550 UPGRADES WITH FIBER: SELECTING COST-EFFECTIVE ARCHITECTURES

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Abstract

As a result of franchise requirements or marketplace demands, many systems will be upgraded to 550 MHz over the next few years. It is clear that fiber optics offers many cost-effective options that can be used in a plant upgrade plan. What is not clear is, which architecture will be the least costly for a given system. A secondary question might be, how the architecture that is selected today will influence the next upgrade.

This paper discusses key objectives that might warrant consideration when analyzing an upgrade plan. It is also suggests approaches to ease the task of comparing the options through design tests. An example of how different architectures might be combined in the same system is provided. The closing remarks address key issues that concern what one might strive for today to make the following upgrade as cost-effective as possible, with the least disruption to the plant.

GUIDELINES & OBJECTIVES

Overview

In order to focus on the task at hand, it may be useful to list some primary objectives of the upgrade process:

-The final approach must be cost-effective when measured against other available solutions

-The approach chosen should provide an easy, low cost, evolutionary path to further bandwidth expansion & new services.

-Improved plant reliability

-Lower plant maintenance requirements & easier plant maintenance

-Some improvement in picture quality

Cost-effