? Each type of cable needs to be looked at separately.

If a significant or increasing percentage of a given type has been replaced, does the type being replaced still comprise a majority of the plant? If so, a rebuild is indicated. If not, replacement of the remainder would be proposed. If the replacement history is spotty and amounts to a low percentage, the type of cable involved should be considered. If this type is outdated (i.e., styrene foam dielectric, corrugated or braided sheath), replacement would be proposed, or if this is the majority of plant, a rebuild would be called for.

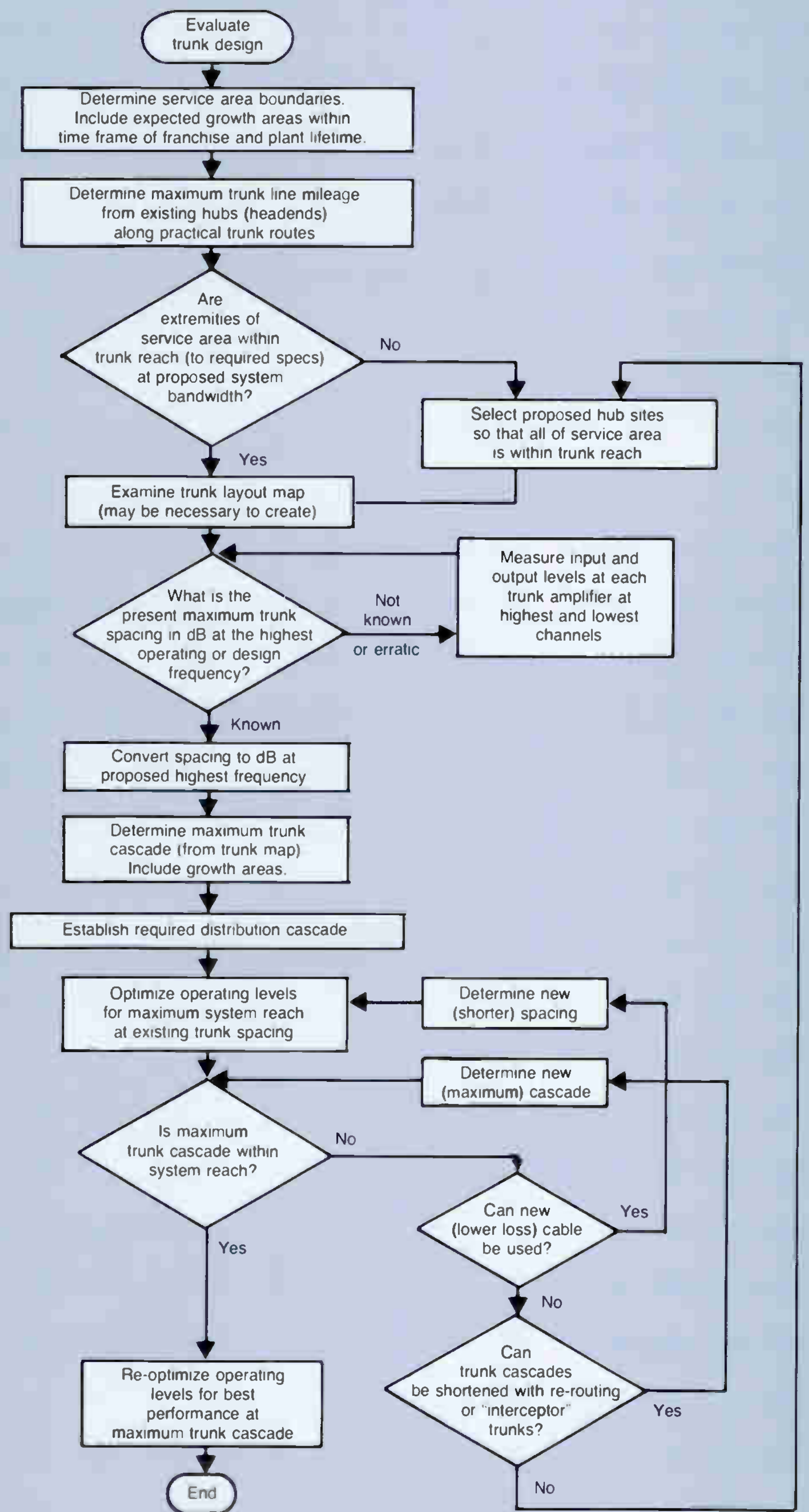
If very little or no cable of a given type has been replaced, it is then necessary to look at the age of the cable. Older types, with solid polyethylene or chemically foamed polyethylene dielectrics, are probably usable to about 35-channel capacity. Cable of medium age, with gas-injected polyethylene or earlier air dielectrics, can typically be used up to about 40 channels. More recent types, such as low-loss versions of gas-injected polyethylene and improved air dielectric cable, will have capacities in excess of 40 channels. If all cable for which replacement has not been proposed is one of these recent types, the cable evaluation is completed. If not, then does the existing cable meet the bandwidth requirements? If not, a rebuild is indicated.

If the needed bandwidth seems attainable with existing cable, this cable should then be tested in the field. To accomplish this, select several long, uninterrupted samples of each age and type to be retained. Each sample is then tested for attenuation and structural return loss across the proposed bandwidth. If the samples show substantially higher loss than the manufacturers' specs, then a rebuild may be required. If the samples do not exhibit acceptable return loss across the required bandwidth, then perhaps the proposed bandwidth can be reduced, or if it cannot, a rebuild is indicated. If samples pass both attenuation and return loss testing, the cable evaluation is complete.

Trunk evaluation

Figure 2 addresses three issues: 1) Are additional hubs required? 2) Can existing

Figure 2: Trunk evaluation



RT/KATEK™ is a classic example of the whole being greater than the sum of the parts.

RT/KATEK COMMUNICATIONS GROUP is the result of the merger of Katek, Inc. and RT Cable Corporation — and a perfect example of two organizations combining to offer much more than twice the services they previously offered.

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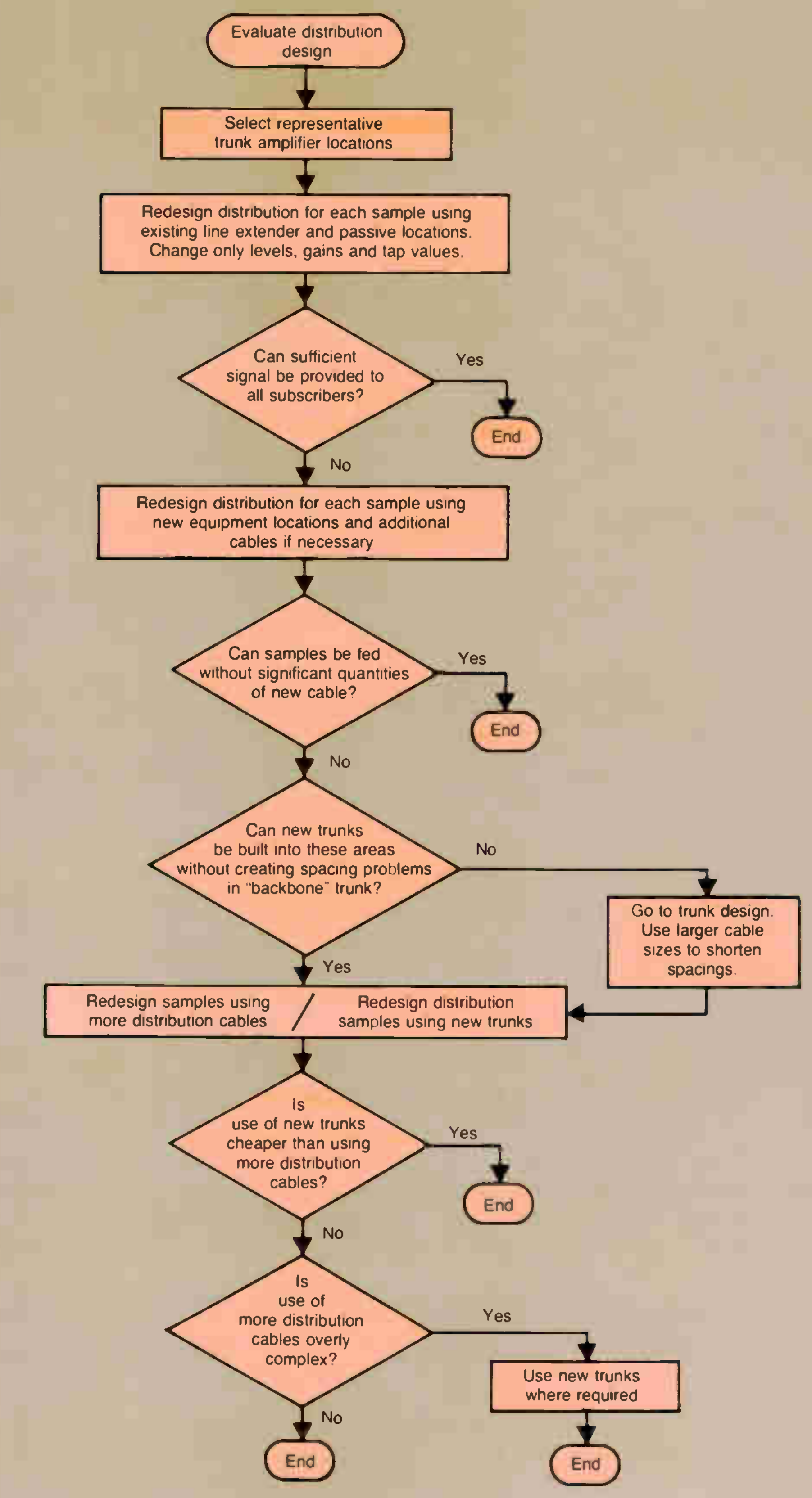
Figure 3: Distribution evaluation



trunk cable be used? 3) What are the optimum operating levels?

To evaluate the trunk layout, it is first necessary to determine the service area boundaries. Expected growth areas within the period of the franchise and plant lifetime should be included. With this information, then, it is possible to determine the maximum trunk line mileage from existing headend or hubs along potential trunk routes to the extremities of the service area. With this distance in mind, can practical trunks be built to serve these areas and meet the required end-of-line specifications at the proposed bandwidth? A negative answer to this general question will quickly indicate the need for additional hub sites with attendant high-performance coaxial, fiber optic or microwave interties.

If service area extremities are within potential trunk reach, a map of the existing trunk layout needs to be examined. In many cases it will be necessary to create such a map. The trunk map and information previously determined about cable types will allow the trunk spacing to be determined at the highest existing operating or design frequency. In cases where spacings are difficult to determine, or if determined spacings appear to be erratic, then some field work is required.

A technique that answers the spacing question and can also yield a lot of other valuable information is to measure the inputs and outputs at each trunk amplifier in the system. The results of such a study can be used to check the trunk map, indicate bad cable and equipment, and spot bad design and construction. Sometimes it also makes sense to set amplifier output levels as system technicians measure their way out into the trunk lines.

Once existing spacings are determined, they can be converted to dB at the highest frequency needed to pass the proposed bandwidth. Now it is possible to examine the option of use of existing trunk amplifier locations.

Determine maximum trunk cascade using the trunk layout map. Be sure to include growth areas. Establish the required distribution cascade. Use manufacturers performance specs to optimize equipment operating levels for maximum system reach at existing trunk spacings and required end-of-line performance.

Is the worst case trunk cascade within system reach? If not, perhaps lower loss cable can be installed to shorten trunk spacings and improve system reach. The operating levels again need to be optimized to find out if this technique will work. If changing trunk cable is not practical, can trunk cascades be shortened through re-routing or use of "interceptor" trunks? Here again, levels must be optimized at the proposed shorter maximum trunk cascade to determine if this is a viable alternative.

If neither of these options alone or in combination will work, then it is necessary to start over again by selecting proposed hub sites and repeating the trunk evaluation. When the final choices have been made, the operating levels can be re-optimized to result in the best performance at the worst case subscriber.

Distribution evaluation

A third chart (Figure 3) will help to answer these three questions: 1) Can line extenders and passives remain in their present locations? 2) Is additional trunking required? 3) Is additional distribution cable required?

To evaluate the distribution section of the plant, first select several trunk amplifiers as samples. Use a sufficient number of samples to represent a cross section of different subscriber densities, trunk depths, design specs/philosophies and system ages. Redesign each sample at the proposed bandwidth. Use existing line extender and passive locations, changing only levels, gains and tap values. Can sufficient signal be provided to all subscribers? If so, the distribution evaluation is complete. If not, redesign samples using new equipment locations and additional cables if necessary.

If the samples can be fed without excessive use of new cable, again the evaluation is complete. If not, can new trunks be built into these areas without creating spacing problems in the "backbone" trunk? If spacing problems come up, return to the trunk evaluation and see if spacing problems can be resolved through use of larger or lower loss cables.

When a method of new trunking has been established, the following comparison can be made. Redesign samples using additional distribution cables and redesign the samples using new trunks. Estimate the cost of each option. If new trunking is cheaper, then it becomes the method of choice. If additional distribution cabling is cheaper, does it result in a complex and hard to maintain layout? If so, new trunks should be used. Analysis of each sample can result in a different conclusion, and the preferred solutions may vary in each situation.

Existing equipment

At this point, cable has been looked at, design problems have been worked out, and operating levels, spacings and required equipment performances are known. Now choices can be made regarding replacement, upgrade and retention of the components of the outside plant.

1. Actives: Trunk amplifiers, bridger and line extenders are of principal importance. In general, existing actives are not adequate for increased channel loading. If the gear is of recent vintage, many manufacturers offer replacement plug-in modules with improved performance and higher gain ratings. Modification kits are available in the aftermarket to upgrade performance and increase gain of existing modules. If the highest performance is a must, then feedforward technology or power doubling amplifiers could be the answer.

2. Passives: The existing splitters, directional couplers and taps must be able to pass the required number of channels. The original manufacturer's spec sheets will indicate the bandwidth of these passives and if satisfactory on paper, samples should be checked to see that they actually pass the bandwidth required with acceptable frequency response. Fortunately, many modern taps are of modular construction and will not only allow the tap value to be changed without resplicing, but the bandwidth as well.

3. Connectors: Existing connectors must be mechanically sound and have sufficient shielding to prevent signal leakage. They also must have high enough return loss to reduce reflections. If connectors need to be changed, the additional splicing labor may negate the cost advantages of retaining existing passives and taps, particularly if these devices are of borderline or questionable performance.

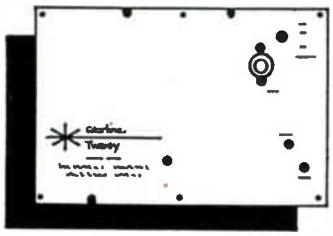
4. Powering: Existing power supplies must have adequate current ratings. If selected amplifiers require more power, or if greater numbers of amplifiers will be used, the powering layout should be checked. Replacement or conversion of 30 volt supplies to 60 volts will often eliminate the need for more supplies at new locations.

The practical mathematics of performance prediction, although not overly complex, can be difficult for non-engineering personnel in management and technical positions at the system operations level. Fortunately, many electronics manufacturers will provide assistance in operating level selection and determination of end-of-line performance.

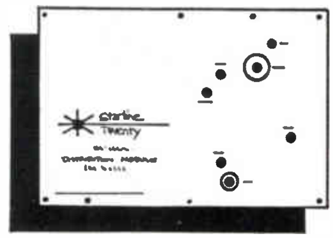
Attention to the evaluation procedures outlined in this article will result in better allocation of financial resources and produce a cable system with dependable performance that will be a good revenue producer for years to come.

JERROLD

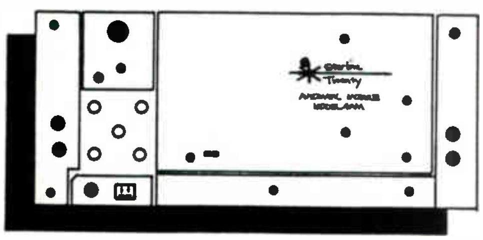
EQUIPMENT SPECIALS



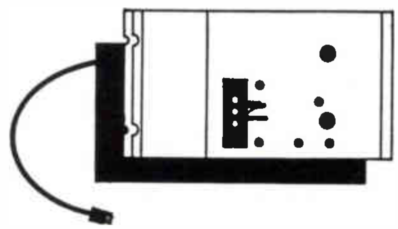
(300 MHZ)	
SJAS-301	$95.00
SJMM-301	85.00
SJBM-301	85.00
SJDL-301	80.00
SJ-1 A/E	260.00
SJ-2 A/E	250.00
SJ-3 A/E	175.00
SJ-4 A/E	165.00
SJ-5 A/E	165.00



(260 MHZ)	
SAM-PT	$80.00
SMM-PT	70.00
SBM-P	70.00
SDH-P	70.00
SP-1	230.00
SP-2	220.00
SP-3	160.00
SP-4	150.00
SP-5	150.00



(240 MHZ)	
SAM	$40.00
SMM	30.00
SBM	40.00
SDH	30.00
ST-1	150.00
ST-2	140.00
ST-3	110.00
ST-4	100.00
ST-5	100.00



STH	$50.00
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SCL-2W	60.00
SCL	50.00
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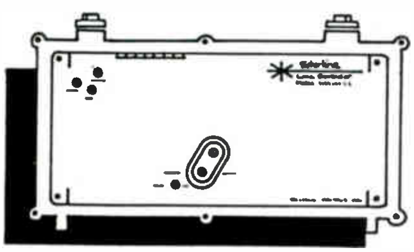

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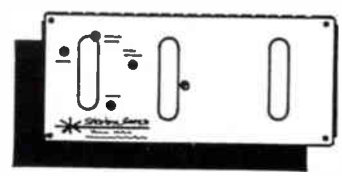

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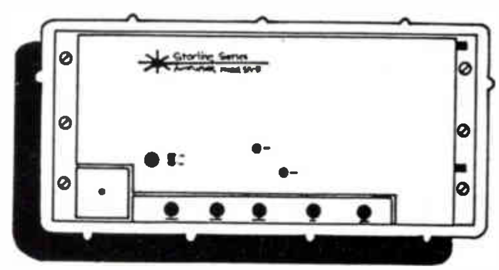

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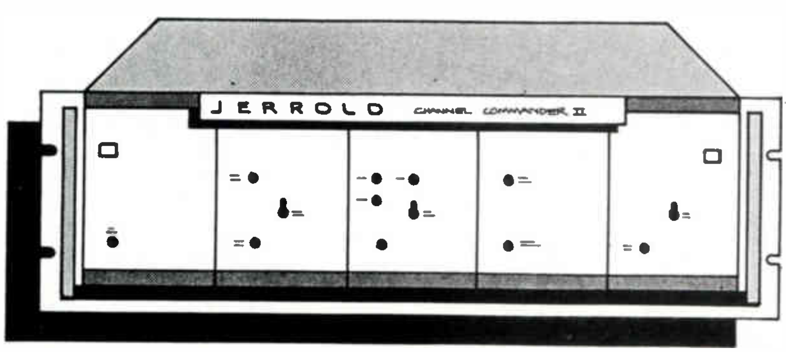

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CATV SERVICES

Module change outs

Keep the housings, coaxial cable, hardware and profits

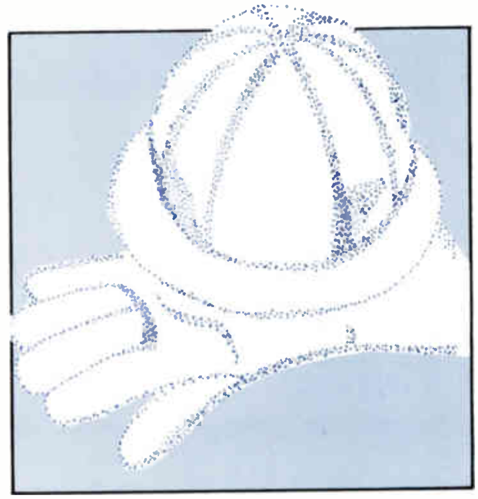
By Fred Rogers
President, Quality R F Services Inc

Competition comes in many forms to challenge modern day CATV system operators. No system—large, small, in a big city or at the end of a country road—is immune to competition for subscribers. Low-cost "dishes," DBS, SMATV, STV, off-the-air channels, local cable systems and public awareness of "blue sky" franchise promises press system operators to continually improve product.

The plan is to keep the original amplifier housings and increase the number of system channels by installing superior specification electronic modules at *existing* locations. A complete system rebuild can be delayed for many years assuming the coaxial cable and hardware remain sound electronically and physically. To date, many systems have been pleasantly surprised that the coaxial cable itself endures and will pass many more channels than was originally specified.

To accomplish an amplifier module change out program, new modules can be purchased or the original modules can be modernized. In many cases, replacement of RF integrated circuits (IC chips) or the installation of advanced designed printed circuits incorporating "super hybrids" can save existing modules. The advantage of reusing modules can be substantial cost savings and custom designed specifications.

Let's face the facts. If a distortion free amplifier with unlimited gain and bandwidth existed, a system operator could add as many channels as desired without degrading picture quality at system extremities. Since the perfect amplifier does not exist, careful evaluation will be needed to assure that plugging in new electronics will give the desired results.



The CA5201 'super hybrid' is one example of the many recent low distortion, low-noise figure hybrids available to CATV.

Example 'super hybrid' specifications

Characteristics	Test conditions	CA5101	CA5201
Gain	450 MHz	19.1 ± 0.6 dB	19.1 ± 0.6 dB
Frequency response	± 0.1 dB	40-450 MHz	40-450 MHz
Slope cable equivalent	50-450 MHz	+0.3 to −1.4 dB	+0.3 to −1.4 dB
Cross-modulation @ +46 dBmV	52 CH	−59 dB	−63 dB
Second order	50 dBmV, CH 2, 13, R	−71 dB	−73 dB
	50 dBmV, CH 2, H5, H14	−68 dB	−70 dB
Triple beat	50 dBmV, CH H14	−74 dB	−78 dB
Composite triple beat 52-channel @ +46 dBmV	CH H14	−58 dB	−62 dB
Noise figure	50 MHz	4.5 dB	5.0 dB
	400 MHz	6.0 dB	6.5 dB
	450 MHz	6.5 dB	7.0 dB
Return loss input/output	40-450 MHz	18 dB	18 dB
Power requirement	24V	180mA (Typ.)	215mA (Typ.)

Set desired goals

The following fill-in-the-blank questions can be used as guidelines when considering a module change out.

1) How many years operation will be needed from the module changeout? ______ years

   . . . Many systems will gain five or more additional years to evaluate new technology and generate profits to justify a total rebuild.

2) How many channels will be required to stay competitive for the duration of that period? ______ number of channels

   . . . Be reasonable, 10 additional channels for an operating 30-channel system is a common goal. Plan quality services for the future and make every additional channel count.

3) What will be the highest frequency required to obtain the additional channels? 270 MHz? 300 MHz? 330 MHz? 400 MHz? Other?

   . . . In our example of 30 to 40 channels, the system upper frequency would be increased from 270 MHz to 330 MHz (6 MHz per channel times 10 channels equals 60 MHz additional bandwidth).

4) What are the worse case distortions to be allowed?

   . . . By setting design distortion goals, modules for change out can be selected by specifications tailored to each system's individual requirements.

   For example:

Composite triple beat	−53 dB
Synchronous cross-modulation	−51 dB
Carrier-to-noise	45 dB
Second order	−60 dB

   Note: These are typical worse case conditions that once determined cannot be exceeded at any location within the system design.

5) Will two-way service be required?
Yes ____ No ____ Maybe ____

. . . Most recent amplifiers are two-way or have bi-directional options available. The key here is can two-way be added easily.

6) Will signal leakage be a problem?

. . . Constant monitoring and correction of signal leakage is a must even in new plant. Signal leakage must be corrected in the original plant before attempting a module change out.

The system evaluation results determine the changeout modules to be selected. In the trunk line, a combination of improved noise figure and additional output level will be required. The increased cable attenuation at the new, higher frequencies will require re-equalization and more gain in the trunk modules.

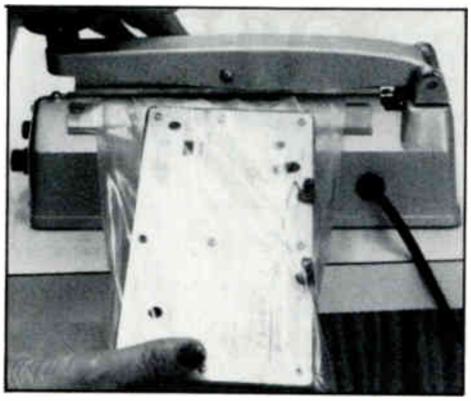
In the feeder section, customer tap levels and higher cable attenuation requires increased output levels at the bridger and line extenders. Due to higher input levels, noise figure improvements in bridgers and line extenders can be disregarded.

Perform field evaluations

Again, fill-in-the-blank questions may aid the evaluation of the present system.

1) How much cable replacement will be required to correct damaged or defective cable?
____% Trunk
____% Feeder
Cost $ ____

2) Will the passive devices including splitters, power inserters and directional taps pass the desired bandwidth for the trunk?
Trunk: Yes ____ No ____
Feeder: Yes ____ No ____



A typical amplifier module used in many CATV systems. Advances in integrated circuitry technology plus improved amplifier design concepts can add extra channels without relocating original housings. Module modernization or replacement with improved modules may be selected for a module change out.

3) Will any serious overspacing have to be corrected with low loss cable?
____% Trunk
Cost $ ____

4) Can the present amplifier housings accept improved specification modules?
Yes ____ No ____

. . . This question should be presented not only to the original amplifier manufacturer, but also to companies specializing in replacement module programs.

5) What will be the attenuation at the highest desired frequency for an averaged spaced amplifier? ____dB at ____MHz

6) What will be the maximum amplifier cascades?
____ trunk amplifiers
____ line extenders?

7) What minimum levels will be acceptable at the customer tap? ____dBmV

8) Will present system powering be sufficient?

. . . If a system has 30 volt AC operation, a change to 60 volts will resolve the problem.

Select modules to meet requirements

To make a module change out successful, the new modules must have improved specifications for the additional channels plus extra head room for increased output levels and lower input levels. Extra channels and higher levels can be obtained through today's improved hybrid technology and a few design tricks to make it all work.

Method A: In conservatively designed systems using hybrid amplifiers, a change to "super hybrids" and associated minor circuit design changes may be all that is required to add channels. For example, hybrid vintage RCA amplifiers are prime candidates for "super hybrid" technology. Except for the very latest vintages, most manufacturers have hybrid amplifiers that can be improved both in specifications and reliabilty with "super hybrids" and minor circuit changes. Each hybrid or module must be tested to *maximum* channel loading to ensure specifications. Testing distortions can only be meaningful with total channel loading, any testing with partial channel loading can be totally erroneous for interpolation of fully loaded specifications. Often, distortions at higher frequencies increase drastically in RF amplifiers.

Method B: Amplifiers using obsolete design techniques may require complete new printed circuit boards with "super hybrids" or replacement with a new module. Inexpensive 35-channel upgrades are available for some popular modules. Make sure all potential suppliers are contacted when considering 35 channel system upgrades.

Method C: Often the system cannot meet engineering specifications using standard amplifiers. A useful tool can be a module with output hybrids in parallel ("P^2"). The addition of one hybrid in these "P^2" modules improves composite triple beat 5 dB and second order 3 dB. The additional 2.5 dB of output level may be required in only one type module to meet overall system specifications. For example, a system bridger output level originally operated at 46 dBmV at 270 MHz and must be increased to 48 dBmV at 330 MHz. A bridger module using "P^2" may be operated at 48 dBmV within distortion specifications. By taking advantage of the improved "P^2" bridger, standard design modules could be used for the trunk and line extenders. Paralleled hybrids also can be used in trunk modules and line extenders as needed to meet system specifications.

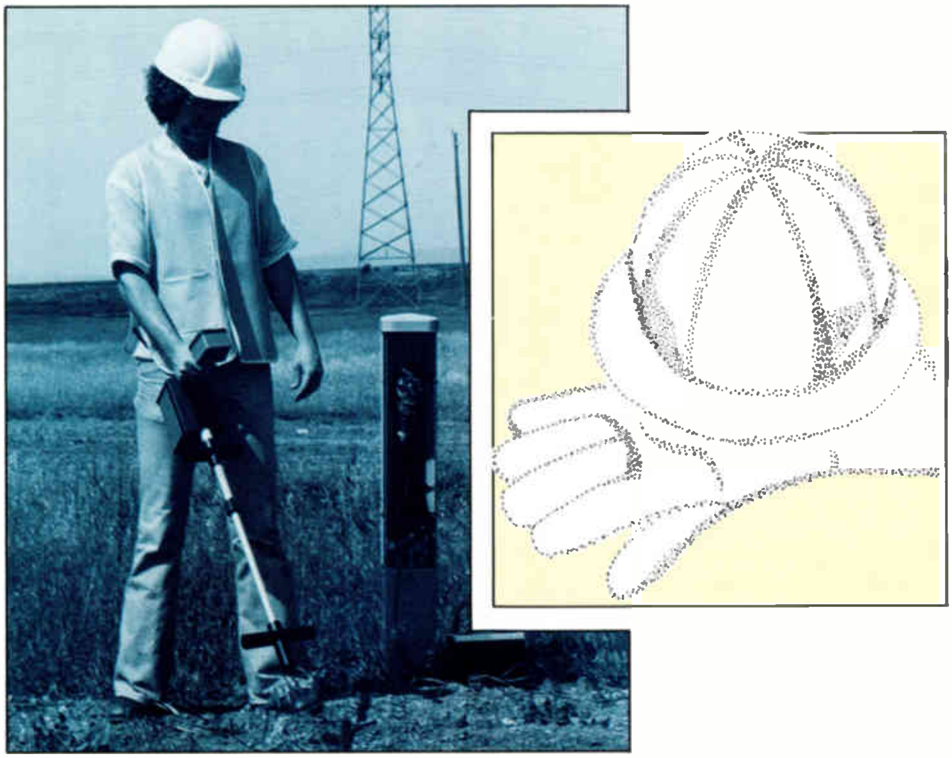
Module change out requires careful evaluation of the original plant. The benefits of correcting problems and good engineering practices will produce revenues instead of rebuilds or opportunities for competitors.

Comparison of conventional amp and 'P^2' output hybrids in parallel

Distortions specifications; (330 MHz, 40 channels)

Type module	Cross-modulation[1]		Second order[2]		Composite triple beat[3]		Noise figure[4]	
	Conv.	'P^2'	Conv.	'P^2'	Conv.	'P^2'	Conv.	'P^2'
Bridger	−62 dB	−67 dB	−67 dB	−70 dB	−61 dB	−66 dB	7 dB	7 dB
Trunk/AGC	−89 dB	−94 dB	−81 dB	−84 dB	−88 dB	−93 dB	6.5 dB	6.5 dB
Trunk/manual	−90 dB	−95 dB	−82 dB	−85 dB	−89 dB	−94 dB	6.5 dB	6.5 dB
Line extender	−64 dB	−69 dB	−70 dB	−73 dB	−63 dB	−68 dB	10 dB	10 dB

[1]Synchronous modulation—trunk levels 33/29 dBmV, bridger levels 48/42 dBmV.
[2]Second order, Ch2, G,13, R worst case with levels shown in Note #1.
[3]CTB 40-channel worst case on channel M-2 with levels shown in Note #1.
[4]Noise figure—Channel M-2.



Locating underground utilities

By Phil Webber
Metrotech Corp

The majority of pipe and cable locators in use today generate radio or audio frequencies that are coupled to the underground utilities.

This signal may be applied by various methods, the first being the conductive or direct mode where there is access to a contact point, such as a valve or a cable sheath. Another is the inductive or indirect mode, whereby the transmitter and antenna are placed on the surface of the ground above the conductor and the signal is induced through earth onto the pipe or cable. One more popular method is the use of an inductive coupler where the signal can be applied to a cable without lifting bonds or disrupting service. The coupler induces a strong electromagnetic field onto the cable and aids in isolating specific conductors.

Once the signal is properly applied, it is then traced by the use of a receiver unit. These will vary according to manufacturer as far as size, antenna configuration, types of controls, etc. However, regardless of make, there are some basic operating procedures that apply to all models.

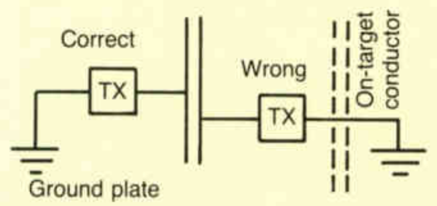
Conductors

To begin with, the user must think of the pipe or cable as a conductor and part of a circuit that must be complete to allow signal flow. The ability of the conductor to carry the signal is very important and this is determined by its composition. For example, copper is an excellent conductor, as is aluminum. Steel is less conductive and one of the poorest is cast iron. These are the most common materials used for underground utilities.

If any of these conductors are coated, wrapped or insulated, the signal will not bleed off into the surrounding soil as rapidly as it does with a bare conductor. Hence, the conductor can be traced further before the transmitter must be moved to a new location and reconnected. Also, insulated conductors are not as easily influenced by their environment, such as poor soil conditions. Size of the conductor is also a factor. A given signal cannot travel as far on large diameter pipe, as it can on a small insulated cable.

The other part of the circuit is the soil surrounding the conductor. The ability of soil to pass current will vary locally. Wet compact soil is clearly a better conductor than loose sandy soil or frozen ground. Moist soil produces a better tracing environment than dry or frozen ground.

Figure 1: Transmitter direct connection and ground



Conductive use

As mentioned before, this mode requires direct contact with a conductor. An independent ground must be established to provide a return circuit path. Proper use of the transmitter and ground rod or plate cannot be over-emphasized (see Figure 1). It can be safely said that at least 80 percent of all application problems result from failure to properly energize the target conductor.

For example, if the ground lead wire is placed nearby, or over a nearby utility, it can cause confusing tracing signals as the lead itself radiates as much signal as the target conductor. In many urban areas where exposed ground is not available, the use of a ground plate is recommended. To establish a good ground on cement or asphalt, one must provide a combination of surface contact, moisture and weight.

Inductive use

This method is probably the easiest and most convenient way to use a locator. However, if not done properly, it can lead to serious tracing errors. Where direct contact is not possible, the transmitter is placed on the ground *directly* above the conductor and the signal is induced through earth onto the target. This conductor then radiates the signal.

There are many different antenna designs for transmitters, which in turn influence the direction the transmitter must be placed in relationship to the target conductor. Also, one must determine the minimum distance the receiver may be used from the transmitter. Air coupling effects can cause erroneous readings if the receiver is too close to the transmitter. The inductive mode generally has a shorter tracing range, especially on conductors at depths over 36 inches. One also must remember that the transmitted signal can be easily induced into other nearby utilities, especially if they are better conductors and at shallower depths.

Inductive couplers

Design and sizes of inductive couplers will vary with each manufacturer, but they all apply signal basically in the same manner (see Figure 2). A tracing signal is induced on the target conductor by an electromagnetic field created by the coupler. The coupler does not make direct contact as in the conductive method, but surrounds the conductor like a current measuring clamp. This method eliminates air coupling and greatly improves isolation of specific conductors.

When using a coupler, the conductor must be grounded at both ends for a complete circuit path. Insulated coupling on gas meters must be bypassed to complete the circuit. Also, care must be taken not to position the coupler above an electrical grounding point, as the signal will seek the path of least resistance and return to ground and not onto the conductor.

Receivers

This is where a noticeable difference exists between manufacturers. Antenna or loop designs will vary greatly. Some are rigid and attached to the outside of the receiver case. Others, called multi-turn loop antennas, are mounted on the inside. A more recent design is the use of search coils in place of the broad loop antennas. In all instances, close attention must be given to the angle of the antennas or search coils in relationship to the conductor. The antenna must be maintained at the proper angle to receive the best signal from the conductor.

Most receivers operate in a peak or null mode. Peak mode is when the antenna receives maximum signal over the conductor. Null mode is when the antenna receives minimum signal over the conductor. Peak and null modes usually are determined by the vertical or horizontal position of the antenna. Generally the peak or maximum mode is used for tracing and the null for pinpointing the center line of the conductor. However, the users preference generally determines the method used.

Obviously, an antenna produces a more accurate and stronger response when it is as close as possible to the target conductor. Therefore, an extended search coil is an advantage to the user, allowing him maximum tracing signal from a standing, upright position. An even more advanced design is the twin coil antenna. This allows a narrower response to the conductor and is very beneficial to the user when locating in congested areas.

Another common feature is sensitivity or gain controls. These controls are used to adjust the amount of signal received from the conductor and transmitter. Receiver sensitivity must be continually and properly adjusted to prevent tracing errors. This feature has been

Figure 3: Determining depth of buried pipe

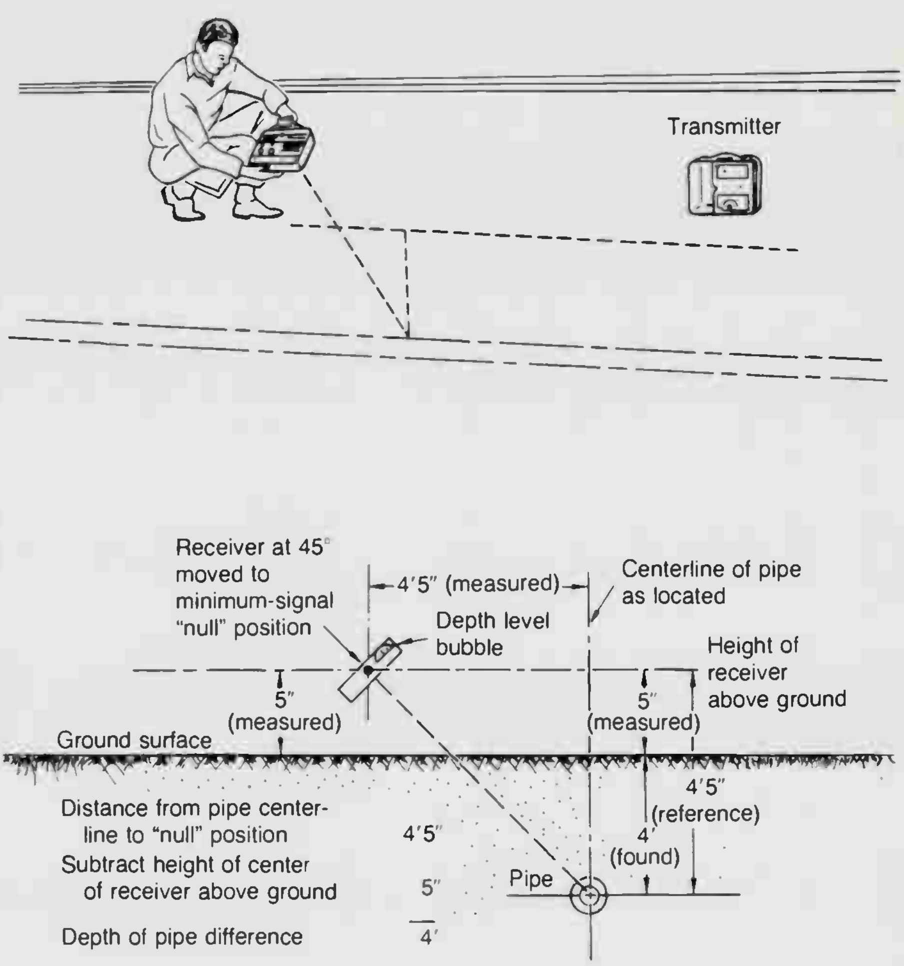
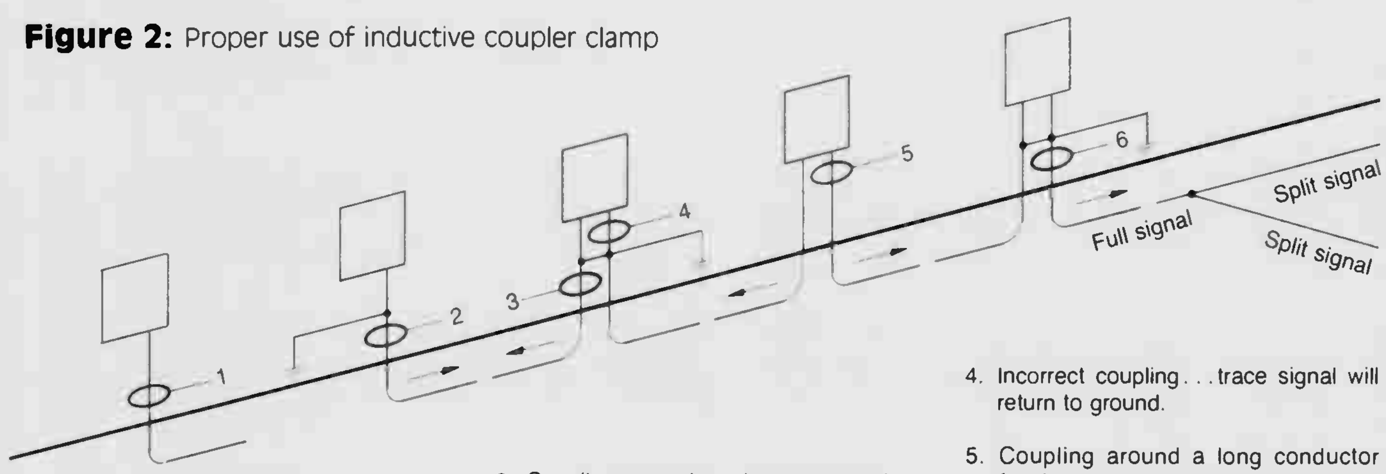


Figure 2: Proper use of inductive coupler clamp



1. The Metroclamp can be used in all trace applications where conductors are exposed at one or more places. The only exception is at a terminated end that is an open circuit.
2. Coupling transmitter clamp to a terminating point of a trace item requires a grounded conductor to provide proper current flow through the ground.
3. Always couple to a conductor between the ground and the point where the conductor enters earth.
4. Incorrect coupling . . . trace signal will return to ground.
5. Coupling around a long conductor feeding in two directions creates a current flow allowing trace in both directions.
6. Coupling to a conductor with drop lines or laterals, feeds full trace signal up to the junction point, and then divides the signal strength into each branch.

eliminated on some models and replaced with automatic gain control. With this feature the user need not make any adjustments. Automatic gain control allows the receiver to respond to other conductors also, which will help the user develop a clearer picture when solving locating problems in congested areas.

In addition to automatic gain control, there are other new features available, such as a digital readout for measuring the relative field or signal strength on a given conductor. This is an important tool that can aid the user in identifying a specific target.

Depth

There are occasions when an estimation of depth is required without exposing the conductor. This can be accomplished by using various methods. The most common in past years has been the triangulation method, where the receiver loop is tilted at a 45 degree angle to the conductor and moved away from the centerline until a null is obtained (see Figure 3). Then, using a simple geometric formula, the approximate depth can be determined.

Variations of this include the use of extention probes with built-in depth levels or simply lifting the receiver loop straight up over the conductor and measuring the height. Of course the accuracy of these methods can be affected by any one of the following conditions: nearby metallic structures, extreme changes in ground conductivity, low signal strength or signal in nearby conductors. The previously mentioned twin coil antenna can lessen the effect of these conditions. However, regardless of make or design, there is not one locator that can magically outsmart all the laws of physics and be 100 percent accurate under all conditions.

Frequency

To date, the most widely used frequencies are in the high radio frequency (RF) ranges. An advantage of RF is that it is generally easier to apply to a conductor, such as with inductive use. Also, the signal can travel, although limited, across small insulators or gaskets commonly used in distribution systems.

There are several disadvantages of RF. The power output of the transmitter cannot be too high, as RF signals can be easily coupled into other nearby conductors. Also, on good conductors, RF signals cannot be traced as far as lower frequency audio signals (AF). Another advantage of the lower audio frequencies is that the applied signal does not bleed off as easily, allowing better isolation. With some audio frequency locators, the user has an option of high output transmitters, ranging as high as 500 watts, which are useful for long-range tracing on cable or gas transmission lines.

A disadvantage of audio is that if there are any insulators or gaskets on a conductor, such as on a water or gas line, the signal will not continue. Another is that AF signals are not induced as easily onto a conductor as RF and therefore are not as efficient in the inductive mode. Also, when applying audio to a conductor, good grounding is more critical for maximum signal strength.

For years, even decades, the evolution of pipe and cable locators has been very gradual. Now with the ever increasing density of underground plant and structures, the need for more advanced locating equipment has become quite clear. There are locators available today to help meet that need with automatic features, digital readouts and audio guidance, which combined, provide new speed, shortened training requirements, plus accuracy and convenience for the user. Not yet mentioned are a few other types of instruments, such as magnetic locators used for locating discrete ferrous structures, passive locators that will trace 60 Hz AC, detachable transmitters for finding sewer service lines, and electronic marker systems that are tuned for specific utilities.

When choosing a locator, one must consider versatility and training requirements. With today's congestion, it is a must for the user to be aware of other utilities and conductors in the area to help him solve the really tough jobs. As stated many times before, pipe and cable locating is not an exact science. It requires experience, knowledge of construction practices and, most importantly, confidence in your instrument.

Off-air antennas

By John R. Mauney
Scientific-Atlanta Inc

The basis for radio transmission without direct wire connection is electromagnetic radiation. The electromagnetic waves are generated and launched as a result of high frequency alternating currents flowing in the conductive elements of a transmitting antenna.

Electromagnetic waves launched into space from the transmitting antenna travel at the speed of light and generally spread in a circular fashion from the transmitting site. As the waves travel and spread, the level of available energy at locations progressively distant from the transmitter site becomes less and less. The ability to intercept a particular free space electromagnetic wave and efficiently convert its energy into current and voltage levels required by processing electronics is a direct function of the receiving antenna.

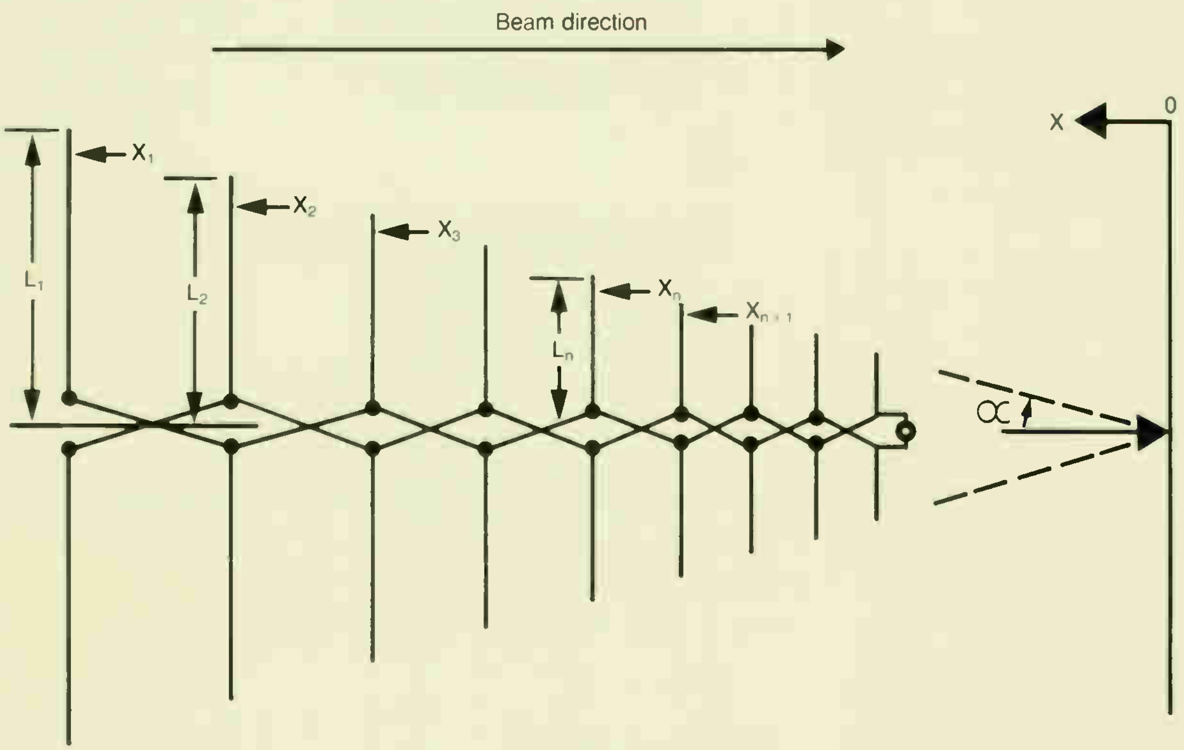
Tower mounted off-air antenna.

'The ability to intercept a particular free space electromagnetic wave. . .is a direct function of the receiving antenna'

Generally, it can be said that the quality of received signals will never be any better than that existing at the output terminals of the receiving antenna. Moreover, from an overall system efficiency standpoint, selection of the receiving antenna is probably the most important engineering task of designing a CATV/SMATV system.

There are several reasons why this is true. First, the antenna is a passive (does not re-

Figure 1: Schematic diagram of a log-periodic array



$$\tau = \frac{L_n + 1}{L_n} = \frac{X_n + 1}{X_n}$$

$$\alpha = \mathrm{Tan}^{-1} \frac{L_n}{X_n}$$

quire electrical power) mechanical device, which, if constructed and installed properly, should give many years of trouble-free, cost-free operation. Secondly, the performance of the antenna determines the required level of performance and sophistication, and consequently cost and reliability of required active devices in the system. Thirdly, since the receiving antenna is solely responsible for capturing and converting the electromagnetic energy of the radiated television signal for input to processing electronics, it becomes the first element of the system that directly affects overall system performance.

Antenna configurations

Off-air (as opposed to satellite) receiving antennas commonly used in the CATV/SMATV industry are either log-periodic or Yagi-type antennas (see Figures 1 and 2). Construction of both typically consists of a main boom with frequency selective elements spaced along the length of the boom. Boom construction and length, plus element spacing, length and number determine the type of antenna and performance. The log-periodic antenna is inherently broadband, easily having multi-channel receive capability. The Yagi antenna is inherently narrow band but has slightly greater gain than the log-periodic for an equivalent boom length. Each has its own particular performance characteristics, therefore, which type to use is dependent on a particular application.

Selection criteria

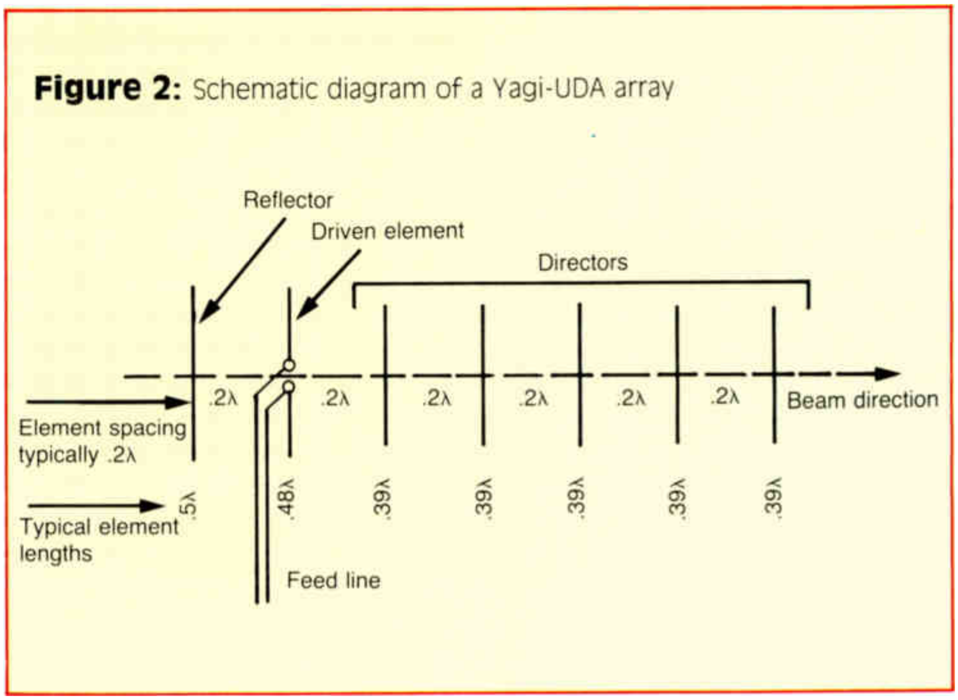
In selecting an off-air antenna, there are both mechanical and electrical performance specifications that should be considered.

- Important electrical specifications include:
  1. Gain vs. frequency
  2. Channel bandwidth
  3. Horizontal and vertical beamwidth
  4. Impedance
  5. Front-to-back ratio
  6. Pattern plots with antenna mounted per manufacturer's recommendation.
- Important mechanical specifications include:
  1. Weight
  2. Ice/wind loading
  3. Dimension
  4. Mounting

To ensure selection of the proper off-air antenna, not only should the above antenna information be available but also detailed information about the particular television signals to be received at a particular site. Site analysis begins with a computer generated survey that lists all television channels within a certain radius of the site. The computer survey will typically list:

1. Station call letters
2. Compass bearing to transmit stations
3. Radiated power (EIRP)
4. Theoretically calculated receive signal level
5. Possible co-channel signals and compass bearing

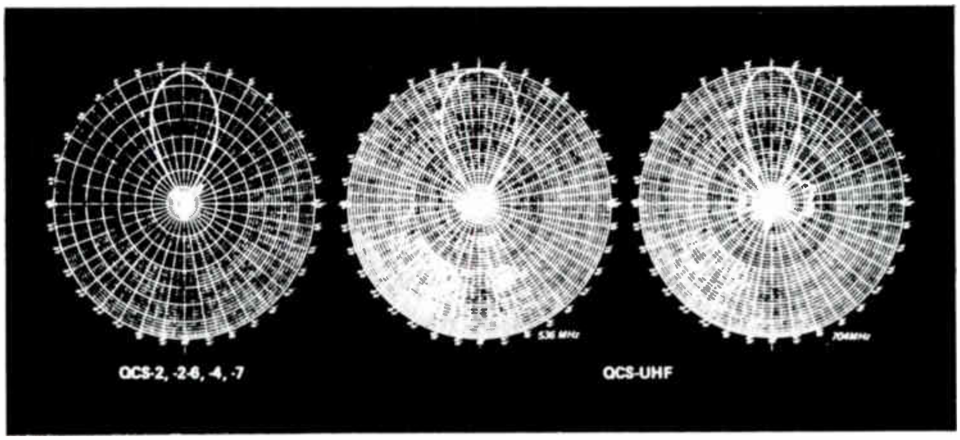
Figure 2: Schematic diagram of a Yagi-UDA array



Armed with the above computer generated information, an on-site 24-hour signal survey should be conducted. The on-site survey should be performed using a reference antenna with specified electrical performance specifications. Detailed notes on each station should be logged on an hourly basis listing received signal level, quality of signal, presence of noise and co-channel plus any other factors that would aid in the final selection of an off-air receiving antenna. Having completed the on-site survey, the computer and on-site survey information can be analyzed and the antenna type and configuration can be specified for each television channel to be received at that site.

As a final note, it should be pointed out that antenna tower mounting is a critical factor in achieving expected antenna performance. Quality antennas specify how the antenna should be mounted and lists performance specifications with the antenna mounted in the specified manner. Moreover, just as with satellite receiving antennas, the mounting structure is an integral part of the antenna design, and hardware to ensure proper mounting should be included with the antenna.

John R. (Bob) Mauney began his communications career in 1967 while in the U.S. Navy as a radio/navigation communications technician. In 1968 he joined Lanier Electronics as a service representative. Later that same year he started with Scientific-Atlanta as an electronics technician and has held numerous technical positions since then. Today, he is manager of video products technical services for S-A. Mauney received his BEET degree in 1977 from Southern Technical Institute.



Polar plot antenna patterns.

A mathematical analysis of distortion as it occurs in CATV amplifiers

This is Chapter V of the "Technical Handbook for CATV Systems." Each month another installment of this excellent technical tool will be presented.

By Ken Simons
Consultant to Wavetek CATV Division.

List of symbols (in the order of their use)

A, B, C	Amplitudes of each of three sinusoidal input voltages.
f_a, f_b, f_c	Corresponding frequencies.
a, b, c	$a = 2\pi f_a t$, $b = 2\pi f_b t$, $c = 2\pi f_c t$.
k_1, k_2, k_3	Constants characterizing the first, second and third order distortion of the amplifier.
e_{in}, e_{out}	The total instantaneous input and output voltages.
L_a, L_b, L_c	First order output levels, in dBmV.
K_2	A decibel constant characterizing second order distortion defined by: $K_2 = 20 \log_{10} \dfrac{\frac{k_2}{\sqrt{2}}}{\left(\frac{k_1}{\sqrt{2}}\right)^2}$ Expressed in dBmV. K_2 is always a negative number since $k_2 \ll k_1^2$.
L_{ab}, L_{bc}, L_{ac}	Sum or difference beat level, in dBmV.
L_{2a}, L_{2b}, L_{2c}	Second harmonic levels, in dBmV.
K_3	A decibel constant characterizing third order distortion, defined by: $K_3 = 20 \log_{10} \dfrac{3}{2} \dfrac{\frac{k_3}{\sqrt{2}}}{\left(\frac{k_1}{\sqrt{2}}\right)^3}$ Expressed in dBmV. K_3 is always a negative number since $k_3 \ll k_1^3$.
L_{abc}	Triple beat levels, in dBmV.
L_{2ab}, L_{2ac}, etc.	Intermodulation component levels, in dBmV.
L_{3a}, L_{3b}, L_{3c}	Third harmonic levels, in dBmV.
$R_{ab/a}$, etc.	The relative level of the sum or difference beat between signals at a and b referred to the level of a, in dB. Similar symbols are used for other pairs of signals and other reference signals.
$R_{2a/a}$, $R_{2b/b}$, $R_{2c/c}$	Relative level of second harmonic, referred in each case to the output level at the fundamental frequency, in dB.
$R_{abc/a}$, $R_{abc/b}$, $R_{abc/c}$	Relative level of the triple beat, referred to each of the three output signals, in dB.
$R_{2ab/a}$, etc.	Relative level of each of the intermodulation components referred to the indicated output. In this example the relative level of the component at $2f_a \pm f_b$ with reference to the level at f_a, in dB.
$R_{3a/a}$, $R_{3b/b}$, $R_{3c/c}$	Relative level of each third harmonic component, referred to the output level at the fundamental frequency, in dB.
XM, xm	XM is the NCTA standard cross-modulation ratio expressed in decibel form, xm is the same ratio in voltage form. $XM = 20 \log_{10} xm$.
M, m	m is the conventional modulation factor: $m = \dfrac{e_{max} - e_{min}}{e_{max} + e_{min}}$ (100 m = percent modulation). M is the modulation factor in decibel form: $M = 20 \log_{10} m$.

n — n is the total number of input signals applied to an amplifier, including the test signal.

$e_{a(D)}$ — This is the amplitude of the output voltage at f_a including the effects of third order distortion. (As contrasted with the undistorted output $= k_1A$.)

r_{abc} — The voltage ratio of the triple beat output component amplitude to the first order output at f_a.

When $A = B = C$, $r_{abc} = 3/2 \frac{k_3}{k_1} A^2$.

$R_{abc\,a} = 20 \log_{10} r_{abc}$.

A summary of the decibel expressions

Output levels expressed in dBmV

First order output component levels

$$L_a = 20 \log_{10}\left(\frac{k_1 A}{\sqrt{2}}\right), \text{ at } f_c$$

$$L_b = 20 \log_{10}\left(\frac{k_1 B}{\sqrt{2}}\right), \text{ at } f_a$$

$$L_c = 20 \log_{10}\left(\frac{k_1 C}{\sqrt{2}}\right), \text{ at } f_b$$

Second order distortion component levels

Sum and difference beats

$$L_{ab} = K_2 + L_a + L_b \text{ (at } f_a \pm f_b\text{)}$$

$$L_{bc} = K_2 + L_b + L_c \text{ (at } f_b \pm f_c\text{)}$$

$$L_{ac} = K_2 + L_a + L_c \text{ (at } f_a \pm f_c\text{)}$$

Second harmonics

$$L_{2a} = K_2 + 2L_a - 6, \text{ at } 2f_a$$

$$L_{2b} = K_2 + 2L_b - 6, \text{ at } 2f_b$$

$$L_{2c} = K_2 + 2L_c - 6, \text{ at } 2f_c$$

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Third order distortion components

Triple beat component levels

$$L_{abc} = K_3 + L_a + L_b + L_c \text{ (at } f_a \pm f_b \pm f_c)$$

Intermodulation component levels

$$\begin{aligned}
L_{2ab} &= K_3 + 2L_a + L_b - 6\text{dB (at } 2f_a \pm f_b) \\
L_{2ac} &= K_3 + 2L_a + L_c - 6\text{dB (at } 2f_a \pm f_c) \\
L_{2ba} &= K_3 + 2L_b + L_a - 6\text{dB (at } 2f_b \pm f_a) \\
L_{2bc} &= K_3 + 2L_b + L_c - 6\text{dB (at } 2f_b \pm f_c) \\
L_{2ca} &= K_3 + 2L_c + L_a - 6\text{dB (at } 2f_c \pm f_a) \\
L_{2cb} &= K_3 + 2L_c + L_b - 6\text{dB (at } 2f_c \pm f_b)
\end{aligned}$$

Third harmonic component levels

$$\begin{aligned}
L_{3a} &= K_3 + 3L_a - 15.5 \text{ (at } 3f_a) \\
L_{3b} &= K_3 + 3L_b - 15.5 \text{ (at } 3f_b) \\
L_{3c} &= K_3 + 3L_c - 15.5 \text{ (at } 3f_c)
\end{aligned}$$

Relative distortion expressed in decibels

Relative second order distortion

Relative sum or difference beat

$$\begin{aligned}
R_{ab/a} &= K_2 + L_b \text{ (at } f_a \pm f_b) \\
R_{bc/b} &= K_2 + L_c \text{ (at } f_b \pm f_c) \\
R_{ac/a} &= K_2 + L_c \text{ (at } f_a \pm f_c) \\
R_{ab/b} &= K_2 + L_a \text{ (at } f_a \pm f_b) \\
R_{bc/c} &= K_2 + L_b \text{ (at } f_b \pm f_c) \\
R_{ac/c} &= K_2 + L_a \text{ (at } f_a \pm f_c)
\end{aligned}$$

Relative second harmonic

$$\begin{aligned}
R_{2a/a} &= K_2 + L_a - 6 \text{ (at } 2f_a) \\
R_{2b/b} &= K_2 + L_b - 6 \text{ (at } 2f_b) \\
R_{2c/c} &= K_2 + L_c - 6 \text{ (at } 2f_c)
\end{aligned}$$

Relative third order distortion

Relative triple beat

$$\begin{aligned}
R_{abc/a} &= K_3 + L_b + L_c \text{ (at } f_a \pm f_b \pm f_c) \\
R_{abc/b} &= K_3 + L_a + L_c \text{ (at } f_a \pm f_b \pm f_c) \\
R_{abc/c} &= K_3 + L_a + L_b \text{ (at } f_a \pm f_b \pm f_c)
\end{aligned}$$

Relative intermodulation

$$\begin{aligned}
R_{2ab/a} &= K_3 + L_a + L_b - 6\text{dB (at } 2f_a \pm f_b) \\
R_{2ab/b} &= K_3 + 2L_a - 6\text{dB} \quad \text{(at } 2f_a \pm f_b) \\
R_{2ac/a} &= K_3 + L_a + L_c - 6\text{dB (at } 2f_a \pm f_c) \\
R_{2ac/c} &= K_3 + 2L_a - 6\text{dB} \quad \text{(at } 2f_a \pm f_c) \\
R_{2bc/b} &= K_3 + L_b + L_c - 6\text{dB (at } 2f_b \pm f_c) \\
R_{2bc/c} &= K_3 + 2L_b - 6\text{dB} \quad \text{(at } 2f_b \pm f_c) \\
R_{2ba/a} &= K_3 + 2L_b - 6\text{dB} \quad \text{(at } 2f_b \pm f_a) \\
R_{2ba/b} &= K_3 + L_a + L_b - 6\text{dB (at } 2f_b \pm f_a) \\
R_{2ca/a} &= K_3 + 2L_c - 6\text{dB} \quad \text{(at } 2f_c \pm f_a) \\
R_{2ca/c} &= K_3 + L_c + L_a - 6\text{dB (at } 2f_c \pm f_a) \\
R_{2cb/b} &= K_3 + 2L_c - 6\text{dB} \quad \text{(at } 2f_c \pm f_b) \\
R_{2cb/c} &= K_3 + L_c + L_b - 6\text{dB (at } 2f_c \pm f_b)
\end{aligned}$$

Relative third harmonic

$$\begin{aligned}
R_{3a/a} &= K_3 + 2L_a - 15.5\text{dB (at } 3f_a) \\
R_{3b/b} &= K_3 + 2L_b - 15.5\text{dB (at } 3f_b) \\
R_{3c/c} &= K_3 + 2L_c - 15.5\text{dB (at } 3f_c)
\end{aligned}$$

NCTA cross-modulation

$$XM = K_3 + 2L + 20 \log_{10} (n - 1)$$

Cross-modulation in terms of 'M'

$$M = K_3 + 2L + 20 \log_{10} (n - 1) - 6\text{dB}$$

Introduction

The preceding chapter "The Fundamentals of Distortion in CATV Amplifiers" develops, chiefly from a graphical standpoint, the general nature of distortion as it occurs in CATV amplifiers. It illustrates the spectra of spurious signals generated by second and third order curvature in the transfer characteristic, and describes the compression and cross-modulation effects resulting from third order curvature. In this chapter the quantitive relationships between the various distortion products will be developed mathematically, and a consistent way of expressing them in the convenient decibel "language" of CATV will be shown.

It must be borne in mind in considering what follows that some of the basic assumptions necessary to permit easy mathematical development are not completely justified in reality. For example, the assumption that the gain and distortion coefficients (k_1, k_2 and k_3) are constant for all input signal frequencies is distinctly at variance with the measured performance of practical amplifiers. These discrepancies, while very significant, do not nullify the usefulness of the relationships developed. However, extreme care must be exercised when drawing conclusions concerning real amplifiers from the mathematical considerations.

Results of the basic mathematical development

Assume an amplifier with 75-ohm input and output impedances and with sinusoidal input voltages at each of three frequencies:

$$e_{in} = A \cos a + B \cos b = C \cos c$$

(Note that A cos a and A sin a are both *sinusoidal* voltages. Their waveforms are identical except for a 90° phase difference. The cosine form is used throughout this analysis because it results in simpler expressions.)

A, B and C are the amplitudes of each voltage respectively, measured in millivolts.

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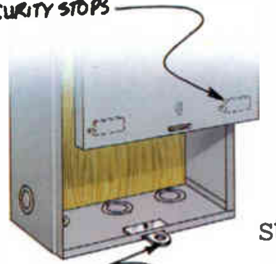

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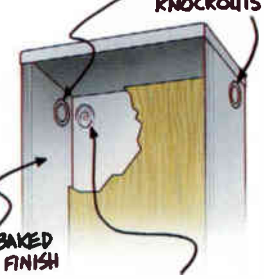

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Also: $a = 2\pi f_a t$, $b = 2\pi f_b t$ and $c = 2\pi f_c t$; $a > b > c$

Assume further that the transfer characteristic of the amplifier can be accurately represented at all frequencies by a power series containing three terms:

$$e_{out} = k_1 e_{in} + k_2 e_{in}^2 + k_3 e_{in}^3$$

e_{in} is the instantaneous input voltage as described above, k k_2 and k_3 are complex numbers describing the gain, phase shift and distortion properties of the amplifier. Although, in a real amplifier, *any* phase angle may be associated with each of these constants, in this example the phase angle for k_1 and k_2 will be assumed to be 0°, and that for k_3 either 0° (indicated by a + sign) or 180° (indicated by a − sign).

With these conditions the output will contain the following sinusoidal components (see Appendix I for derivation):

First order components:

Components identical with the input signals except with increased amplitude.

$$k_1 e_{in} = + k_1 A \cos a + k_1 B \cos b + k_1 C \cos c$$

Three first order output components. *These represent the result of linear amplification. k_1 is the small-signal voltage gain of the amplifier.*

Second order distortion components:

$$k_2 e_{in}^2 =$$

These represent a shift in average level.

$$+\frac{k_2A^2}{2} + \frac{k_2B^2}{2} + \frac{k_2C^2}{2}$$

Three DC components *due to second order distortion.*

Components at frequencies which are combinations of input signal frequencies.

$$+ k_2AB \cos (a \pm b) + k_2AC \cos (a \pm c) + k_2BC \cos (b \pm c)$$

Six sum and difference beat components.

Components at twice the input signal frequencies.

$$+\frac{k_2A^2}{2} \cos 2a + \frac{k_2B^2}{2} \cos 2b + \frac{k_2C^2}{2} \cos 2c$$

Three second harmonic components.

Third order distortion components:

The first three groups of third order components contain components at frequencies differing from the frequencies of the input signals.

$$k_3 e_{in}^3 =$$

Components at three times each input frequency.

$$+ 1/4k_3A^3 \cos 3a + 1/4k_3B^3 \cos 3b + 1/4k_3C^3 \cos 3c$$

Three third harmonic components.

Components at frequencies which are combinations of input signal frequencies.

$$+ 3/4k_3A^2B \cos (2a \pm b) + 3/4k_3A^2C \cos (2a \pm c) + 3/4k_3B^2A \cos (2b \pm a) + 3/4k_3B^2C \cos (2b \pm c) + 3/4k_3C^2A \cos (2c \pm a) + 3/4k_3C^2B \cos (2c \pm b)$$

Twelve intermodulation (2a ± b beat) components, and

$$+ 3/4k_3ABC \cos (a \pm b \pm c)$$

Four triple (abc) beat components.

The last two groups contain components at the frequencies of the input signals. When k_3 is positive, these components *add* to the first order output causing an increase in gain which is called *expansion*. When k_3 is negative, they *subtract* causing a decrease in gain which is called *compression*.

Components at the frequency of each input signal with amplitude determined by the input voltage of that signal cubed.

$$+ 3/4k_3A^3 \cos a + 3/4k_3B^3 \cos b + 3/4k_3C^3 \cos c$$

Three components causing self-compression *when k_3 is negative,* self-expansion *when k_3 is positive.*

(Continued on page 53.)

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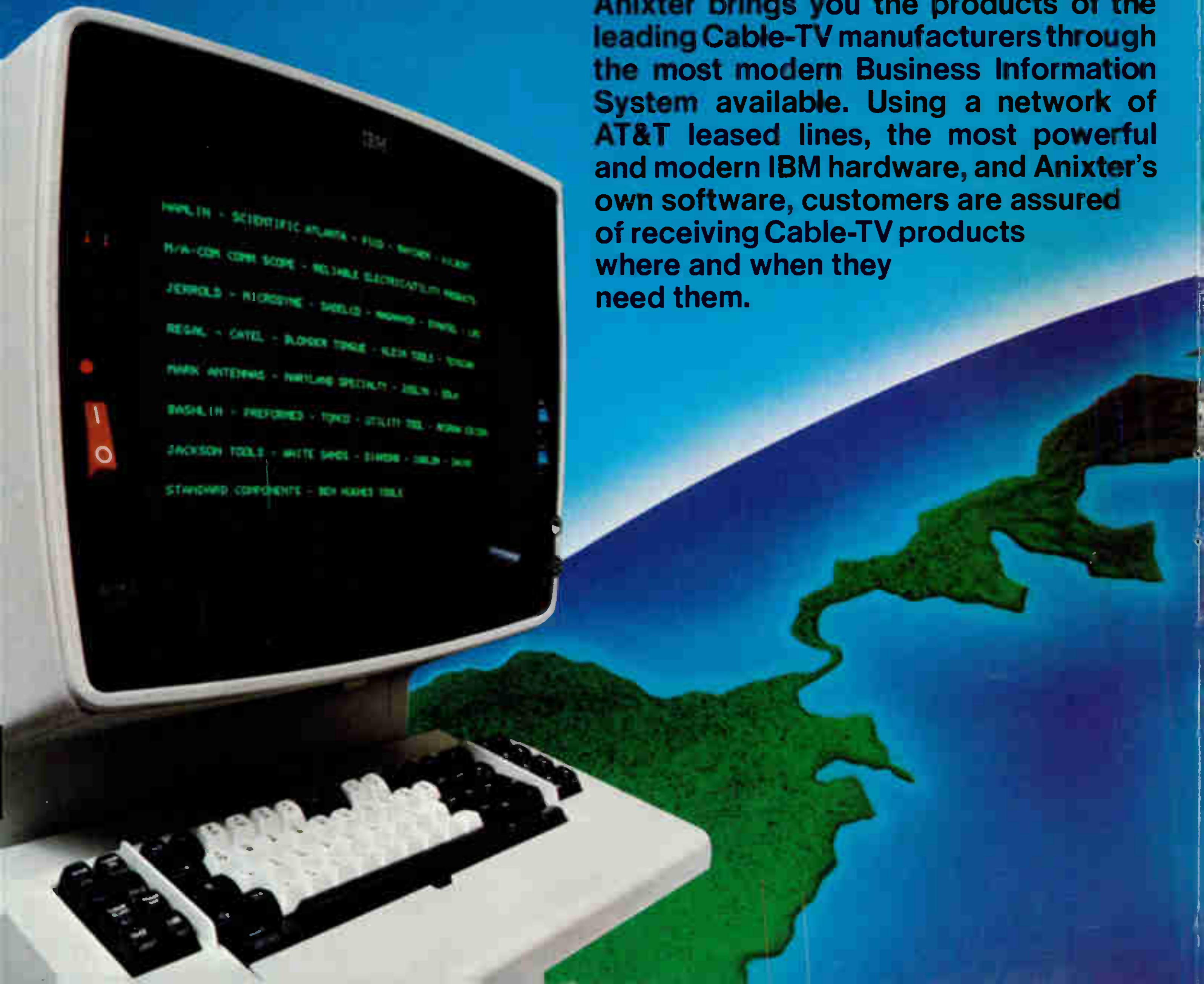

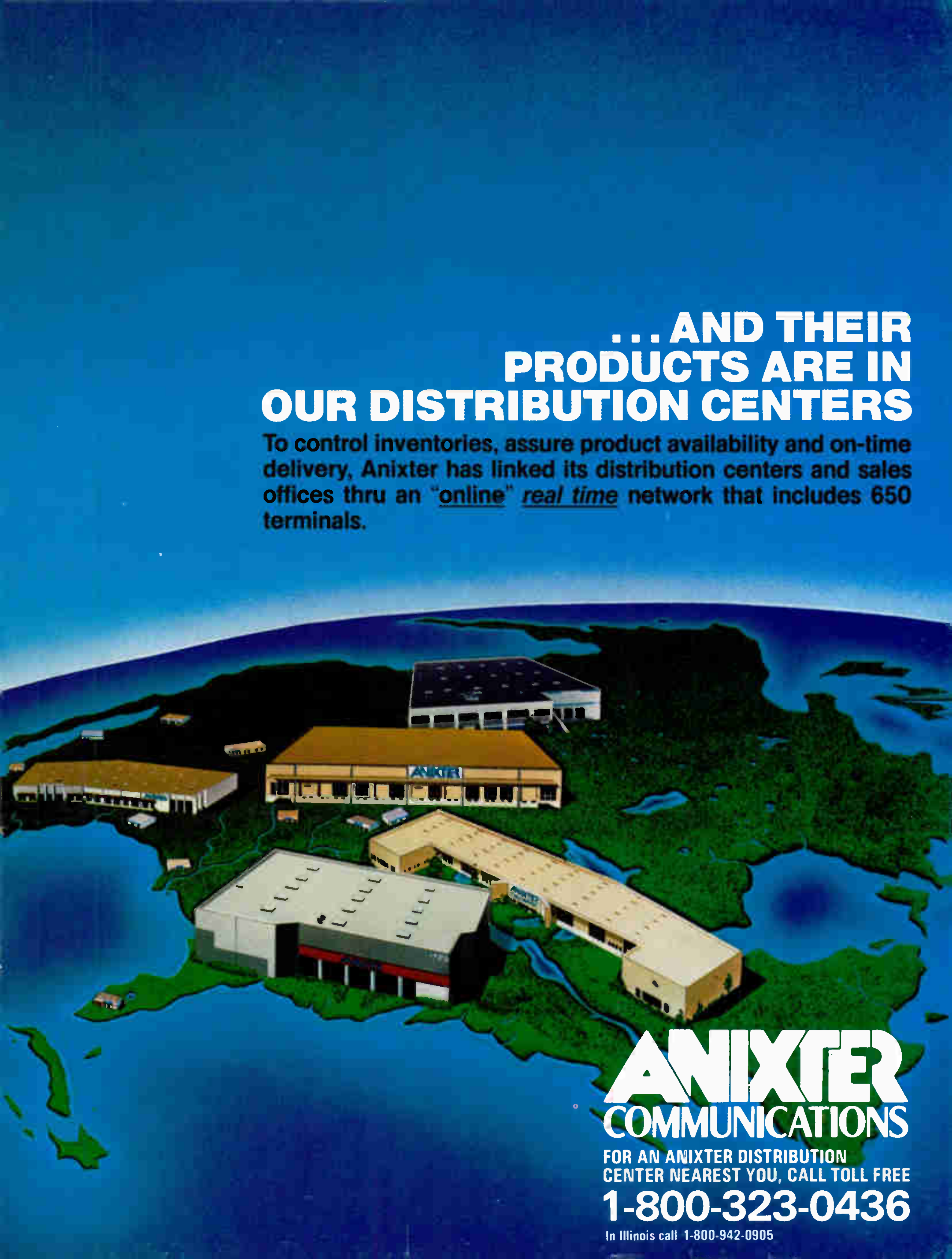
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(Continued from page 40.)

Components at the frequency of each input signal with amplitude determined by the input voltage at that frequency, and the square of the input voltage at one other frequency.

$+ 3/2k_3AB^2 \cos a$
$+ 3/2k_3AC^2 \cos a$
$+ 3/2k_3BA^2 \cos b$
$+ 3/2k_3BC^2 \cos b$
$+ 3/2k_3CA^2 \cos c$
$+ 3/2k_3CB^2 \cos c$

Six components causing cross-compression *when k_3 is negative,* cross-expansion *when k_3 is positive.*

Self-compression and *self-expansion* describe a condition where the gain at the frequency of one of the input signals is decreased or increased as a result of increasing the input voltage of that signal.

Cross-compression and *cross-expansion* describe a condition where the gain at the frequency of one of the input signals is decreased or increased as a result of increasing the voltage of another input signal.

Decibel expressions for the levels of the output components

Decibel expressions for the output levels of each of the AC distortion components will now be formulated, and for CATV purposes they are most conveniently expressed in dBmV, the decibel ratio of the RMS voltage of the component to 1 millivolt RMS. The dBmV is an expression of power level, 0 dBmV = −48.75 dBm.

First order output component levels

Since the instantaneous input voltage at f_a is A cos a, where A is measured in millivolts across 75 ohms, the peak input voltage is A, and the RMS input voltage is $\frac{A}{\sqrt{2}}$, both in millivolts.

The corresponding first-order RMS output voltage is $\frac{k_1A}{\sqrt{2}}$, obtained by multiplying the input voltage by k_1, the small signal voltage gain. Since the level in dBmV is defined as $20 \log_{10}$ (RMS voltage in millivolts) the first order output levels, expressed in dBmV are:

$$L_a = 20 \log_{10}\left(\frac{k_1A}{\sqrt{2}}\right), \text{ at } f_a$$
$$L_b = 20 \log_{10}\left(\frac{k_1B}{\sqrt{2}}\right), \text{ at } f_b$$
$$L_c = 20 \log_{10}\left(\frac{k_1C}{\sqrt{2}}\right), \text{ at } f_c$$

Second order distortion component levels

Sum and difference beats: Expressions for second order distortion levels can be obtained in the simplest form by carefully defining the constant "K_2" in the decibel equation. Its definition is accomplished in the following manner: The voltage expression for the amplitude of a sum beat is "k_2AB", so "$K_2 + L_a + L_b$" is chosen as a convenient decibel expression for its level. With this choice, since the level of a component is $20 \log_{10}$ of the RMS voltage of that component:

$$K_2 + L_a + L_b = 20 \log_{10}\left(\frac{k_2AB}{\sqrt{2}}\right)$$

Substituting previously defined quantities for L_a and L_b:

$$K_2 + 20 \log_{10}\left(\frac{k_1A}{\sqrt{2}}\right) + 20 \log_{10}\left(\frac{k_1B}{\sqrt{2}}\right) = 20 \log_{10}\left(\frac{k_2AB}{\sqrt{2}}\right)$$

$$\text{so } K_2 = 20 \log_{10}\left(\frac{k_2AB}{\sqrt{2}}\right) - 20 \log_{10}\left(\frac{k_1A}{\sqrt{2}}\right) - 20 \log_{10}\left(\frac{k_1B}{\sqrt{2}}\right)$$

$$= 20 \log_{10}\left[\frac{k_2AB}{\sqrt{2}} \cdot \frac{\sqrt{2}}{k_1A} \cdot \frac{\sqrt{2}}{k_1B}\right]$$

$$\text{or } K_2 = 20 \log_{10} \frac{\frac{k_2}{\sqrt{2}}}{\left(\frac{k_1}{\sqrt{2}}\right)^2}$$

With this definition of K_2 sum and difference beat levels in dBmV are expressed as follows:

$$L_{ab} = K_2 + L_a + L_b \text{ (at } f_a \pm f_b)$$
$$L_{bc} = K_2 + L_b + L_c \text{ (at } f_b \pm f_c)$$
$$L_{ac} = K_2 + L_a + L_c \text{ (at } f_a \pm f_c)$$

Second harmonics: The amplitude of the second harmonic output at $2f_a$ is $\frac{k_2A^2}{2}$

The corresponding RMS voltage is $\frac{k_2}{\sqrt{2}} \cdot \frac{A^2}{2}$

so the level is: $L_{2a} = 20 \log_{10}\left(\frac{k_2}{\sqrt{2}} \cdot \frac{A^2}{2}\right)$

Dividing the quantity in parentheses into convenient factors:

$$L_{2a} = 20 \log_{10}\left[\frac{\frac{k_2}{\sqrt{2}}}{\left(\frac{k_1}{\sqrt{2}}\right)^2}\right]\left(\frac{k_1}{\sqrt{2}}A\right)^2\left(\frac{1}{2}\right)$$

$$20 \log_{10}\left[\frac{\frac{k}{\sqrt{2}}}{\frac{k_1^2}{\sqrt{2}}}\right] = K_2,\ 20 \log_{10}\left(\frac{k_1}{\sqrt{2}} \cdot A\right)^2$$

$$= 2L_a, \text{ and } 20 \log_{10}\frac{1}{2} = -6\text{dB}$$

So the second harmonic output levels expressed in dBmV are:

$$L_{2a} = K_2 + 2L_a - 6, \text{ at } 2f_a$$
$$L_{2b} = K_2 + 2L_b - 6, \text{ at } 2f_b$$
$$L_{2c} = K_2 + 2L_c - 6, \text{ at } 2f_c$$

Third order distortion components

First, a quantity "K_3" is defined to provide a simple expression for each triple beat component.

$$\text{Assume: } K_3 + L_a + L_b + L_c = 20 \log_{10}\left(\frac{3/2\ k_3ABC}{\sqrt{2}}\right)$$

$$K_3 = 20 \log_{10}\left(\frac{3}{2} \cdot \frac{k_3}{\sqrt{2}} \cdot ABC\right) - 20 \log_{10}\frac{k_1}{\sqrt{2}}A$$
$$-20 \log_{10}\frac{k_1}{\sqrt{2}}B - 20 \log_{10}\frac{k_1}{\sqrt{2}}C$$

$$= 20 \log_{10}\left[\left(\frac{3}{2}\frac{k_3}{\sqrt{2}}ABC\right)\left(\frac{1}{\frac{k_1}{\sqrt{2}}A}\right)\left(\frac{1}{\frac{k_1}{\sqrt{2}}B}\right)\left(\frac{1}{\frac{k_1}{\sqrt{2}}C}\right)\right]$$

$$\text{or } K_3 = 20 \log_{10} 3/2 \frac{\frac{k_3}{\sqrt{2}}}{\left(\frac{k_1}{\sqrt{2}}\right)^3}$$

With this definition of K_3, the triple beat levels are given by:

Triple beat component levels:

$$L_{abc} = K_3 + L_a + L_b + L_c \text{ (at } f_a \pm f_b \pm f_c)$$

Intermodulation component levels: Since the coefficient of each of the intermodulation components is ¾, which is ½ of the coefficient of the triple beat components, $20 \log_{10} ½ = -6$ dB is added to obtain the decibel expressions for the intermodulation components:

$$\begin{aligned}
L_{2ab} &= K_3 + 2L_a + L_b - 6\text{dB (at } 2f_a \pm f_b) \\
L_{2ac} &= K_3 + 2L_a + L_c - 6\text{dB (at } 2f_a \pm f_c) \\
L_{2ba} &= K_3 + 2L_b + L_a - 6\text{dB (at } 2f_b \pm f_a) \\
L_{2bc} &= K_3 + 2L_b + L_c - 6\text{dB (at } 2f_b \pm f_c) \\
L_{2ca} &= K_3 + 2L_c + L_a - 6\text{dB (at } 2f_c \pm f_a) \\
L_{2cb} &= K_3 + 2L_c + L_b - 6\text{dB (at } 2f_c \pm f_b)
\end{aligned}$$

Third harmonic components levels: The coefficient of each third harmonic component is ¼, which is $\frac{1}{6}$ the coefficient of each triple beat component.

To express this in dB, $20 \log_{10} \frac{1}{6} = -15.5$dB is added to each third harmonic component level:

$$\begin{aligned}
L_{3a} &= K_3 + 3L_a - 15.5 \text{ (at } 3f_a) \\
L_{3b} &= K_3 + 3L_b - 15.5 \text{ (at } 3f_b) \\
L_{3c} &= K_3 + 3L_c - 15.5 \text{ (at } 3f_c)
\end{aligned}$$

Expansion/compression: It is pointless to express the levels of the expansion/compression terms in dBmV. They are considered later in this chapter.

Relative distortion expressed in decibels

In the measurement and specification of distortion, it is common practice to deal with *relative* distortion, i.e., to relate the amplitude of the distortion component to the amplitude of the undistorted output component. Harmonic distortion, for example, is commonly described in terms of "percent harmonic" which is 100 times the ratio of the harmonic component amplitude to the fundamental component amplitude.

When the levels of the undistorted (first order) components and of the various distortion components are expressed in decibel terms it is easy to arrive at a statement of relative distortion. The relation, in decibels, between any given distortion component, expressed in dBmV, and a given first order output, also in dBmV, is simply the difference (in dB) between the two levels.

Relative second order distortion

Relative sum or difference beat: The level of a particular sum beat component is, for example:

$$L_{ab} = K_2 + L_a + L_b \text{ (at } f_a + f_b)$$

and the level of the first order output at f_a is L_a, so the *relative* sum beat is the difference of the two levels:

$$\begin{aligned}
R_{ab\,a} &= L_{ab} - L_a = K_2 + L_a + L_b - L_a \\
&= K_2 + L_b
\end{aligned}$$

Where "$R_{ab\,a}$" is read "the sum beat (at $f_a + f_b$) in dB relative to the output level at f_a." L_a, L_b and K_2 are expressed in dBmV. $R_{ab/a}$ is expressed in dB. So for the 12 possible combinations of sum and difference beat components related to the three first order output levels:

$$\begin{aligned}
R_{ab/a} &= K_2 + L_b \text{ (at } f_a \pm f_c) \\
R_{bc/b} &= K_2 + L_c \text{ (at } f_b \pm f_c) \\
R_{ac/a} &= K_2 + L_c \text{ (at } f_a \pm f_c) \\
R_{ab/b} &= K_2 + L_a \text{ (at } f_a \pm f_b) \\
R_{bc/c} &= K_2 + L_b \text{ (at } f_b \pm f_c) \\
R_{ac/c} &= K_2 + L_a \text{ (at } f_a \pm f_c)
\end{aligned}$$

Relative second harmonic: Similarly the second harmonic of the output at f_a relative to the fundamental is given by:

$$\begin{aligned}
R_{2a/a} &= L_{2a} - L_a = K_2 + 2L_a - 6 - L_a \\
&= K_2 + L_a - 6
\end{aligned}$$

so

$$\begin{aligned}
R_{2a/a} &= K_2 + L_a - 6 \text{ (at } 2f_a) \\
R_{2b/b} &= K_2 + L_b - 6 \text{ (at } 2f_b) \\
R_{2c/c} &= K_2 + L_c - 6 \text{ (at } 2f_c)
\end{aligned}$$

Relative third order distortion

Relative triple beat:

$$R_{abc/a} = K_3 + L_a + L_b + L_c - L_a$$

and similarly for other terms, so:

$$\begin{aligned}
R_{abc/a} &= K_3 + L_b + L_c \text{ (at } f_a \pm f_b \pm f_c) \\
R_{abc/b} &= K_3 + L_a + L_c \text{ (at } f_a \pm f_b \pm f_c) \\
R_{abc/c} &= K_3 + L_a + L_b \text{ (at } f_a \pm f_b \pm f_c)
\end{aligned}$$

Relative intermodulation:

$$\begin{aligned}
R_{2ab/a} &= K_3 + L_a + L_b - 6\text{dB (at } 2f_a \pm f_b) \\
R_{2ab/b} &= K_3 + 2L_a - 6\text{dB (at } 2f_a \pm f_b) \\
R_{2ac/a} &= K_3 + L_a + L_c - 6\text{dB (at } 2f_a \pm f_c) \\
R_{2ac/c} &= K_3 + 2L_a - 6\text{dB (at } 2f_a \pm f_c) \\
R_{2bc/b} &= K_3 + L_b + L_c - 6\text{dB (at } 2f_b \pm f_c) \\
R_{2bc/c} &= K_3 + 2L_b - 6\text{dB (at } 2f_b \pm f_c) \\
R_{2ba/a} &= K_3 + 2L_b - 6\text{dB (at } 2f_b \pm f_a) \\
R_{2ba/b} &= K_3 + L_a + L_b - 6\text{dB (at } 2f_b \pm f_a) \\
R_{2ca/a} &= K_3 + 2L_c - 6\text{dB (at } 2f_c \pm f_a) \\
R_{2ca/c} &= K_3 + L_c + L_a - 6\text{dB (at } 2f_c \pm f_a) \\
R_{2cb/b} &= K_3 + 2L_c - 6\text{dB (at } 2f_c \pm f_b) \\
R_{2cb/c} &= K_3 + L_c + L_b - 6\text{dB (at } 2f_c \pm f_b)
\end{aligned}$$

Relative third harmonic:

$$\begin{aligned}
R_{3a/a} &= K_3 + 2L_a - 15.5\text{dB (at } 3f_a) \\
R_{3b/b} &= K_3 + 2L_b - 15.5\text{dB (at } 3f_b) \\
R_{3c/c} &= K_3 + 2L_c - 15.5\text{dB (at } 3f_c)
\end{aligned}$$

Compression and expansion

In the foregoing the first order output levels (L_a, L_b and L_c) have been used as reference levels in expressing relative distortion. It should be carefully noted that these are not the levels that would be meausred at f_a, f_b and f_c when third order distortion is present. The effect of the self- and cross-compression (or expansion) components is to reduce (or increase) the actual output at these frequencies as compared with the first order levels, and thus introduce errors in measurements of relative distortion.

In practical measurements, errors due to this effect can be avoided by temporarily removing all input signals except the one at the frequency of measurement (to eliminate cross-compression/expansion effects) or by measuring output levels with a known reduction in input levels (which reduces all distortion). The degree of error to be expected is a function of output level, and is related to other effects of third order distortion as shown in the accompanying compression and expansion tables.

Compression: The degree of compression (assuming k_3 is negative) can be expressed as the dB ratio of the actual output at f_a to the first order output. This ratio is determined by the number of input signals, and by the relative third order distortion expressed by $R_{abc/a}$ (chosen as a convenient measure of third order distortion) as shown in the accompanying table. (See Appendix II for derivation.)

Expansion: The degree of expansion (assuming k_3 is positive) can be similarly expressed, and the results are shown in the accompanying table. (Also see Appendix II for derivation.)

Cross-modulation

All the preceding developments have assumed unmodulated input signals. The signals introduced into operating CATV amplifiers are, of course, modulated TV picture and sound signals. The distortion components that occur in this situation are very much affected by modulation. The triple beat between three modulated signals, for example, carries all three sets of modulation components.

Degree of compression

$R_{abc/a}$	Total compression in dB with the number of equal voltage input signals indicated				
(= $L_{abc} - L_a$)	1	2	3	12	20
–20dB	–0.45dB	–1.41dB	–2.50dB	–	–
–25	–0.25	–0.76	–1.32	–9.03dB	–
–30	–0.14	–0.42	–0.71	–3.92	–8.32dB
–35	–0.08	–0.24	–0.40	–1.99	–3.70
–40	–0.04	–0.13	–0.22	–1.06	–1.88
–45	–0.02	–0.07	–0.12	–0.58	–1.01
–50	–0.01	–0.04	–0.07	–0.32	–0.55
–55	⟨–0.01	–0.02	–0.04	–0.18	–0.31
–60	"	–0.01	–0.02	–0.10	–0.17
–65	"	⟨–0.01	–0.01	–0.06	–0.10
–70	"	"	–0.01	–0.03	–0.05

Degree of expansion

$R_{abc/a}$	Total expansion in dB with the number of equal voltage input signals indicated				
(= $L_{abc} - L_a$)	1	2	3	12	20
–20dB	0.42dB	0.83dB	1.93dB	6.64dB	9.40dB
–25	0.24	0.48	1.14	4.33	6.43
–30	0.14	0.27	0.66	2.69	4.17
–35	0.08	0.15	0.38	1.62	2.59
–40	0.04	0.09	0.21	0.95	1.55
–45	0.02	0.05	0.12	0.54	0.90
–50	0.01	0.03	0.07	0.31	0.52
–55	0.01	0.02	0.04	0.18	0.30
–60	⟨0.01	0.01	0.02	0.10	0.17
–65	"	⟨0.01	0.01	0.06	0.094
–70	"	"	0.01	0.03	0.054

One principle allows application of the simplified analysis to the situation where the signals are modulated. The output level of a picture-modulated signal, as normally expressed, describes its maximum excursion (at the tip of sync). Thus, the distortion component levels obtained by using the dBmV levels of the modulated signals in the distortion equations are those that would exist in the worst case, where all sync pulses on the interfering signals momentarily coincided in time.

One important form of distortion, cross-modulation, occurs only when the input signals are modulated. It is generated by the same effects that produce cross-compression (or expanson) when the inputs are unmodulated. The interfering test signals used to measure cross-modulation in the NCTA standard method are 100 percent square-wave modulated. In this case the degree of modulation on the desired test carrier (which is otherwise unmodulated) can be developed in a reasonably simple way from the CW distortion relationships. This is done in Appendix III.

It is shown in part 1 that, for equal signal output levels the NCTA standard cross-modulation, expressed in dB (symbol XM) is given approximately by this equation:

$$XM = K_3 + 2L + 20 \log_{10} (n - 1)$$

L is the output level of each signal (measured at the peak of modulation when the signal is modulated), n is the total number of input signals, including the unmodulated test signal. This relationship is accurate within ± 0.5dB when operating conditions are such that $R_{abc/a} \leq -20$dB, and when the amplifier meets all the conditions assumed in this analysis.

It is shown in part 2 that, for equal signal output levels the decibel modulation factor (symbol M) is given approximately by this equation:

$$M = K_3 + 2L + 20 \log_{10} (n - 1) - 6\text{dB}$$

i.e., M = XM – 6dB. This equation is accurate within ± 0.5dB, when $R_{abc\ a} \leq -20\text{dB} + 20 \log_{10} (n - 1)$, and the amplifier meets all conditions assumed in this analysis.

Conclusion

This chapter has presented a mathematical analysis of distortion, with particular reference to cable television amplifiers. Although the analysis is based on a simplified mathematical model, which differs from real amplifiers in several respects, the results of the analysis prove to be useful in understanding the behavior of real amplifiers.

The author wishes to express his thanks to Israel Polidi for much help in developing the analysis, and in minimizing errors in the final result.

Appendix I: The detailed mathematical development of the distortion components

Let $e_{in} = A \cos a + B \cos b + C \cos c$
where $a \rangle b \rangle c$
and $e_{out} = k_1 e_{in} + k_2 e_{in}^2 + k_3 e_{in}^3$

First order components

By direct multiplication:

$$k_1 e_{in} = k_1 A \cos a + k_1 B \cos b + k_1 C \cos c$$

Second order components

$$k_2 e_{in}^2 =$$
$$= k_2 (A \cos a + B \cos b + C \cos c)^2$$
$$= k_2 A^2 \cos^2 a + k_2 B^2 \cos^2 b + k_2 C^2 \cos^2 c$$
$$+ 2k_2 AB \cos a \cos b + 2k_2 AC \cos a \cos c + 2k_2 BC \cos b \cos c$$

To reduce these expressions to ones containing identifiable frequencies, expand each term in accordance with the applicable one of the following two relationships (Equation 1 or 2): (These can be found in any elementary trigonometry text, or on pages 1041-2 of the ITT "Reference Data for Radio Engineers" Fourth Edition.)

Equation 1: $$\boxed{\cos x \ \cos y = \frac{1}{2}\cos(x+y) + \frac{1}{2}\cos(x-y)}$$

Equation 2: $$\boxed{\cos^2 x = \frac{1}{2} + \frac{1}{2}\cos 2x}$$

Substituting the appropriate expressions from above into Equation 2 gives the DC and second harmonic components:

$$k_2A^2\cos^2 a = \frac{k_2A^2}{2} + \frac{k_2A^2}{2}\cos 2a$$

$$k_2B^2\cos^2 b = \frac{k_2B^2}{2} + \frac{k_2B^2}{2}\cos 2b$$

$$k_2C^2\cos^2 c = \frac{k_2C^2}{2} + \frac{k_2C^2}{2}\cos 2c$$

Substituting the other three expressions from above into Equation 1 gives the sum and difference beat components:

$$2k_2AB \cos a \cos b = k_2AB\cos(a+b) + k_2AB\cos(a-b)$$

$$2k_2AC \cos a \cos c = k_2AC\cos(a+c) + k_2AC\cos(a-c)$$

$$2k_2BC \cos b \cos c = k_2BC\cos(b+c) + k_2BC\cos(b-c)$$

Third order components

$$\begin{aligned} k_3e_{in}^3 &= k_3(A\cos a + B\cos b + C\cos c)^3 \\ &= k_3A^3\cos^3 a + k_3B^3\cos^3 b + k_3C^3\cos^3 c \\ &+ 3k_3A^2B\cos^2 a\cos b + 3k_3A^2C\cos^2 a\cos c \\ &+ 3k_3B^2C\cos^2 b\cos c + 3k_3B^2A\cos^2 b\cos a \\ &+ 3k_3C^2A\cos^2 c\cos a + 3k_3C^2B\cos^2 c\cos b \\ &+ 6k_3ABC\cos a\cos b\cos c \end{aligned}$$

Three trigonometric relationships are needed to allow expansion of the terms of the types "$\cos^3 x$", "$\cos^2 x \cos y$", and "$\cos x \cos y \cos z$."

From the ITT handbook (loc. cit.) p. 1041:

$$\cos 3x = -3\cos x + 4\cos^3 x$$

$$4\cos^3 x = 3\cos x + \cos 3x$$

giving Equation 3: $$\boxed{\cos^3 x = \frac{3}{4}\cos x + \frac{1}{4}\cos 3x}$$

$$\cos^2 x \cos y = \left(\frac{1}{2} + \frac{1}{2}\cos 2x\right)\cos y \text{ (substituting from Equation 2)}$$

$$= \frac{1}{2}\cos y + \frac{1}{2}\cos 2x \cos y$$

but: $$\cos 2x \cos y = \frac{1}{2}\cos(2x+y) + \frac{1}{2}\cos(2x-y)$$

giving Equation 4:

$$\boxed{\cos^2 x \cos y = \frac{1}{2}\cos y + \frac{1}{4}\cos(2x+y) + \frac{1}{4}\cos(2x-y)}$$

$$\begin{aligned} \cos x\cos y\cos z &= (\cos x\cos y)\cos z \\ &= \left[\frac{1}{2}\cos(x+y) + \frac{1}{2}\cos(x-y)\right]\cos z \\ &= \frac{1}{2}\cos(x+y)\cos z + \frac{1}{2}\cos(x-y)\cos z \\ &= \frac{1}{2}\left[\frac{1}{2}\cos(x+y+z) + \frac{1}{2}\cos(x+y-z)\right] \\ &+ \frac{1}{2}\left[\frac{1}{2}\cos(x-y+z) + \frac{1}{2}\cos(x-y-z)\right] \end{aligned}$$

giving Equation 5:

$$\boxed{\begin{aligned} \cos x\cos y\cos z = \frac{1}{4}\cos(x+y+z) + \frac{1}{4}\cos(x+y-z) \\ + \frac{1}{4}\cos(x-y+z) + \frac{1}{4}(x-y-z) \end{aligned}}$$

Applying Equation 3 to the appropriate terms gives the self-expansion/compression and third harmonic components:

$$k_3A^3\cos^3 a = \frac{3}{4}k_3A^3\cos a + \frac{1}{4}k_3A^3\cos 3a$$

$$k_3B^3\cos^3 b = \frac{3}{4}k_3B^3\cos b + \frac{1}{4}k_3B^3\cos 3b$$

$$k_3C^3\cos^3 c = \frac{3}{4}k_3C^3\cos c + \frac{1}{4}k_3C^3\cos 3c$$

Applying Equation 3 to the appropriate terms gives the cross-expansion/compression and intermodulation components:

$$3k_3A^2B\cos^2 a\cos b = \frac{3}{2}k_3A^2B\cos b + \frac{3}{4}k_3A^2B\cos(2a+b) + \frac{3}{4}k_3A^2B\cos(2a-b)$$

$$3k_3A^2C\cos^2 a\cos c = \frac{3}{2}k_3A^2C\cos c + \frac{3}{4}k_3A^2C\cos(2a+c) + \frac{3}{4}k_3A^2C\cos(2a-c)$$

$$3k_3B^2C\cos^2 b\cos c = \frac{3}{2}k_3B^2C\cos c + \frac{3}{4}k_3B^2C\cos(2b+c) + \frac{3}{4}k_3B^2C\cos(2b-c)$$

$$3k_3B^2A\cos^2 b\cos a = \frac{3}{2}k_3B^2A\cos a + \frac{3}{4}k_3B^2A\cos(2b+a) + \frac{3}{4}k_3B^2A\cos(2b-a)$$

$$3k_3C^2A\cos^2 c\cos a = \frac{3}{2}k_3C^2A\cos a + \frac{3}{4}k_3C^2A\cos(2c+a) + \frac{3}{4}k_3C^2A\cos(2c-a)$$

$$3k_3C^2B\cos^2 c\cos b = \frac{3}{2}k_3C^2B\cos b + \frac{3}{4}k_3C^2B\cos(2c+b) + \frac{3}{4}k_3C^2B\cos(2c-b)$$

Using Equation 5 gives the triple beat components:

$$\begin{aligned} 6k_3ABC\cos a\cos b\cos c &= \frac{3}{2}k_3ABC\cos(a+b+c) + \frac{3}{2}k_3ABC\cos(a+b-c) \\ &+ \frac{3}{2}k_3ABC\cos(a-b+c) + \frac{3}{2}k_3ABC\cos(a-b-c) \end{aligned}$$

Appendix II: The detailed mathematical development of self- and cross-compression (and expansion) with unmodulated input signals

The output voltage at f_a, for example, including the effects of distortion is:

$$e_{a(D)} = k_1A + 3/4\, k_3A^3 + 3/2\, k_3AB^2 + 3/2\, k_3AC^2$$

A measure of the degree of cross-compression (or -expansion) is found by dividing this output by that which would occur if there were no distortion:

$$\frac{e_{a(D)}}{k_1A} = \frac{k_1A + 3/4\ k_3A^3 + 3/2\ k_3AB^2 + 3/2\ k_3AC^2}{k_1A}$$

$$= 1 + 3/4\frac{k_3}{k_1}A^2 + 3/2\frac{k_3}{k_1}B^2 + 3/2\frac{k_3}{k_1}C^2$$

Although the foregoing has only been concerned with conditions involving *three* CW input signals, in this case it is instructive to discover the relationship with any number of input signals. Assume all input amplitudes = A. Then:

$$\frac{e_{a(D)}}{k_1A} = 1 + 3/4\frac{k_3}{k_1}A^2 + 3/2\frac{k_3}{k_1}A^2 + 3/2\frac{k_3}{k_1}A^2 + + \text{etc.}$$

$$= 1 + \frac{k_3}{k_1}A^2\ (3/4 + 3/2 + 3/2 + \ldots\text{etc.})$$

$$= 1 + 3/2\frac{k_3}{k_1}A^2\ (1/2 + 1 + 1 + \ldots\text{etc.})$$

When there is one input signal the quantity in parentheses = ½, with two it = 1½, with three it = 2½ and in general:

Equation A: $$\boxed{\frac{e_{a(D)}}{k_1A} = 1 + 3/2\frac{k_3}{k_1}A^2\left(n-\frac{1}{2}\right)}$$

where n is the total number of input signals.

To allow comparison between the various effects of third order distortion, a common measure of this distortion is needed. The triple beat component is chosen. Its amplitude is given by:

$$e_{abc} = 3/2\ k_3\ ABC;$$

where $A = B = C$, $e_{abc} = 3/2\ k_3A^3$

and the ratio of this component to the first order output is:

$$\frac{e_{abc}}{k_1A} = \frac{3/2\ k_3A^3}{k_1A} = 3/2\frac{k_3}{k_1}A^2$$

Because this expression is frequently used in what follows, it is abbreviated r_{abc} (the ratio of the triple beat output voltage to the first order output voltage).

$$r_{abc} = \frac{e_{abc}}{k_1A} = 3/2\frac{k_3}{k_1}A^2.$$

(Note that r_{abc} may be either positive or negative depending on the sign of k_3.)

This is identical with the term preceding the parentheses in Equation A. Substituting in that equation:

Equation B: $$\boxed{\frac{e_{a(D)}}{k_1A} = 1 + r_{abc}\left(n-\frac{1}{2}\right)}$$

Which shows the relationship between the degree of expansion (or compression) and the ratio of triple beat to first order output.

Compression or expansion, in dB is expressed

Equation C: $$\boxed{20\log_{10}\frac{e_{a(D)}}{k_1A} = 20\log_{10}\left[1 + r_{abc}\left(n-\frac{1}{2}\right)\right]}$$

The tables for compression and expansion were computed by selecting progressive values for $R_{abc\ a}$ ($= L_{abc} - L_a$) and calculating the corresponding value for r_{abc} from the relationship:

$$R_{abc\ a} = 20\log_{10} r_{abc}$$

The value for r_{abc} was then inserted in equation B, with a – sign for compression, or a + sign for expansion. With a chosen number of inputs (n) the ratio of $\frac{e_{a(D)}}{k_1A}$ was then calculated. Finally this ratio was expressed in decibel form by the use of Equation C.

Appendix III: The detailed mathematical development of the relationship between cross-modulation and the triple beat ratio

1. NCTA standard cross-modulation

The NCTA standard "amplifier distortion characteristics" requires that the interfering signals be modulated approximately 100 percent with a 15.75 KHz square-wave [Section IV (D)], and that modulation on the desired carrier shall be expressed in terms of the "cross-modulation ratio," the ratio of the peak-to-peak variation in the amplitude of the desired carrier with interfering signals applied, to its amplitude with no interfering signals [Section IV(E)].

For the purposes of this analysis the effect of 100 percent square-wave modulation is achieved by assuming that the amplitudes of the interfering signals vary periodically between two extreme conditions. During the "on" half of the modulation cycle the amplitudes of the interfering signals are given by: $B_{max} = B$, $C_{max} = C$, etc. During the "off" half of the modulation cycle, these amplitudes are given by: $B_{min} = O$, $c_{min} = 0$, etc.

When third-order distortion exists, the output voltage at f_a during the "on" half of the modulation cycle is found by summing all the components at that frequency including the first order output (k_1A), the self-compression/expansion component ($3/4\ k_3K^3$) and the cross-compression/expansion components ($3/2\ k_3AB^2$, $3/2\ k_3AC^2$, and so on for any number of inerfering signals). So:

$$e_{ON} = k_1A + 3/4\ k_3A^3 + 3/2\ k_3AB^2 + 3/2\ k_3AC^2 + \ + \text{etc.}$$

(including the effects of compression and cross-compression) and during the "off" half of the modulation cycle the amplitudes of the interfering signals are zero so the output at f_a is:

$$e_{OFF} = k_1A + 3/4\ k_3A^3$$

(including the effect of compression only).

The NCTA "cross-modulation ratio" (xm) is defined as the ratio of the variation on the output at f_a, to its amplitude with no other inputs:

$$xm = \frac{e_{ON} - e_{OFF}}{k_1A + 3/4\ k_3A^3}$$

$$= \frac{(k_1A + 3/4\ k_3A^3 + 3/2\ k_3AB^2 + 3/2\ k_3AC^2 + \ + \text{etc}) - (k_1A + 3/4\ k_3A^3)}{k_1A + 3/4\ k_3A^3}$$

$$= \frac{3/2\ k_3AB^2 + 3/2\ k_3AC^2 \ldots + \ldots\text{etc.}}{k_1A + 3/4\ k_3A^3}$$

This can be simplified by assuming equal input amplitudes at all frequencies: ($A = B = C = \text{etc.}$)

$$\text{then } xm = \frac{(n-1)\ 3/2\ k_3A^3}{k_1A + 3/4\ k_3A^3}$$

where n is the total number of input signals including the one at f_a.

To get this into a more convenient form, divide the numerator and the denominator by k_1A:

$$xm = \frac{(n-1)\ 3/2\frac{k_3}{k_1}A^2}{1 + \frac{1}{2}\left(3/2\frac{k_3}{k_1}A^2\right)}$$

In Appendix II the triple beat ratio was defined as a convenient measure of third-order distortion:

$$r_{abc} = 3/2\frac{k_3}{k_1}A^2$$

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Substituting this in the above equation:

$$XM = \frac{(n-1)\, r_{abc}}{1 + \frac{r_{abc}}{2}}$$

which expresses the NCTA cross-modulation ratio in terms of the triple beat ratio.

$\frac{r_{abc}}{2}$ is usually ⟨⟨ 1, so $1 + \frac{r_{abc}}{2} \approx 1$ and $\quad xm \approx (n-1)\, r_{abc}$

This is accurate within 5 percent when:

$1 + \leq 1.05$, or ≤ 0.05 when $r_{abc} \leq 0.1$

A decibel expression for this relationship can be obtained by defining the NCTA decibel ratio:

$$XM = 20 \log_{10} xm$$

and the relative triple beat (in dB):

$$R_{abc\,a} = 20 \log_{10} r_{abc}$$

then, for equal input levels ($L_a = L_b = L_c = L$):

$$XM = R_{abc\,a} + 20 \log_{10} (n-1)$$

Since $R_{abc\,a} = K_3 + 2L$,

$$XM = K_3 + 2L + 20 \log_{10} (n-1)$$

with an accuracy of ± 0.5dB (equivalent to ± 5 percent when $R_{abc\,a} \leq -20$ dB ($r_{abc} \leq 0.1$).

2. Cross-modulation measured in terms of "m," the conventional modulation factor

While cross-modulation measurements in terms of the NCTA "cross-modulation ratio" are commonly used in CATV, it may sometimes be convenient to express the modulation transferred to the desired carrier in terms of the "modulation factor" defined by:

$$m = \frac{e_{max} - e_{min}}{e_{max} + e_{min}} \text{(100 m = percent modulation)}$$

Assuming the same 100 percent square-wave modulation on the intefering signals as in section 1 of Appendix III, and assuming that k_3 is positive, the maximum amplitude of the output signal at f_a occurs during the "on" period in the modulation cycle:

$$e_{max} = k_1A + 3/4\, k_3A^3 + 3/2\, k_3AB^2 + 3/2\, k_2AC^2 + \ldots + \text{ etc}$$

And the minimum amplitude occurs during the "off" period

$$e_{min} = k_1A + 3/4\, k_3A^3$$

In this case "m" is given by:

$$m = \frac{e_{max} - e_{min}}{e_{max} + e_{min}}$$

$$= \frac{-k_1A - 3/4\, k_3A^3 + k_1A + 3/4\, k_3A^3 + 3/2\, k_3AB^2 + 3/2\, k_3AC^2 + \ldots \text{ etc}}{-k_1A + 3/4\, k_3A^3 + k_1A + 3/4\, k_3A^3 + 3/2\, k_3AB^2 + 3/2\, k_3AC^2 + \ldots \text{ etc}}$$

$$= \frac{3/2\, k_3AB^2 + 3/2\, kAC^2 + \ldots + \text{ etc.}}{2k_1A + 3/2\, k_3A^3 + 3/2\, k_3AB^2 + 3/2\, k_3AC^2 + \ldots + \text{ etc}}$$

If we had assumed initially that k_3 was negative e_{max} and that e_{min} would have been interchanged in the expressions above, we would have obtained the same final result, except preceded by a – sign, indicating negative cross-modulation.

The expression can be simplified by considering the special case where all input signals have the same amplitude (A = B = C = etc.). Then

$$m = \frac{(n-1)\, 3/2\, k_3A^3}{2k_1A + n(3/2\, k_3A^3)}$$

where n is the total number of input signals.

Dividing numerator and denominator by $k_1 A$:

$$\frac{(n-1)\left(3/2\,\frac{k_3}{k_1}A^2\right)}{2 + n\left(3/2\,\frac{k_3}{k_1}A^2\right)}$$

Since $3/2\,\frac{k_3}{k_1}A^2 = r_{abc}$ as previously defined:

$$m = \frac{(n-1)\,r_{abc}}{2 + n\,r_{abc}}$$

This relates the modulation factor to the triple-beat ratio for any number of input signals.

Since $n\,r_{abc}$ is very much smaller than 2 in most practical cases, it is convenient to consider the approximate relationship:

$$m_a \approx \frac{(n-1)\,r_{abc}}{2}$$

where m_a is the approximate modulation factor.

To determine the degree of error involved in this approximation under various conditions, take the ratio:

$$\frac{m_a}{m} = \frac{(n-1)\,r_{abc}\,(2 + n\,r_{abc})}{2 \times (n-1)\,r_{abc}}$$

$$= \frac{2 + n\,r_{abc}}{2} = 1 + \frac{n\,r_{abc}}{2}$$

$m_a \approx m$ within 5%

when $1 + \frac{n\,r_{abc}}{2} \leq 1.05$,

or $\frac{n\,r_{abc}}{2} \leq 0.05$

when $r_{abc} \leq \frac{0.1}{n}$

The following table shows the limiting value of r_{abc} and $R_{abc\,a}$ ($= 20\log_{10} r_{abc}$) for various number of inputs:

n	r_{abc}	$R_{abc/a}$
2	0.050	–26.0dB
5	0.020	–34.0
7	0.014	–36.9
12	0.008	–41.6
20	0.005	–46.0

The use of the apprximation $m_a = \frac{n-1}{2} r_{abc}$ allows a simple decibel expression for cross-modulation:

Let $M = 20\log_{10} m$, then:

$$M = 20\log_{10} m_a = 20\log_{10}\frac{n-1}{2} r_{abc}$$

$$= R_{abc\,a} - 6 + 20\log_{10}(n-1)$$

However for equal input levels: $R_{abc\,a} = K_3 + 2L$, hence: $M = K_3 + 2L + 20\log_{10}(n-1) - 6$ dB.

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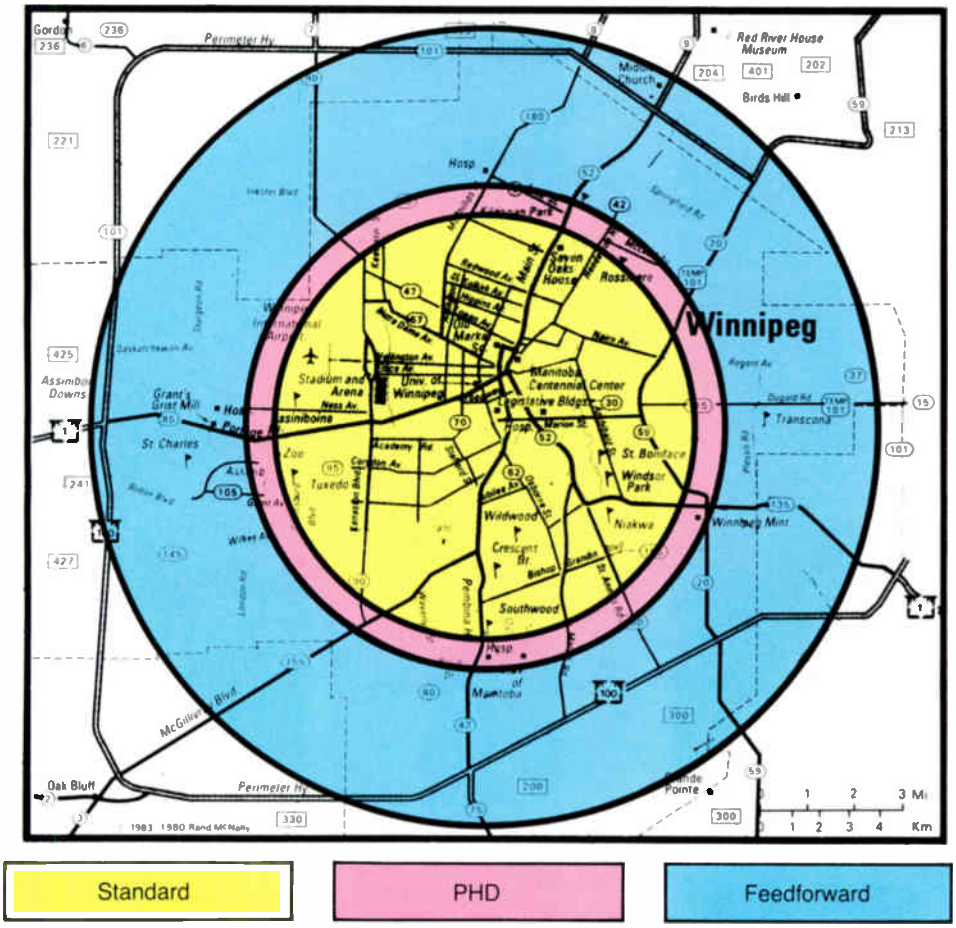
Figure 1: Service area comparison



Feedforward technology in broadband systems

This is the second of a three-part series on the fundamentals of feedforward technology. The third installment—on maintenance, test and repair considerations for feedforward systems—will appear next month.

By Joseph P. Preschutti and Colin J. Horton
C-COR Electronics Inc

Feedforward technology is providing a means to improve broadband communications distribution systems. An order of magnitude improvement in the distortion performance of the output stages used in the amplifier stations can be provided by the feedforward circuit. This improvement can be taken full advantage of in trunk stations that operate at moderate output levels. Application examples wherein feedforward trunk stations can be used to improve system cost and performance will be presented. Comparisons are made to both standard and parallel hybrid trunk technologies.

Feeder applications of feedforward and parallel hybrid technology are presented showing the advantages and disadvantages of each in bridger module, remote bridger and line extender applications. Cost versus performance comparisons are defined.

Conclusions are presented which favor parallel hybrid bridgers and standard line extenders over the alternate technology selections for these functions.

Finally, sample system designs using each of the technologies are presented that clarify the cost/performance benefits of several practical combinations of technologies.

In the first article of this series ("CT," 7/84, p. 19), it was mistakenly stated that Motorola feedforward modules are used in C-COR's feedforward product line. C-COR's feedforward circuit uses standard RF hybrids and plug-in microstrip delay lines. We regret any confusion this may have caused.

Trunk applications

Feedforward output amplifiers applied to trunk stations provide the system designer with the best application of this technology.

In general, a feedforward circuit will have 18 to 20 dB better distortion performance than a push-pull hybrid amplifier. When feedforward circuits are used as output amplifiers in trunk stations, the performance of the trunk station is greatly improved. However, pre-amplifier distortion does contribute to overall distortion performance of a trunk station.[1] Nevertheless, typical trunk station distortion specificatons for feedforward trunks will be 15 dB or so better than standard trunks. This performance improvement can be taken advantage of in several ways. The following sections show applications of feedforward technology to trunk line designs.

- *Feedforward trunks increase reach:* One of the prime uses of feedforward technology is to increase the reach of a trunk line. The improved distortion performance of feedforward technology allows the system designer to cascade more trunks than using standard technology or parallel hybrid device (PHD) technology. This can be shown by examining a system that must have a given end-of-trunk distortion and noise performance. Data shown on Table 1 clearly shows this advantage. Three types of trunk stations are compared: standard, PHD and feedforward. The feedforward trunk reach is almost 100 percent greater than standard trunks and more than 60 percent greater than PHD technology.

This example is for a 22 dB spaced trunk station. Similar results are obtained for 26 dB trunk stations. The output levels are somewhat unconventional due to each amplifier being operated at precisely the correct output level to achieve maximum reach assuming desired performance of 45 dB carrier-to-noise ratio

Table 1: Reach comparison of several trunk technologies

Trunk type	Trunk specifications: Output level, dBmV	C/N	CTB	Maximum cascade: Reach, dB	# of amps
Standard	29.8	58.7	88.5	506	23
Parallel hybrid	30.7	59.4	89.9	594	27
Feedforward	35.5	61.5	94.0	968	44

Note: Assumes 45 dB C/N, 61 dB CTB desired cascade performance, 450 MHz, 60 channels. All trunks 22 dB spaced, o/p levels optimized for maximum reach.

(C/N) and 61 dB carrier-to-composite triple beat ratio (CCTB) for a 450 MHz 60-channel system.

- *Service area:* The use of feedforward trunks can dramatically increase the service area which can be covered by a single hub site or headend. Since the reach of a feedforward trunk can be twice that of standard technology, the area covered by a given hub can be expanded considerably. Figure 1 shows a metropolitan area with three approximate service areas defined by a circle whose radius is equal to the maximum cascade of standard. PHD and feedforward trunks. The assumption of a straight line distance for each of these trunks has been used. Naturally, the trunk line must follow the geographic features of the service area, but a valid pictorial representation of the differences is made by this presentation. A feedforward trunk can service nearly four times the system area covered by standard trunks and can be used to reduce the number of hubs.
- *Feedforward trunks in rebuilds/upgrades:* Whether a system is being totally rebuilt or being upgraded by simply changing out amplifiers, the feedforward technology has attractive advantages. Expanding the bandwidth and channel handling capability of systems requires the use of higher upper frequencies. Since the coaxial cable attenuation will increase at higher frequencies, the system length in dB will naturally increase if the same service area is to be covered.

The lower distortion and higher gains available in feedforward circuits provide amplifiers that can be dropped into existing amplifier locations, increase the channel loading, provide better performance than the existing system, operate at higher output levels and minimize the number of trunks which need to be placed in cascade to service a given area.

Table 2 summarizes some typical upgrade or rebuild situations. The bandwidth, channel loading, trunk spacing in dB, and performance of both the old system and new system are presented. The new system assumes a direct physical drop-in at existing trunk station locations with higher gain feedforward gear operated at higher output levels. In each case, the performance of the system has been improved, while the channel loading has been increased.

- *Feedforward trunks provide more trans-*

Figure 2: Output capability comparison

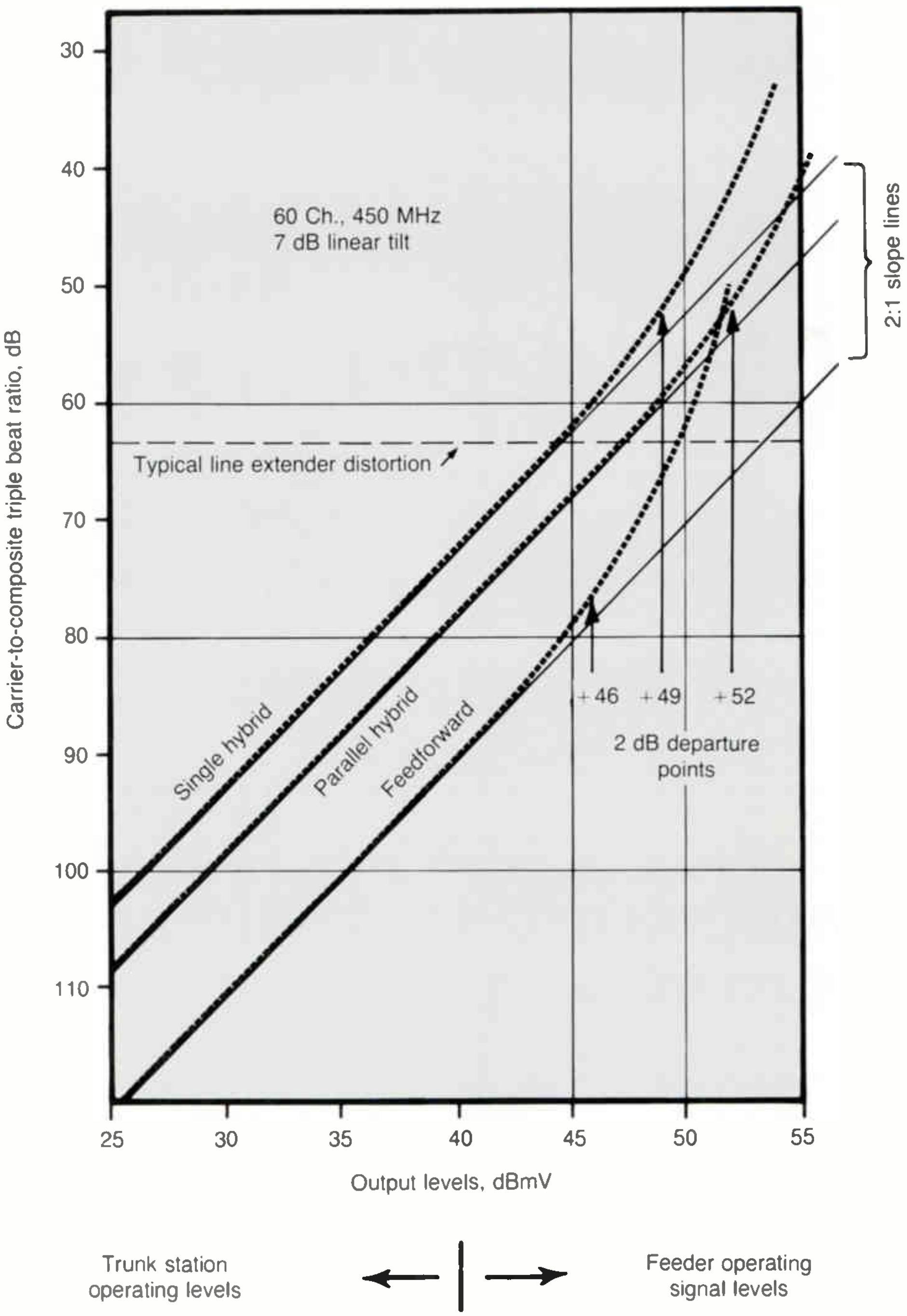


Table 2: Typical trunk upgrade situations using feedforward trunks

Old system						New system with feedforward					
Bandwidth	Channels	Trunk spacing	Output levels	C/N	CTB or (XMOD)	Bandwidth	# of channels	Trunk spacing	Output levels	C/N	CTB
220	12	21	32	59	99	300	35	26	36	59	102
220	21	21	32	59	93	400	52	26	36	59	96
300	35	21	32	59	90	450	60	26	36	59	94

Table 3: Supertrunk transparency comparisons

Trunk line technology	C/N in dB	CCTB in dB
Standard	45.7	62.5
Parallel hybrid	46.4	63.9
Feedforward	48.5	68.0

Note: Supertrunk length, 440 dB at 450 MHz, 60-channel performance. Twenty amplifiers in cascade, 22 dB spacing, levels as shown in Table 1.

parent supertrunks: Another application of feedforward technology is the supertrunk, which must connect two fixed points in a system. This dedicated portion of the system should be as transparent as possible and feedforward technology is particularly attractive in this application. Table 3 compares the performance of three types of supertrunk amplifiers in an example using 22 dB spaced stations to connect two points that are 440 dB apart in the system. Again, the feedforward trunk line outperforms other technologies by substantial margins.

If instead a 26 or 30 dB feedforward trunk was applied to this situation, the design could reduce the number of trunk stations used to build the supertrunk.

- *Feedforward trunks can reduce costs:* The total cost to build a system with feedforward trunk amplifiers can be lower than the cost to build a system with standard trunk amplifiers. This is true if a smaller size of trunk cable is used in the feedforward system than would be used in the conventional. Feedforward trunks with higher spacings than conventional trunks can be used to build a system that has the same reach, and end-of-line performance as a system built with conventional amplifiers, but uses a smaller size of cable.

For example, a 300 MHz system could be built with a cascade of twenty 21 dB spaced conventional trunks and 1.00-inch cable to reach 58,000 feet (10.6 miles). The end-of-trunk performance would be C/N = 46 dB, CCTB = 68 dB.

The same system could also be built with a cascade of twenty 26 dB spaced feedforward trunks and .750-inch cable to reach the same distance. The end of trunk performance for the feedforward version would be C/N = 46 CCTB = 76. The total cost of both trunk runs including cable costs is compared in Table 1. The total cost is $366.00 less per trunk if feedforward trunks and .750 cable are used. The difference in construction cost between 1.00-inch and .750-inch would make the feedforward trunk system even less expensive than the conventional. Table 4 summarizes this data.

This example shows how creative use of feedforward techniques can provide better performance and lower cost simultaneously. The system designer should consider this approach to feedforward circuit utilization.

Feeder applications

Feedforward circuits utilize cancellation techniques to reduce the distortion produced in the amplifier. This process does not, however, provide an amplifier with improved power handling capability. In trunk applications full advantage of the distortion reduction provided by a feedforward circuit can be realized. At trunk output signal levels, which are generally below those required of feeder amplifiers, the main RF amplifier in a feedforward circuit is operating in a well-behaved manner. However, the phenomenon that has been called gain compression[2] will reduce the improvement of feedforward circuits compared to other technologies at the high output levels required of bridgers and line extenders.

Figure 2 presents the CCTB ratio versus output levels for a 450 MHz 60-channel system operating with output levels having a 6 dB linear tilt between the highest and lowest channel on the system.

Note the performance of the single hybrid. At levels below 45 dBmV, the third order distortions behave in a well-mannered fashion and follow the two-for-one slope lines indicated on the chart. Above this, higher order terms such as 5th, 7th, and 9th order terms, start coming into play and the distortion performance departs from the well-behaved performance.

The other two performances indicated on the chart, the parallel hybrid and feedforward performance, are determined by using the single hybrid performance as a reference and then constructing the other two traces according to the following rules

The parallel hybrid performance is obtained by shifting the single hybrid performance to the right 3 dB at each point

The feedforward curve is constructed by taking any point on the single hybrid line, shifting to the left 3 dB, and then shifting downwards 24 dB

The shift to the left of 3 dB accounts for the insertion loss of the components in a feedforward circuit that are between the main amplifier output and the output of the feedforward circuit.[3] The 24 dB downward shift accounts for typical cancellation of the feedforward circuit

Figure 7 presents an analytical approach to determining the expected performance of the feedforward feeder amplifier at the higher output levels required for bridger and line extender functions in the distribution system. Note that at 51.5 dBmV out the feedforward amplifier performance is identical to the parallel hybrid performance. Also note that if the lines were extended further that at 54 dBmV out the single hybrid performance would be better than the feedforward circuit performance

This unique behavior, that is, poor derating at elevated signal levels, complicates the task of the system designer when selecting and specifying the output signal level for feedforward distribution amplifiers in bridger and line extender applications

This analysis indicates that if a 3 dB safety margin were required in the system design that equivalent performance between parallel hybrids and feedforward circuits would be achieved at 48.5 dBmV output levels. At this point, a parallel hybrid device would have 60 dB CCTB while a feedforward device would have 67 dB CCTB. However, if the output levels of each were increased by 3 dB, each would have a 55 dB CCTB

• *Bridger applications* The objective of a bridger design is to provide the highest output signal levels possible in a cost effective manner. The bridger location is unique in this re-

Figure 3: Standard push-pull bridger amp module

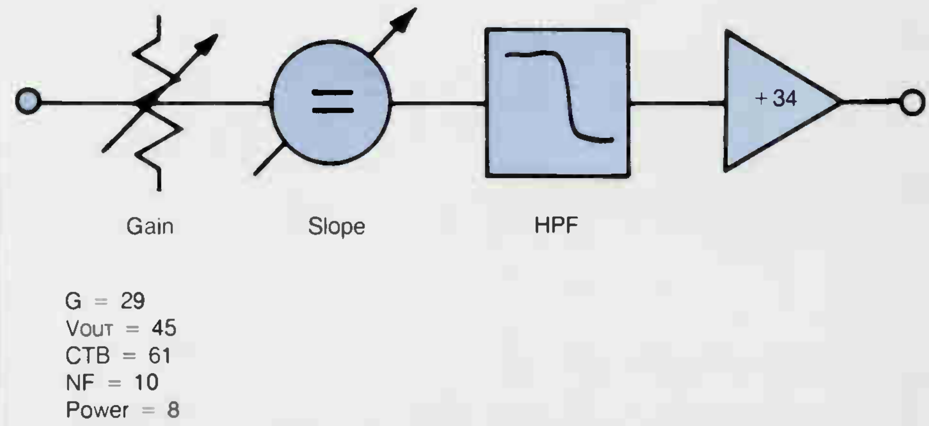


Figure 4: Parallel hybrid bridger amp module

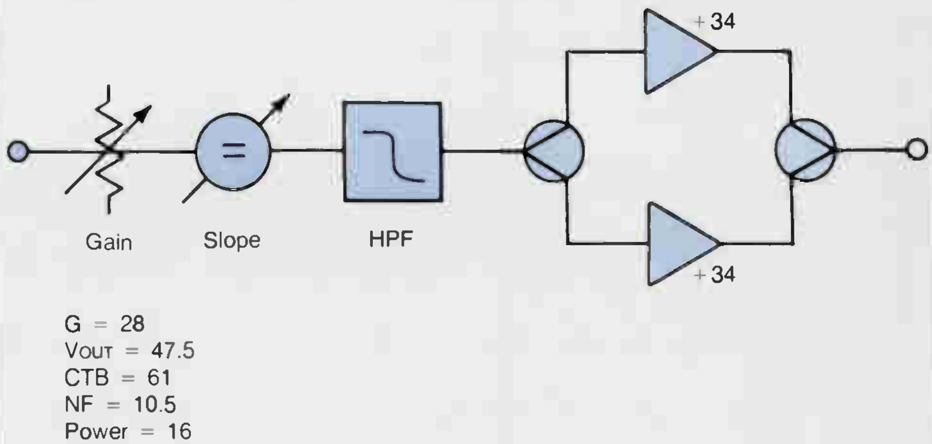
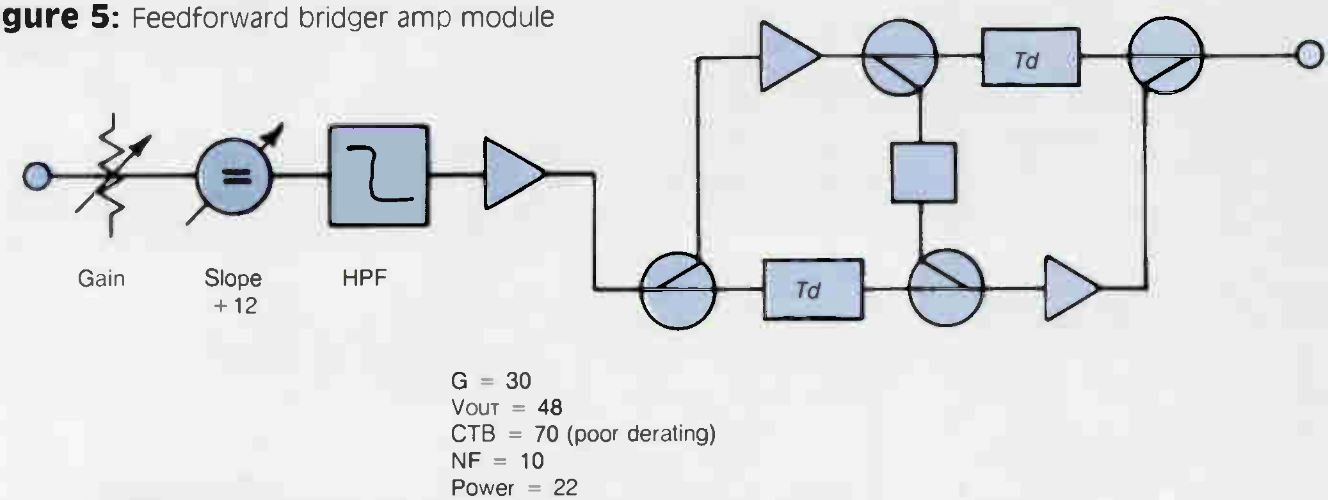


Figure 5: Feedforward bridger amp module



gard because there are usually many "end-of-feeder" locations fed from a single bridger. Both theoretically and practically, an extra dB of output signal level at a bridger will be translated into longer reach between the bridger and the 10, 20 or more end-of-feeder locations that the bridger feeds. The longer feeder reach means lower system cost. The bridger is a natural location to apply techniques that increase the power delivered by new technologies.

The following sections describe performance and cost of several types of bridger modules and remote or terminating bridger amplifiers.

• *Bridger amplifier module configuration:* Bridger modules, which are plug-in amplifiers co-located with trunk stations, are fed from high value directional couplers internally connected to the trunk station output. Assuming a 32 dBmV trunk station output with a 12 dB directional loss, the input to a bridger module will be approximately 20 dBmV. Gains of near 30 dB are required to produce high level outputs.

Figures 3, 4 and 5 show standard, PHD and feedforward bridger modules indicating gain, output level at 61 dB CCTB, noise figure and power consumption. The feedforward amplifier is actually operated with 70 dB CCTB but at this point, the output level derates 4-to-1 instead of the 2-to-1 behavior normally seen for triple beat performance in a well-behaved amplifier.

Another notable characteristic of the feedforward bridger amp is that an additional preamplifier is required in order to provide the gain necessary for the bridger function. The feedforward gain block has 23 dB gain, which is not sufficient, by itself, to provide the required gain.

Since the gain compression phenomenon indicated in the previous sections reduces the improvement in distortion reduction of the feedforward circuit, the system designer has a difficult choice in selecting the proper technology for bridger applications. Clearly, the feedforward circuit can be operated at levels only slightly higher than or equal to those of a parallel hybrid bridger. Since the feedforward circuit consumes more power and is significantly more complex, the tradeoff between a tenuously better CCTB performance that will derate 4-to-1 and a simpler, lower cost, well-behaved PHD circuit is a difficult choice.

However, the economics of using one of these technologies, either PHD or feedforward, instead of a single output RF hybrid circuit in a bridger module seems to favor the more complex approach. The packaging and power supply for a trunk station, which has many other circuits in the package, does not dramatically increase in cost with the new technologies compared to the cost of the overall package. So the cost versus performance tradeoff gives the system designer maximum value in the bridger module with the PHD or feedforward circuits.

• *Remote/terminating bridger applications:* There are two main objectives to the design of a terminating or remote bridger. First, this type of amplifier requires the high output levels of the bridger module, which plugs into a trunk station for the same reason. Namely, multiple end-of-feeder locations provide a good opportunity to have cost effective high output level equipment. The second objective is to have about 38 dB of gain so that the remote bridger can be optimally located in the system independent of the trunk.

Several important cost contributors play a role in the selection of the proper technology for the remote bridger:

1) Trunk station type packaging and powering are usually applied to this function, which usually provides an input plus four outputs.
2) PHD output stages can be configured using lower gain blocks with lower power consumption.
3) Both PHD and feedforward technologies require a separate pre-amplifier to get the required gain.
4) Modern power packs in these packages are designed to supply a load of 2.0 to 2.5 amperes at 24 volts DC bias.
5) PHD output stages using 18 dB gain blocks can be used instead of the 34 dB gain blocks used in the PHD bridger amp module used in trunks. This reduces the power consumption and improves performance.

The terminating bridger then has both the packaging and power available to reasonably and practically have more than one PHD output amplifier stage. This type of configuration, that is, a dual-output PHD remote bridger, seems to be the best application of the technologies available for this function. It can provide higher output levels, in a well-behaved manner, than the feedforward circuits.

- *Line extender applications:* Application of either the feedforward or the PHD technologies to line extenders is not as simple and straightforward as applications in trunks and bridgers. The equipment designer must provide more complex power supply and packaging to reliably provide a high output level extender.

First, consider powering. The standard two-way line extender requires a 14 watt output from the power pack. The PHD version requires 24 watts. The feedforward counterpart requires 28 watts. The low-cost line extender commonly employed in system designs use linear regulators that can be 50 percent to 65 percent efficient, depending on output voltage.

This translates to an input power requirement of 48 and 56 watts respectively for the PHD and feedforward type two-way extender. The linear regulator is clearly a poor choice for these power levels since the excess power is being absorbed by the regulator circuitry creating excess heating and reducing reliability. The cost of this low efficiency is higher power consumption, substantial reliability degradation and higher operating costs. An efficient switch mode supply is technically more practical for the high power extender.

Now, once a switch mode supply is chosen, the packaging becomes a major concern A common packaging configuration for extenders with linear regulators is to combine RF and power supply circuits on one module, sharing head sinking, PC boards and mechanical mounting parts. This results in a low-cost assembly. The switch mode supply does not generally fit into these existing packages. Therefore, the designer suffers a dual cost increase situation in a PHD or feedforward extender. First, the increased cost of the RF technology and second, the extra cost of more complex power supply and packaging.

Table 5 shows the relative cost, performance, power consumption of the RF circuits and gain blocks required to produce four different two-way line extenders. These are the standard single hybrid, standard dual hybrid, PHD and feedforward line extenders. The cost

Table 4: Feedforward trunks can cost less

	Standard	Feedforward
Bandwidth	300	300
Trunk spacing, dB	21	26
Cable	1.00"	0.750"
Loss at 450 MHz dB/100'	0.75	0.90
Spacing between trunks, ft.	2,800	2,800
Cable loss between trunks, dB	21	25.5
Cable cost	$2,234	$1,458
Amp cost	$750	$1,160
Total cost per trunk	$2,984	$2,618

Table 5: Line extender comparisons

Type	Gain	Vout	Forward hybrids	Modules	Power supply output watts	Cost
Standard single hybrid	28	45	GB34	Amp	Linear (14)	100%
Standard dual hybrid	32	45	GB22 GB17	Amp	Linear (18)	115%
Parallel hybrid	27	47.5	GB34 GB34	Amp + power pack	Switching (24)	150%
Feedforward	34	48	GB34 GB17 GB17	Amp + Power pack	Switching (28)	200%

Table 6: Feeder amplifier selection, actives and cost per mile for equivalent performance

Feeder type	Actives per mile T's per mile	B's per mile	E's per mile
Conventional	.78	.47	4.4
Feedforward	.61	.30	2.8
PHD feeder	.62	.47	3.7
PHD bridger conventional line extender	.62	.36	4.3

Feeder type	Cost per mile
Conventional	$2,930.19
Feedfoward	$3,064.17
PHD	$3,084.56
PHD bridger conventional	$2,686.56
line extender	$2,686.56

Note: Costs are non-discounted list prices.
T = Trunk
B = Bridgers
E = Extenders

penalty for PHD is 50 percent and feedforward is 100 percent compared to a standard single hybrid extender.

Since line extenders are used at the rate of approximately three per mile, an additional cost of line extenders will show up trebled on the total system cost. Compare this to a trunk station that is used at the rate of approximately 0.5 per mile and intuitively one draws the conclusion that it is comparitively more cost effective to apply higher cost technologies to trunks than it is to do so with line extenders.

Another consideration is the main purpose of the line extender. The primary objective of the line extender function is gain. The use of extenders is naturally as stated by the name of the device. A feeder line design requires an amplifier to boost signals, which have been attenuated, back up to levels suitable for continued tapping. Unlike the bridger location, which feeds many "end-of-feeders," the line extender sees relatively few. Thus, while a higher output level capability is a desirable characteristic, the value of increased extender output levels is substantially less than the value of increased bridger output levels. For this reason, gain is the primary objective of line extension while output levels are, within reason, of secondary importance in this system design function.

- *A possible feedforward extender system design:* One unique design approach to utilizing feedforward technology in extenders has been discussed[4] but not thoroughly inves-

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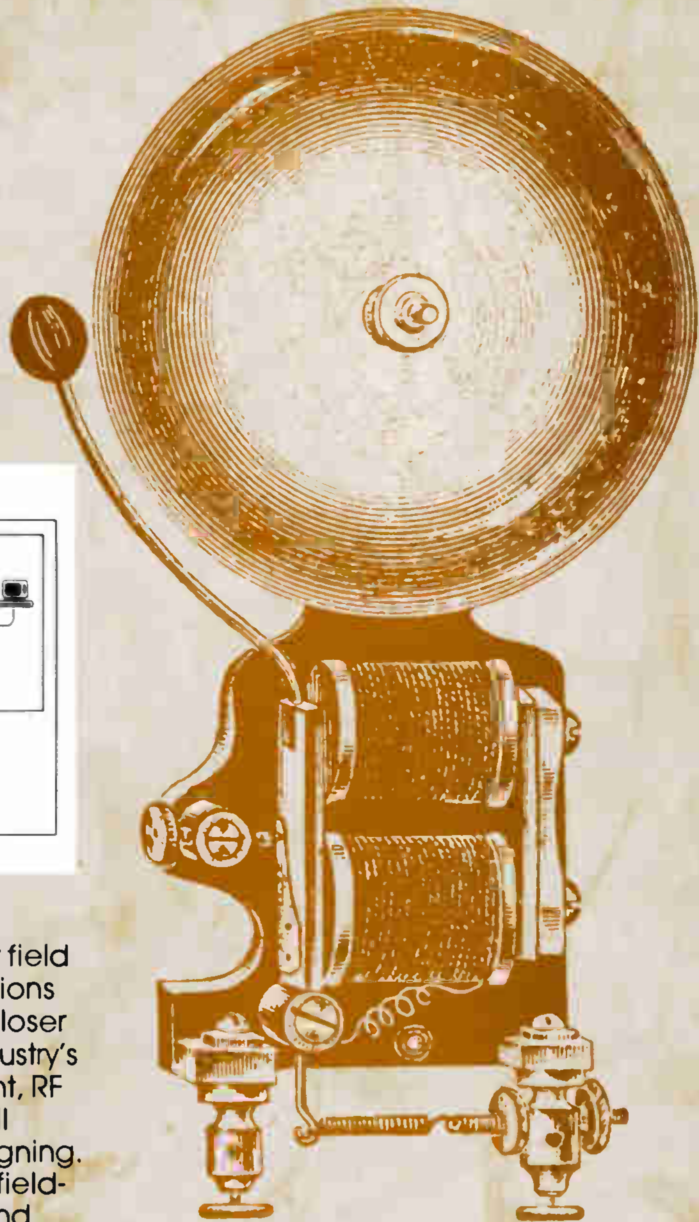
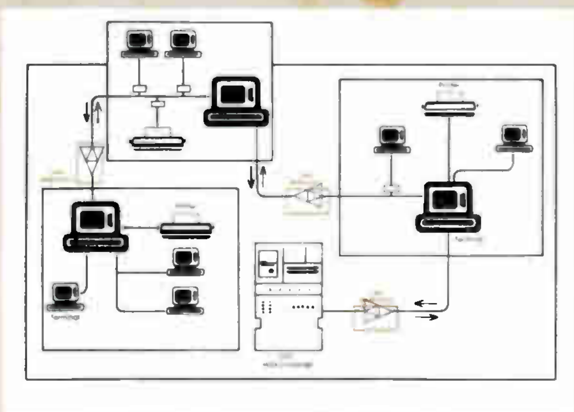


C-COR keeps it simple.



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tigated That is, allow the designer to cascade up to five extenders, operate the feedforward extenders with high gain and moderate output levels, and use a smaller size cable in the feeders

This dramatically improves feeder-to-trunk ratios, reducing cost, and also reduces cost by using smaller cables, connectors, etc. This approach deserves further study.

Sample designs follow which highlight some of the points made in the sections dealing with feeder applications of PHD and feedforward technology

• *Sample feeder designs:* The cost of four different combinations of feeder amplifier technologies were compared by preparing four designs of the same area The four different combinations were:

1) Conventional bridger and line extender.
2) PHD bridger and line extender.
3) Feedforward bridger and line extender.
4) PHD bridger and conventional line extender.

Table 7: Cost to operate completed system

Feeder type	Monthly power cost per mile
Conventional	$10.80
Feedforward	$12.60
PHD feeder	$13.36
PHD bridger conventional line extender	$10.01

Table 8: Net present value of powering costs

Feeder type	NPV per mile
Conventional	$780.03
Feedforward	$910.04
PHD feeder	$964.93
PHD bridger conventional feeder	$722.98

Cost incurred to pay for extra power at 12 percent annual interest for 10 years.

Table 9: Cost per mile including powering costs

Feeder type	Cost per mile
Conventional	$3,710.22
Feedforward	$3,974.21
PHD	$4,049.49
PHD bridger conventional line extender	$3,409.54

The same set of strand maps, as well as the same cable, tap output and powering were used for each design. In each design, the amplifier output levels were chosen to meet the same end-of-line performance after a cascade of twenty 26 dB spaced feedforward trunks. Thus, the variables in the design were the amplifier output levels and cost. Table 6 compares the cost per mile of each of these designs. The least expensive by far is the PHD bridger and conventional line extender design.

In addition, an analysis of the cost to power the four designs was done. The results calculated at $.06 kwh (Table 7) show that the monthly power cost per mile of the PHD bridger and conventional line extender design is lower than that of any other three designs.

The "net present value" (NPV) of these powering costs has been calculated over a period of 10 years with a 12 percent annual interest rate. These results in Table 8 show the cost/mile of the 10 years of paying for power in terms of equivalent cost now. This NPV/mile can be added to the electronics cost per mile, the results of which are shown in Table 9.

The total costs per mile in Table 9 shown conclusively that the PHD bridger and conventional line extender design is by far the least expensive of the four combinations of technology.

Conclusion

Feedforward technology can be applied in many ways to trunk line systems to improve performance. Several applications exist including new-builds, upgrades, rebuilds and super trunks. Also, cost reduction can be achieved using smaller cables with higher gain feedforward trunks.

PHD and standard trunks do not have nearly the performance of feedforward trunks.

Application of feedforward technology does not generally provide good cost/performance tradeoffs in feeder situations although some limited unique system design problems may be exceptions to this rule.

PHD technology appears best suited to bridger applications where multiple "end-of-feeders" enhance the value of high output level devices.

Conventional or standard line extenders still provide the best value for a cost effective system design, primarily due to two reasons. First, a dollar spent on an extender translates into three or more dollars per mile expended. Second, higher ouput levels in extenders do not generally reduce system costs due to limited "end-of-feeder" situations.

The optimum system design utilizes feedforward trunks, PHD bridgers and standard line extenders.

The discrete approach

There currently exist several approaches to achieve feedforward technology: the use of a discrete circuit (with plug-in microstrip delay lines, as used by C-COR) or the hybrid version of this circuit. It is the feeling of the authors that the discrete approach to feedforward circuits clearly is advantageous to any hybridized approach available now or in the foreseeable future. The reasons for this are:

1. Performance of the discrete circuit is equal to or better than hybridized versions.
2. No packaging standard exists for the hybridized version.
3. Second sources for hybrid push-pull amplifiers are commonplace. No second source exists for hybridized feedforward circuits.
4. Power consumption and heat are major concerns with feedforward. The discrete version has a clear advantage, physically separating the major heat sources, improving reliability.
5. Delivery and availability of equipment for major jobs requires reliable mass manufacturing processes. These do not now exist for the hybridized feedforward circuits. As well, production yields are low for the hybridized versions.
6. The manufacturing costs of C-COR's discrete approach are substantially lower than the cost of the hybridized versions of feedforward circuits.
7. The repair costs of the discrete circuits are substantially lower. The material costs for replacing a hybridized feedforward circuit are at least four times the material costs of replacing a standard 34 dB gain push-pull hybrid.

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[5]Dworkin, Donald Z., "Evaluation of Feedforward Amplifiers, Microwave Transmission and Other Long-Distance Methods of Signal Carriage," NCTA Technical Papers, June 1983

[6]Pike, Dan, 'On the Use of Feedforward Techniques," NCTA Technical Papers, June 1983

Polar mount

Microdyne's new motorized polar mount and programmable controller make it possible for cable television operators and broadcasters to switch between satellites along the geosynchronous arc.

The polar mount is designed primarily as an option for Microdyne's 5- and 7-meter parabolic antennas and joins their current line of motorized polar mounts for 10-foot and 12-foot antennas. The rack-mounted programmable position controller for the polar mount is simple to operate and has storage capacity for up to 16 satellite positions, including presetable polarization.

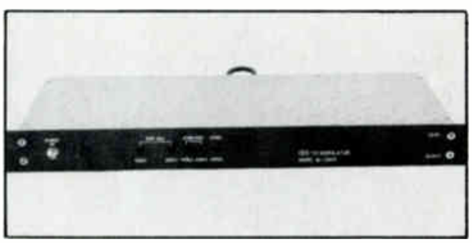
For more information, contact Microdyne Corp., P.O. Box 7213, Ocala, Fla. 32672, (904) 687-4633.

600 MHz subpassives

A new line of subpassives, with excellent performance out to 600 MHz, has been introduced by Magnavox CATV Systems Inc. The new subpassives feature RFI isolation of 100 dB or better and provide optimum insertion loss, return loss, tap-to-tap isolation and tap-to-out isolation.

The subpassives are cast in Zamak-3, an aluminum alloy that prevents spigots and tap tabs from breaking off. The subpassives are irridited to prevent corrosion and sealed for outdoor applications.

For more information, contact Magnavox CATV Systems Inc., 100 Fairgrounds Dr., Manlius, N.Y. 13104, (800) 448-5171, in New York State (800) 522-7464.

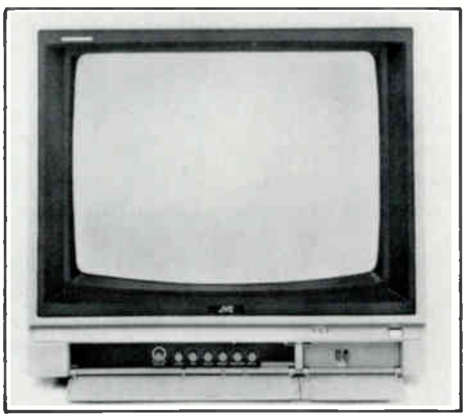


Modulator

International Satellite supply introduced the GL-2600 frequency agile modulator for CATV, DBS, SMATV and MATV applications. Output frequency selection is made with the setting of a switch. Output channels include the following: low-band, mid-band, super-band (all 35 channels), 2-13 and A-W.

A saw filter is incorporated for adjacent channel performance and a saw resonator for low phase noise and frequency stability. IF modulation with loop thrus for both audio and video are located on the rear of the unit. Audio video level indicators and adjustments are located on the front panel.

For more information, contact International Satellite Supply, 2225 Sharon Rd., #224, Menlo Park, Calif. 94025, (415) 854-8987.



Video monitor

JVC Co. of America has introduced the TM-2084U, a reliable 19-inch color monitor that delivers a sharp, clear picture.

The monitor-only TM-2084U features an aperture control to increase sharpness and a comb filter, which adds definition by processing luminance and chrominance signals separately. Horizontal resolution measures 350 lines. The monitor has a single audio channel and its controls are located on the front panel. The A input has BNC video connectors and RCA audio connectors, while the B input is an eight-pin connector for hook-up to a VCR. There is a loop-through connector for BNC/RCA hook-up.

For complete details, contact US JVC Corp., 41 Slater Dr., Elmwood Park, N.J. 07407, (201) 794-3900.

Narrowband video

Colorado Video Inc. has reconfigured its single frame narrowband video (freeze-frame) equipment for transmission by satellite subcarrier channels, MDS or FM radio. The Model 290C transmitter transmits a single field, NTSC-like color video image in eight seconds over a 7.5 kHz bandwidth. It is used in conjunction with the Model 250R receiver.

Specialized information, such as video "catalog" services, public service listings, real estate listings, travel information and continuing education courses are ideal for this medium. Use of a second 7.5 kHz channel provides an audio voiceover.

For information about the models 290V and 250C and a copy of an article on "The Subcarrier Transmission of Narrow-Band Video Signals," contact Colorado Video, Box 928, Boulder, Colo. 80306, (303) 444-3972.

Pay TV system

Blonder-Tongue Laboratories has introduced its new pay TV system, an economical method of adding up to six premium (pay) channels to any CATV system. The Guardsman utilizes off-premise scramblers to deny the premium services to non-subscribers and non-paying customers. The system can be configured as an addressable, non-addressable or hybrid addressable/non-addressable system.

An address encoder located at the headend provides channel and tier authorization to individual scramblers throughout the CATV system. The encoder also interfaces with the central billing station to provide essential commands, message validations and data.

The Guardsman subscriber module provides video scrambling on up to five channels and video-plus-audio scrambling (for adult programs) on one channel. The module can be strand, pole or pedestal mounted and has a plug-in AC transformer and power/RF diplexer, which is placed in the subscriber's home. Separate drops are not required for multiple TV sets in a home or apartment. Since subscriber units are inserted into individual drops, the CATV system needs no plant modifications. Authorization address information is sent in-band so a system does not need two-way capability and headend modification is minimal.

For complete details, contact Blonder-Tongue, 1 Jack Brown Rd., Old Bridge, N.J. 08851, (201) 679-4000.

Satellite receiver

Channel Master Satellite Systems recently announced the availability of a new Channel Master Model 6121 dual block conversion satellite receiver designated for use in CATV or SMATV systems.

This receiver utilizes advanced microprocessor technology to provide a number of convenient performance-control features such as a multi-functional LED display, which provides instant readout of either transponder number, audio frequency, fine tune level, offset or signal strength. Depressing the appropriate button locks the controls to prevent unauthorized use.

Additional features include full 5-8 MHz synthesized audio tuning, 24-channel agility and IF and block conversion loop-thru for interference filtering and elimination of expensive power dividers. For multiple channel applications this receiver can also be stacked in a standard 19-inch EIA cabinet.

For more details, contact Channel Master Satellite Systems Inc., Industry Drive, Oxford, N.C. 27565, (919) 693-3141.

Motorization kit

Channel One has announced a retrofit Az/El motorization kit for the Microdyne 5-meter antenna. No crane is needed for installation. The unit uses 12 or 36 VDC, microprocessor controller with 99 memory slots, memory loss protection and comes with a one-year limited warranty.

For more information contact, Channel One Inc., 79 Massasoit St., Waltham, Mass. 02154, (617) 899-1025.

FM tap

Addressability of all control frequencies to set-top converters is now possible with the new FM tap introduced by CWY Electronics. The Model TFM TV/FM splitter allows the TV tap port to be addressed with control signals throughout the RF spectrum while providing a pass band filtered output to the FM tap port. The splitter provides frequency response of 5-500 MHz for TV and 84-130 MHz for FM. Other specifications include maximum insertion loss of 1.5 dB for 5-300 MHz TV, 2.5 dB for 300-500 MHz TV and 10 dB (+/– 1.5 dB) for 84-130 MHz FM; rejection of 30 dB minimum and isolation of 35 dB minimum. For further details, contact CWY Electronics, P.O. 4519, Lafayette, Ind. 47903, (800) 428-7596, in Indiana (800) 382-7526.

Interference canceller

Avantek Inc. has announced the AIC-2000 interference canceller for their AR1000 and AR2000 Simulchannel 3.7 to 4.2 GHz earth station receiver systems. This unit, which plugs into the mainframe in these receivers, will suppress one or two RF interfering signals by a minimum of 20 dB with no distortion to the desired carrier, even with interference to signal ratios as poor as 1:1, according to the company.

A small, separate antenna must be installed and pointed to obtain a clean sample of the interfering signal(s), which are then combined with the main carrier in such a way as to cancel the interfering signal(s) without affecting the desired signal. This now allows satellite receive sites to be located in RF congested areas.

Suppression is automatic; once installed, no further operator intervention is required. Two separate interfering signals may be simultaneously cancelled by aiming two separate antennas, one at each source of interference.

For more information, contact Avantek Inc., 481 Cottonwood Dr., Milpitas, Calif. 95035, (408) 943-7637.

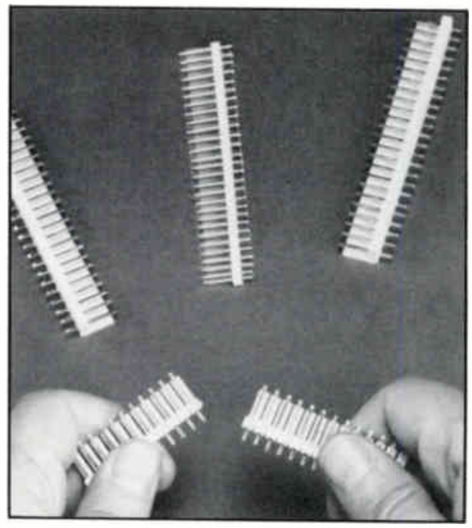
Trunk amp module

Scientific-Atlanta has introduced its drop-in upgrade trunk amplifier module designed to upgrade either 216 or 270 MHz systems to 300 MHz or 330 MHz. The new amplifier modules provide an economical solution to system channel expansion, according to S-A, and can be installed in existing systems or configured as a complete automatic trunk station. The high-gain upgrade trunk module incorporates tamper-resistant stepped pads and equalizers for gain and slope control. Minimum gain at 300/330 MHz is 28.2 dB.

S-A also introduced its 5-174 MHz high-split reverse amplifier, allowing expanded reverse channel capability for metropolitan area network (MAN) systems. The new equipment is designed to support a full combination of data, voice and video signals. It uses effective thermal compensation, eliminating the need for pilot carrier generators. Through the use of highly accurate thermal drivers, signal quality is maintained over a temperature range of −40°C to +140°C. In addition, a full range of fixed pads and equalizers provide protection against unauthorized adjustments. This high-split equipment can be inserted into any Scientific-Atlanta trunk station without modification.

S-A's new Model 6822 amplifier is designed to distribute high-quality signals throughout multi-dwelling facilities, including apartments, hotels, motels and condominiums. The 6822 is compatible with Scientific-Atlanta's line extender amplifier, allowing inventory of a single amplifier for replacement of both the outdoor line extender and the indoor house amplifier. Available in bandwidths to 450 MHz, the Model 6822 amplifier features 115 VAC switching-regulated power supply, selection of three forward/reverse frequency splits and optional AGC/thermal compensation. Packaging has been designed for the indoor environment and includes all mounting hardware. Use of discrete pads and equalizers eliminates the possibility of unauthorized tampering and adjustment. Modular construction ensures ease of maintenance.

For additional information, contact Scientific-Atlanta Inc., 1 Technology Parkway, Box 105600, Atlanta, Ga. 30348, (404) 441-4000.

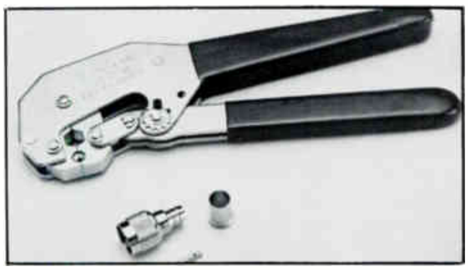


Hazard tape, PC board headers

A new line of underground hazard tape for use with buried utility lines is available from Panduit Corp. Designed for installation below ground above the buried utility lines or cables, the tape is available with six legends, warning construction crews that either electric, telephone, sewer, gas, water or cable TV lines are buried underneath. Custom legends are available on request. Legends are printed in black on colored backgrounds, including recommended APWA colors (orange for cable TV and telephone lines, red for electric, green for sewer, blue for water and yellow for gas lines). The hazard tape is made from 4-mil polyethylene film to provide long-term protection. It is acid, alkali and ultraviolet resistant and will not deteriorate in the soil. Two sizes are furnished: 3-inch tape in 2000-foot rolls and 6-inch tape in 1000-foot rolls.

A new line of molded wafer PC board headers also is available from Panduit for use with the company's MAS-CON mass terminated IDC connector systems. Offered in both 0.100-inch and 0.156-inch centerline versions with straight or right angle posts in flat, locking or polarizing types, the new PC board headers are dimensionally more accurate than extruded types, according to the company. The pre-scored wafer permits breaking the header to any desired length for prototype and short production runs.

For complete specs, contact Panduit Corp., 17301 Ridgeland Ave., Tinley Park, Ill. 60477-0981, (312) 532-1800.



In-line LNA

Macom Industries/OEM Enterprises has announced the addition of a new in-line, low-noise amplifier capable of providing 10 dB gain from 5 to 950 MHz. The Model LA-10 has been specifically developed for use with 70 MHz and block converter satellite systems requiring additional low-noise amplification to extend distances between receivers and dish, or for use with new lower gain LNAs. The LA-10 provides a thru-path for DC to power LNAs and converters and uses only 10 MA of current. Input and output line spike protection and a brass housing with nickel plating make the LA-10 ideal for outdoor line use.

Macom/OEM also introduced the NMC-21 crimp-on "N" connector for RG-213 cable and a mating low-cost hex crimp tool, Model HX-2131 able to crimp both center pin and ring. The HX-2131 has an adjustable tension adjustment to ensure high quality crimps. The NMC-21 is made of brass with a weather resistant nickel plate.

For details, contact, Macom Industries, 8230 Haskell Ave., Van Nuys, Calif. 91406, (800) 421-6511.

Addressable system

Regency Cable Products (formerly Octagon-Scientific Inc.) has developed a micro-computer addressable control system (MACS) that offers the smaller cable operator addressable converter control, and also easily adapts as the cable operator expands. The system uses an IBM personal computer with dual floppy disk drives, a third RAM drive and an IBM dot matrix parallel printer.

MACS communicates with Regency's non-volatile intelligent data controller (NIDC). Designed to act as a modem, the NIDC takes decoder address and tiering authorization information from MACS via a RS232 serial data link and sends this information to the appropriate converters. The system is a user friendly menu driven one that allows the cable operator to maintain up to 3,500 subscribers and converters. Utilizing a dual access aiming method (subscriber account number or converter box I.D. number) each converter can be activated or deactivated and/or its tiering information can be upgraded or downgraded. The converter serial number and the subscriber name also are maintained and can be modified at any time.

As the cable operator expands and opts for a link-up with one of the billing houses, MACs easily adapts to become a local override control and audit listing (LOCAL) system. The LOCAL system provides the operator with the ability to override the billing computer in an emergency and to audit transactions where the NIDC and computer are not co-sited.

For more information, contact Regency

Cable Products, 4 Adler Dr., East Syracuse, N.Y. 13057, (315) 437-4405.

Ku-band upconverter, low-rate modem

Harris Satellite Communications Division has introduced a new Ku-band upconverter system Model 8220/8221 for Ku-band satellite networks. This system provides frequency agile signal conversion from 70 MHz to Ku-band frequency. The upconverter Model 8220 converts a 70 MHz signal to 1080 MHz (L-band). A frequency agile synthesizer in the unit controls the selection of any one of 99 preassigned channels in the Ku-band transmit frequency range of 14.0 to 14.5 GHz in the Model 8221. The Model 8221 completes the up-conversion process by converting the L-band signal to the desired Ku-band channel assignment as directed by the synthesizer. Channel tuning may be accomplished locally or remotely via a serial data interface to an optional external network processor.

Harris also introduced the Model 8003 low-rate modem, a full duplex PSK modulator/demodulator for transmission and reception of data or digitized voice via satellite or microwave radio. This unit is ideal for single channel per carrier (SCPC) or multichannel time division multiplex (TDM) applications for private networks and international communications utilizing data rates from 6 to 256 kilobits per second. The operational data rate can be changed in the field to meet expanding network requirements. The standard Model 8003 features full transmit/receive capability, fault monitoring and reporting and digital and IF loopbacks.

For more details, contact Harris Corp., Satellite Communications Division, P.O. Box 1700, Melbourne, Fla. 32901, (305) 724-3174.

Microwave system

M/A-COM's MA-23CC system is a low cost, solid-state video FM microwave radio system that provides broadcast quality, full bandwidth, video and audio links in the 21.2 to 23.6 GHz frequency band. The MA-23CC system adapts readily to many short-haul applications including common carrier, and broadcast ENG receive sites to studio, CATV, SMATV and industrial uses such as teleconferencing and surveillance.

The MA-23CC system permits transmission of up to three audio subcarrier program channels, or with the addition of external modems, transmission of data at rates up to 1.544 megabits (T1 line) simultaneously with a full color video channel over the same link. A choice of both 2-foot and 4-foot parabola links are available for duplex or simplex operation.

The MA-23CC system is engineered to provide troublefree performance and simplicity of operation, according to M/A-COM. Easy access is provided to all RF and electronic assemblies. Transmitter and receiver antenna assemblies consist of weather-resistant integrated antenna and RF assemblies designed for outdoor use and rack mountable, indoor baseband processing and interface units containing power supply and baseband circuits. Coax cable is used to connect the indoor and outdoor units. No waveguide is necessary. Typical delivery is 60 days ARO, subject to backlog.

For specifics, contact M/A-COM MVS Inc., 63 Third Ave., Burlington, Mass. 01803, (617) 272-3100.

Demographic display

Compucon announced the availability of the Tele/Map series. Tele/Map provides a visual display of any market's telephone exchange area in conjunction with local demographic information. It is designed to assist in strategic and network planning or market research involved in the evaluation of the communications industry in local market areas. It can be useful in assessment of bypass potential, business network design, installation of new plant and facilities or conversion to equal access arrangements.

Tele/Map comprises a series of computer-generated maps containing communications data and demographic variables. Accompanying the map series is a data summary report that acts as a guide in locating key exchanges, rapid growth areas, dense business areas and other important user clusters that may be vital to long-term growth.

For further information, contact Compucon, P.O. Box 809006, Dallas, Texas 75380-9006, (214) 235-5300.

Advertising software

Tele-Engineering Corp. has introduced new software for its COBIAS™ cable advertising system. The data processing packages automate billing and verification and provide management information for sales, traffic and production of video advertising.

The basic COBIAS I package performs billing and verification for single market applications. The advanced COBIAS II package

Connector cover

The new Model CC16 connector cover from CWY Electronics is an alternative to heat shrink or other type covers when splicing or connecting drop cable. The new cover fits RG59 and RG6 connectors, is easy to install and allows for servicing while securely sealing against the elements.

For more information, contact CWY Electronics, P.O. Box 4519, Lafayette, Ind. 47903, (800) 428-7596, in Indiana (800) 382-7516.

C-COR catalog

C-COR Electronics is now offering its new cable television products catalog. The catalog, which covers C-COR's complete line of cable television electronic distribution equipment, includes information on a number of products and services not featured in the previous catalog.

For further information and a copy of the catalog, contact C-COR Electronics Inc., 60 Decibel Rd., State College, Pa. 16801 (814) 238-2461.

performs billing and verification functions and provides mangement information for high volume markets and multiple market operators. Originally developed for regional advertising interconnects, the software interfaces solely with Tele-Engineering commercial insertion equipment.

For more information, contact Tele-Engineering, 2 Central St., Framingham, Mass. 01701, (800) 832-8353.

RF devices selection guide

The 12-page, comprehensive "Selection Guide" for the full line of transistors, hybrid amplifiers, and other semiconductor devices manufactured by the RF Devices Division of TRW Electronic Components Group, is now available.

Using drawings, diagrams and charts, the guide provides information, in an easy to use format. Included are transistors for HF mobile, VHF/UHF, and microwave applications, thin film hybrid amplifiers for CATV and general purpose RF linear applications, and a complete line of small signal, low-noise transistors for high performance applications.

Copies of this guide may be obtained from RF Devices Division, TRW Electronic Components Group, 14520 Aviation Blvd., Lawndale, Calif. 90260, (213) 536-0888.

I.D. products catalog

A 28-page, full-color catalog describing the complete line of Panduit Corp.'s Insta-Code® identification products is now available. The catalog presents detailed information on custom markers, wire marker books and cards, wire markers on tape, clip-on wire markers, pre-titled write-on labels, voltage markers, larger numbers and letters, hazard tape, pipe markers and safety signs. Included in the catalog are: application photos; complete performance data, sizes, colors and materials; applicable industry and military approvals; and ordering information.

Free copies of Catalog E-ID-1 are available from Manager, Inside Sales, Panduit Corp., 17301 Ridgeland Ave., Tinley Park, Ill. 60477-0981, (312) 532-1800.

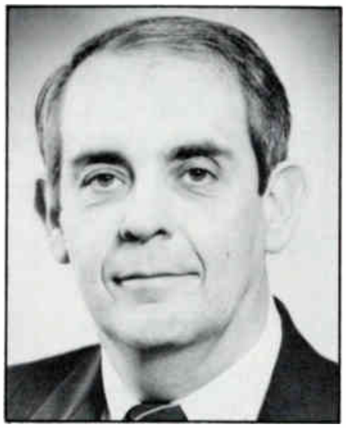
Coleman

Times Fiber Communications Inc. announced that **Kenneth Coleman** has been elected vice president and general manager of the company's Cable Television Division. Coleman most recently was with the Jerrold Division of General Instrument Corp. where he served as vice president of marketing, and vice president and general manager of the Jerrold Distribution Systems Division. Contact: 358 Hall Ave., P.O. Box 384, Wallingford, Conn. 06492, (203) 265-8500.

Burg

Stanley Burg has joined **General Instrument Corp.'s** Jerrold Division as vice president of marketing for the company's Distribution Systems Division. Prior to joining Jerrold, Burg was vice president of marketing and sales for Kentrox Industries Inc. of Portland, Ore., manufacturers of analog, digital voice and data communications products. Contact: 2200 Byberry Rd., Hatboro, Pa. 19040, (215) 674-4800.

George Fenwick, executive vice president of **RT/Katek Communications Group's** Converter Services Division (formerly Katek Inc.), has been named president of the Computer Services Division. The division provides overnight replacement of IBM PCs and peripheral equipment and provides on-site corrective and preventive maintenance. Contact: 7 Glenwood Ave., East Orange, N.J. 07017, (201) 678-2083.



Bowler

John Bowler has been named vice president-operations for the Zenith Cable Products division of **Zenith Electronics Corp.** Bowler, who joined Zenith in 1973, had been general manager-color monitor operations for Zenith's Systems and Components Group since July 1983. Contact: 1000 Milwaukee Ave., Glenview, Ill. 60025, (312) 391-8181.

Scientific-Atlanta Inc. announced the appointment of **Michael Green** as general manager for the company's Coaxial Cable Division located in Phoenix, Ariz. Green comes to S-A from Syntex Opthalmics where he served as vice president of operations for four years. Contact: P.O. Box 21007, Phoenix, Ariz. 85036, (800) 528-3211.

The appointment of **Steve Nussrallah** as engineering manager for the company's Distribution, Data and Subscriber Products Division also was announced. Prior to joining Scientific-Atlanta, Nussrallah served as a private consultant in the areas of video software, semicustom integrated circuit design and communications.

Scientific-Altanta also announced the appointment of **Tina Mayland** as marketing communications manager. Mayland joined S-A in 1980 and was most recently advertising manager. Contact: 1 Technology Parkway, Box 105600, Atlanta, Ga. 30348, (404) 441-4000.

Stoesser

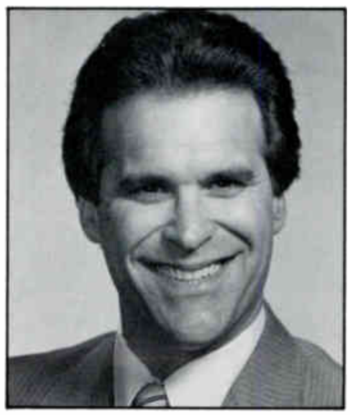
Pico Products Inc. has named **Gerry Stoesser** as Western district sales manager. Prior to joining Pico, Stoesser was an account executive with Oak Communications. Contact: 103 Commerce Blvd., Liverpool, N.Y. 13088, (315) 451-7700.

Chiddix

Jim Chiddix has been named senior vice president of **Oceanic Cablevision**, Hawaii's largest cable operator. Chiddix has been vice president, engineering for Oceanic since 1978, and was vice president and general manager of Cablevision Inc. in Waianae, Hawaii, before joining the company. Contact: 2669 Kilihau St., Honolulu, Hawaii 96819, (808) 836-2888.

C-COR Electronics Inc. announced the promotion of a number of sales and accounting personnel. **Michael Doto** has been appointed marketing operations manager, a new position. He will be responsible for sales, computer interface, statistical analysis, price lists, model numbers and market research. His former position as manager-sales administration has been filled by **Carolyn Fleming** who, prior to her promotion, was C-COR's payroll accounting clerk. **Janet Brumbaugh** has been promoted from inside sales to supervisor, inside sales. Added to the inside sales force is **Leslye Evans**, who was formerly an order service clerk. Taking her position is **Cynthia Wolfe** who had been a printroom clerk prior to her promotion. **Terri Breon** has been assigned new responsibilities as promotions coordinator, a new position. She had been a printroom clerk. **Barbara Ream** who was an assembler in manufacturing, has taken the printroom clerk position.

In the accounting department, **Dolores Connelly** has been promoted to payroll accountant from accounts payable clerk. Taking her position is **Korena Martin**, who was formerly a general accounting clerk. Contact: 60 Decibel Rd., State College, Pa. 16801, (814) 238-2461.



Panella

The Drop Shop Ltd. recently announced two sales appointments: **Sam Winstead** as West Coast regional sales representative and **Ric Panella** as a Western regional sales representative for The Drop Shop West Ltd. Winstead brings with him more than 20 years of sales experience through his associations with Rancho Bernardo CATV and most recently, Cable TV Supply. Panella previously was involved in audio video production services. Contact: P.O. Box 4771, Hayward, Calif. 94540, (800) 227-0700.

F. Frederick Kennedy, president of Cable Communications Inc., North Augusta, S.C., has been elected to a one-year term on the 30-member board of the **National Cable Television Association** as a director from District 5.

Also, Washington attorney **Bertram Carp** has been named executive vice president of the NCTA. Carp, a partner in Boston-based Hale and Dorr since 1981, served at the White House from January 1977 to January 1981 as deputy assistant to the president for domestic affairs and policy. He was legislative counsel to former U.S. Sen. Walter Mondale from 1970 to 1977; and from 1969 to 1970 was an attorney in the Civil Rights Division, office of the General Counsel, Department of Health, Education and Welfare. Contact: 1724 Massachusetts Ave., N.W., Washington, D.C. 20036, (202) 775-3629.

Magnicom Systems has appointed **Judith Spurgeon** as a marketing representative. Before joining Magnicom, Spurgeon was a sales manager at Toner Cable Computer Systems, Littleton, Colo. Contact: 1177 High Ridge Rd., Stamford, Conn. 06905, (203) 968-0088.

Kazda

James Kazda has been named an account representative for **Magnavox CATV Systems Inc.**, responsible for the Southern U.S. region. Before joining Magnavox, Kazda was a market specialist for Scientific-Atlanta. Contact: 100 Fairgrounds Dr., Manlius, N.Y. 13104, (315) 682-9105.

The Professional Video Division of **JVC Co. of America** has hired **Fred Lewis** as sales engineer for the Southwest region. Lewis comes to JVC from Taft Broadcasting, where he was assistant production center supervisor for the last four years. Conact: 41 Slater Dr., Elmwood Park, N.J. 07407, (201) 794-3900.

Two recent promotions were announced by **Gill Management Services Inc. Jeff Brambir** was appointed manager of the Field Technical Services group, and **Neil Weiser** was named manager of the Engineering Services group. Brambir had been a field consultant assigned to GMS's Eastern region office in New Jersey. Weiser joined GMS in 1982 as manager of remote systems. Contact: 2050 Bering Dr., San Jose, Calif. 95131, (408) 998-8078.

Michael Stone has joined **Dolby Laboratories** as vice president, finance and administration. Stone comes to Dolby from McKesson Corp., San Francisco, where he was assistant controller for 12 years. His previous experience includes five years with Crocker Estate Co. as accounting manager and five years with Arthur Young & Co. as a senior accountant. Contact: 731 Sansome St., San Francisco, Calif. 94111, (415) 392-0300.

Ronald Groenendal has been named manager-adhesive products for **Panduit Corp.** Groenendal reports to Jim LeBlanc, vice president of adhesive products. In his new position, he will be responsible for the operation of the Adhesive Division as well as new product development. He previously was with Ludlow Specialty Papers and Daubert Chemical. Contact: 1000 Jorie Blvd., Oak Brook, Ill. 60521-2293, (312) 323-1220.

RMS Electronics Inc. announced the appointment of **Michael Soloman** as general manager of its Western operations in Santa Ana, Calif. Soloman has worked in the cable industry for 17 years, and has been in the position of general manager for such companies as Valley Center Cablevision and Liberty Cable Television. Contact: 50 Antin Pl., Bronx, N.Y. 10462, (212) 892-6700.

The **Jerrold Division** of General Instrument recently announced three new account executive appointments. **James Martin** will be responsible for accounts in the states of Illinois, Indiana and Wisconsin. Prior to joining Jerrold, he was an account executive for CATV sales with Oak Communications in Crystal Lake, Ill. **James Faerber** will handle sales in North and South Carolina. He previously was marketing manager for American Science and Engineering Inc. of Cambridge, Mass. **Stephen Hester** will be responsible for accounts in the Michigan territory. Prior to joining Jerrold, Hester was national sales manager for cable television products with Arvin CATV in Lancaster, Ohio. Contact: 2200 Byberry Rd., Hatboro, Pa. 19040, (215) 674-4800.

What the groundhog sees that you can't—Part 3

By Anthony J. DeNigris
President, Nationwide CATV Services Inc

In continuing our discussion of what is really a basic, commonsense approach to underground cable placement, let's go beyond the tip of the iceberg. Last month we left off by just scratching the surface of conduit placement, with the emphasis being on properly placed conduit. Continuing along these lines, let's examine some of the ramifications of "improperly placed" conduit and lack of planning.

The good...

A good example of a well-planned, laid out and executed conduit placement could be a situation where multiple cables have to be placed—for instance, two .750-inch and two .500-inch cables in a common conduit along a particular run. We are going to assume at this point that the trenching and restoration necessary are performed according to specifications. The system engineer planning the project, who for the sake of this example we'll call Rex Foresight, has looked down the road and contemplates the ever-existing possiblity that technological advances could necessitate further changes in the underground cable plant.

Bearing this in mind, Mr. Foresight already has procured the proper budgeting to allow for the following provisions: rather than placing conduit that only will accommodate the four cables, he elects to put in oversize conduit, which will not only allow for the initial placement of two spare cables but at the same time will provide future ease in replacing existing cables or adding additional ones.

He also reviews the design and layout for the proposed routing of the cable and conduit, at which time he makes some minor changes in an attempt to limit the number of turns or bends (sweeps) in a particular cable run. Although this may have the effect of increasing total footage slightly, the concern expressed here is aimed at reducing pulling tension through the run, therefore minimizing the risk of damage to cables in the initial pulling operation as well as at any time in the future that cables may have to be pulled in or out of the conduit. Another action that aids what has just been noted is that "good old Rex" has been out on the job to ensure that the contractor installs the conduit in such a manner that the sweeps, where they must exist, are of the widest practical radius possible. Mr. Foresight understands that certain steps taken today can eliminate headaches tomorrow.

The bad...

Now let's take an example where the chief tech, who we'll call Andy Ankshus, takes charge of a small project where steel conduit has to be run from the headend to the first pole 350 feet away. The conduit has to run through a couple of city streets and a bonded, town approved contractor has to be chosen.

This particular run is placed far in advance of any actual cable being installed in the conduit, because it is being done at the time the building housing the headend is being erected and the conduit has to be in place before the floor is poured. Bearing in mind that Andy, the chief tech, has regular cable duties in a nearby system owned by the same company, and having confidence in the piping contractor, he merely indicates the point-to-point, beginning and end, of the conduit run and leaves the contractor to do his thing. However, he has made sure that there are going to be no sizing problems by selecting 4-inch conduit for the two cables that have to be fed in later.

'Special consideration should be given to longevity and performance of the finished product'

Four months later, the contractor who has been building the cable system arrives at the headend location to pull in the cables. He arrives fully prepared with a pulling winch, cable lubricant and all the necessary apparatus to pull cable properly. However, he is disappointed. Andy Ankshus, the chief tech, assured him that the conduit, which had been installed by the town approved contractor, already had a pulling line within it. This was not the case. What was found, however, was a totally inadequate, thin piece of string suitable only as a lead line for a pulling rope. So far no big problem exists—all the contractor has to do is tie his regular pulling rope to the lead line and pull that through prior to setting up for the cable. And this is attempted; but the foreman on the scene now is wondering why it seems rather difficult to get the pulling rope through 4-inch conduit. However, he is very skilled at his trade and does manage to get the pulling line through without too much of a problem.

Now it's time for the cable pull. Two jacketed trunk cables are affixed to pulling grips and attached to the pulling line and the winch is started. The first few feet of cable starts feeding into the conduit fairly smoothly and lubricant is being applied liberally to facilitate this. On the other end, however, the winch crew soon begins to observe an ever-increasing strain on the winch and the rope is starting to

Improper selection of conduit can lead to major problems in the future.

For more information, please see our card on page 25.

come through with some minor fraying, which seems to get worse foot by foot.

This situation goes quickly downhill from here, when in a few minutes and after about a hundred feet has been pulled in, the tension is so great on the winch that no further footage can be pulled in—the job comes to a complete halt! The rope is now frayed so much that the foreman is not willing to take responsibility for any further pulling. "Get the chief tech! What in 'Knot's Landing' is going on here?" "I don't know," exclaims Andy Ankshus, "As far as I'm concerned, there shouldn't be any problems here . . . ."

Okay, what really transpired here? Well it seems that the piping contractor had no idea of what kind of cables were going to be installed in the conduit and didn't use sweeps of a wide enough radius. Besides that, there were too many sweeps in the run as well. These two problems coupled together made for an impossible situation. Looking back, it is quite obvious that the chief tech did not follow any guidelines (which are really common sense) in order to get the job done properly.

He was too preoccupied with his other responsibilities to control this vital and "small" project. Fortunately, redigging in critical spots along the run, which had to be plotted with a metal detector, enabled the use of specialized couplings and proper sweeps to finalize the project in a manner that was acceptable, but which was nowhere near what was originally intended.

. . . and the ugly

The ugly is a situation that we will explore very briefly. It involves the illustrious Marty Messup, underground foreman for Lowball Construction Inc., which has been selected to install a single feeder system using .500-inch cable in 2-inch PVC conduit throughout an apartment complex.

This is a "turnkey" situation, and the contractor purchases "schedule 20" (for the purpose of this example, let's just say "extremely too thin") PVC conduit. And furthermore, when the conduit is placed in the trench, which is not very deep because Marty has determined that since the cable is protected by conduit it doesn't have to go in deep, little consideration is given to the radius of the sweeps and the quantity of sweeps in a particular run. A nylon line is run through the conduit at the time of installation and the restoration is completed in a satisfactory manner. All looks well.

On the day that the final cable pulls are to be made, Marty clips the end of the rope to the back of his pick-up truck, while another member of the crew sets up the reel of cable at the other end of the pull and attaches the grip to the cable. Marty hops into his truck, and a third crew member hollers, "Let 'er rip!" Unfortunately, this poor fellow was straddling the trench as the whole run pulled up and out of the ground—conduit and all. In this particular case, about the ramifications . . . need we say more?

What appears to be a humorous view should not be taken lightly, because this is an actual account of what I have seen happen with my own eyes in the earlier, free-wheeling days of cable TV. Reputation and goodwill are not the only issues at stake. As pointed out in the above illustration, the lack of common sense can result in severe damage to property and more importantly, people. And none of this can be measured in dollars and cents.

In closing this series on underground cable installation, I want to strongly emphasize the need for thorough analysis and proper planning of any project, regardless of how large—or not so large—it might be. Special consideration should be given to longevity and performance of the finished product. So much plant has been replaced to date precisely because of the lack of what is really, and always has been, nothing more than simple common sense. Let us not become complacent in thinking that our techniques have become perfected. Each new situation we face provides a challenge when it comes to the mechanisms of the task, but one thing never changes, and that is . . . the lessons of the past!

Anthony DeNigris is president and chief executive officer of Nationwide CATV Services Inc. The company is a complete service CATV construction firm offering engineering, consulting, aerial and underground plant construction, headend and system design.

CALENDAR

August

Aug. 8-10: Magnavox CATV training seminar, Chicago. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Aug. 13-15: Magnavox CATV training seminar, Chicago. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Aug. 15: SCTE Rocky Mountain Meeting Group business meeting and seminar on data communications, University of Denver. Contact Bruce Catter, (303) 740-9700.

Aug. 21: Southern California Cable Association meeting, Los Angeles Airport Hilton Hotel. Contact (213) 684-7024.

Aug. 21-23: Jerrold technical seminar, Denver. Contact Kathy Stangl, (215) 674-4800.

Aug. 21-23: C-COR Electronics technical seminar, Ontario, Canada. Contact Deb Cree, (814) 238-2461.

Aug. 22: SCTE Golden Gate Meeting Group "Cable Workshop," Napa Valley College, Napa, Calif. Contact Pete Petrovich, (415) 828-8510.

Aug. 22: SCTE Delaware Valley Chapter meeting on microwave systems, George Washington Motor Lodge, Willow Grove, Pa. Contact Bruce Furman, (215) 657-4690; or John Kurpinski, (717) 323-8518.

Aug. 22: SCTE Chattahoochee Chapter meeting, Holiday Inn-South, Atlanta. Contact Alice Soltysiak, (404) 393-8772; or Gary Donaldson, (404) 971-5860/977-9903.

Aug. 22-24: Magnavox CATV training seminar, Hartford, Conn. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Aug. 27-29: Magnavox CATV training seminar, Hartford, Conn. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Aug. 28-30: Annual Satellite Communications Users Conference, ***Satellite Communications***, Louisiana Superdome, New Orleans. Contact Kathy Kriner or Cheryl Carpinello, (303) 694-1522.

September

Sept. 5-7: Magnavox CATV training seminar, Buffalo, N.Y. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Sept. 6-8: Southern Cable Television Association annual convention, Eastern Show, Georgia World Congress Center, Atlanta. Contact (404) 252-2454.

Sept. 10-12: Magnavox CATV training seminar, Buffalo, N.Y. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Sept. 12-14: Computers and Communications International Worldcom '84 conference, Hilton Hotel, San Francisco. Contact (415) 574-3145/921-3114.

Sept. 18-20: C-COR Electronics technical seminar, Denver. Contact Deb Cree, (814) 238-2461.

Sept. 18-20: Jerrold technical seminar, Atlanta. Contact Kathy Stangl, (215) 674-4800.

Sept. 19: SCTE Golden Gate Meeting Group, seminar on video by Tektronix, location to be announced. Contact Pete Petrovich, (415) 828-8510.

Sept. 19-21: Magnavox CATV training seminar, Ogdensburg, N.Y. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Sept. 20: QV Publishing seminar on "Addressing Addressability and Pay-Per-View," Loews Anatole, Dallas. Contact Barbara Freundlich, (914) 472-7060.

Sept. 24-26: National Cable Television Association minority business symposium, Washington, D.C. Contact (202) 775-3629.

Sept. 24-26: Magnavox CATV training seminar, Ogdensburg, N.Y. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

October

Oct. 10-12: Magnavox CATV training seminar, Philadelphia. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Oct. 15-17: Magnavox CATV training seminar, Philadelphia. Contact Laurie Mancini, (800) 448-5171; in New York, (800) 522-7464.

Oct. 16-18: Jerrold technical seminar, Columbus, Ohio. Contact Kathy Stangl, (215) 674-4800.

Oct. 16-18: Mid-America CATV Association annual convention, Hilton Plaza Inn, Kansas City, Mo. Contact (913) 887-6119.

Oct. 17: SCTE Delaware Valley Chapter meeting on amplifier technology, George Washington Motor Lodge, Willow Grove, Pa. Contact Bruce Furman, (215) 657-4690; or John Kurpinski, (717) 323-8518.

Oct. 17: SCTE Golden Gate Meeting Group, seminar on converters and earth stations by M/A-COM, location to be announced. Contact Pete Petrovich, (415) 828-8510.

Oct. 29: QV Publishing seminar on "Addressing Addressability and Pay-Per-View," Harrahs Triumph Place, Atlantic City, N.J. Contact Barbara Freundlich, (914) 472-7060.

Oct. 30-Nov. 1: Annual **Atlantic Cable Show**, Atlantic City (N.J.) Convention Center. Contact Jan Sharkey, (609) 848-1000.

November

Nov. 13-15: Jerrold technical seminar, Spokane, Wash. Contact Kathy Stangl, (215) 674-4800.

Nov. 13-15: C-COR Electronics technical seminar, Tampa, Fla. Contact Deb Cree, (814) 238-2461.

Planning ahead

Sept. 6-8: Southern Cable Television Association annual convention, Eastern Show, Georgia World Congress Center, Atlanta.

Oct. 16-18: Mid-America CATV Association annual convention, Hilton Plaza Inn, Kansas City, Mo.

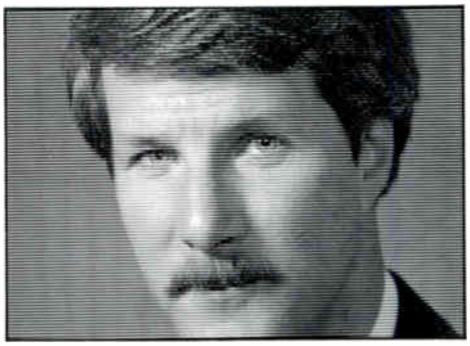
Oct. 30-Nov. 1: Atlantic Show, Atlantic City (N.J.) Convention Center.

Dec. 5-7: California Cable Television Association annual convention, Western Show, Anaheim (Calif.) Convention Center.

March 4-6: Society of Cable Television Engineers annual convention, Cable-Tec Expo '85, Sheraton Washington Hotel, Washington, D.C.

AD INDEX

Blister packs and butchers: What they mean to cable



By Bob Luff
Vice President, Engineering, United Artists Cablesystems Corp

There is an inevitable force to more seriously consider in a maturing and price competitive industry such as ours—"blister pack" service organizations, for lack of a better term—as a potentially more cost-effective alternative to those functions you and I and thousands of other hardworking and loyal employees provide for a salary to our respective operating companies in areas of construction, installation, customer service, billing, technical operations and management. Blister pack is the name I give to "low bid" generic service organizations or contractors whose whole business is oriented on lowest price rather than performance. I am not referring to the many excellent contractors and service organizations who offer competitive pricing but draw the line at sacrificing professionalism and quality performance.

Blister packs, as everyone is aware, are those cheap little transparent packages holding a low quality but overpriced item or two on a cardboard backing that also serves as the display mounting. Automotive, grocery and especially hardware stores are cluttered with them. Many times the blister pack itself must cost more than the items in it. But blister packs are more than a packaging or marketing device; they have become a business philosophy on which all too many businesses are built—lowest price rather than cost effective performance.

It's short sighted creed, maintaining the highest possible margin of profit by cutting the quality and quantity of goods and services, that has sabotaged many of those industries and careers based on high quality and high performance. I hope the service organizations and contractors that support the CATV industry resist the ruinous "blister pack mentality" as we enter the next chapter of our industry's development.

As consumers, we all know that the blister pack philosophy leaves a lot to be desired. The quality of the basic product and store service all but disappears, resulting more times than not in so many unexpected problems and return trips back to incompetent store personnel, that in the end, there is no bargain at all. And perhaps worst of all, the bleeding competition posed by the prevailing blister pack mentality to buy cheaply regardless of performance, dries up needed sources for quality alternatives at any price.

Unfortunately, like a bad case of poison ivy, once the lowest minimum performance approach gets a foothold in an industry, it seems to spread no matter how strong the desire is not to participate or what medication is later applied.

Where did the butcher go?

Consider the butcher industry. Not very long ago, we bought meat from a professional neighborhood butcher. He knew us by name and took great pride in his business and the quality of products and services, much like today's cable operator and operating staff. He was available to add his expertise and recommend cuts for special occasions. We would not think of going anywhere else to buy our meat!

Along came the supermarkets with their prewrapped blister pack, scientifically cut and packaged lower-priced meats, always with their best side up for more profit, not to enhance satisfaction. It forced an end to the local butcher and his special quality service and cuts. For a while, even the supermarkets kept up the "personal" touch with a resident butcher who you could ring with a buzzer for a special request, but he did not last long.

Soon the same price pressures that the supermarket started forced more centralization and larger off-premises meat processing, packaging and distribution. The supermarkets simply contracted with outside low bid firms to provide the total service. And as the local butcher evolved unwillingly from a visible quality profession to an invisible blister pack service organization, the quality of the product, personal service and loyalty of the consumer suffered. So did the salary of the butcher, which is the point we are coming to.

CATV demands quality

Outside service organizations and contractors opposed to in-house labor and personnel have been around in our industry for a long time. While, as in all things, there has been a wide range of the professionalism and quality of work provided, the intent of the CATV industry has clearly been to select the best bidder in terms of performance first and fair price second. As a result, the CATV industry has always very successfully utilized quality service organizations and contractors as a very cost-effective tool in many areas including pole setting, walkouts, design, construction and installation.

For example, during the recent franchise frenzy that made the industry what it is today, a great deal of emphasis was placed on contractors, and their performance was utmost in the selection process. Price was no object. Overall management and quality control of the work remained with the operating company. The industry learned early that it cannot contract out responsibility. This type of relationship, even though it resulted in some job displacement from the operating companies to contractors, was necessary in the natural course of meeting peak or specialized workload demands. Any salary depression that might have occurred as a result was only incidental.

As our industry rebounds from the frantic pace of franchising and historic growth, it is not only natural but healthy that it pause to re-evaluate its internal organizational charts and review on a case-by-case basis, at every level of operation, in-house labor and personnel versus third party service organizations and contractor alternatives.

Service organizations abound

This maturing phase of our $8 billion industry has caught the eye of many existing third party institutions and is triggering the creation of many more new service organizations and contracting firms. Also, scores of the construction oriented firms facing the recent downturn in new construction demand have branched out into a multitude of diversified contract services covering just about every facet of daily CATV system operations.

The influx of so many new service organizations and contractors, some large and some small, some with competent staff and some without, some well-financed and some desperate, suggests that there are alarming signs of blister packs making inroads in our industry.

Many of the new or the more desperate service organizations and contractors are offering the traditional specialized services (construction, installation and billing) as well as "comprehensive" packages.

At first, this may appear to be a windfall opportunity for some CATV operators to take advantage of the wider offerings and lower prices of the buyers' market situation as they review their in-house personnel versus third party alternatives. It might appear to be someone else's free choice (which it is) or worse, someone else's short-sightedness. But if these isolated price and personnel trimming cases develop into a trend, it could force an unwilling and profound change upon all of us.

Seen any butchers lately, or their paychecks?

COMMAND CENTER

It gives subscribers
everything except free service.

Theft prevention:

A new dimension in prevention of signal and service theft. The Command Center allows physical location of any illegal converter in your system. Protect your asset.

Addressability:

The TM-1 makes two-way addressability available now without any change to your present plant. The TM-1 actually adds more benefits without added cost and maintenance.

Pay-per-view programming:

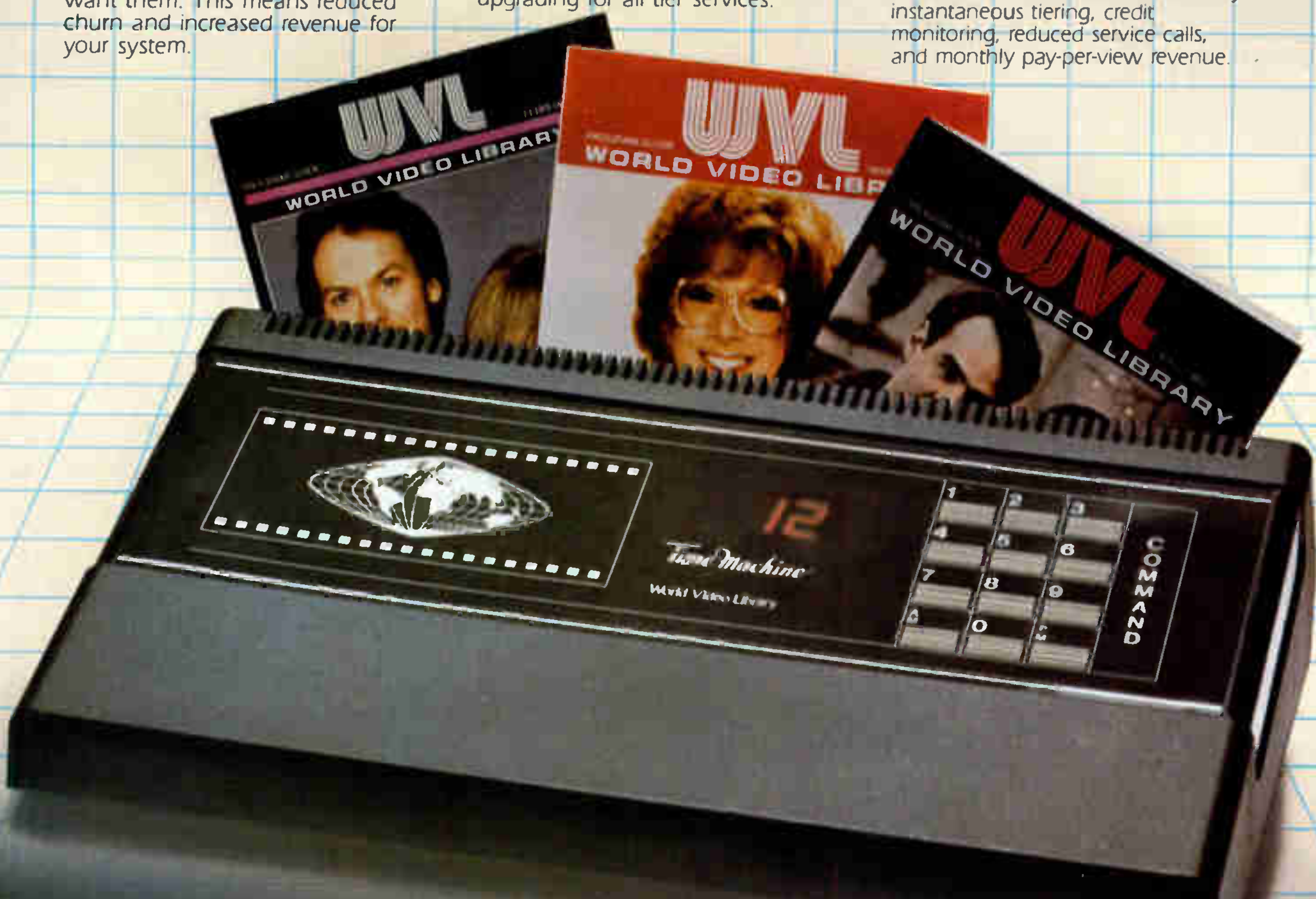
WVL's own unique pay-per-view service brings your subscribers the major movies they want when they want them. This means reduced churn and increased revenue for your system.

Automatic billing and total tier control:

This totally automatic system can produce monthly statements and instantaneously monitor credit. The Command Center provides impulse upgrading for all tier services.

Added revenue:

The TM-1 pays for itself by reduced maintenance, state-of-the-art security, instantaneous tiering, credit monitoring, reduced service calls, and monthly pay-per-view revenue.



WVL [redacted]

World Video Library, Inc. Corporate Offices 2747 Airport Freeway, Fort Worth, Texas 76111 (817) 831-3811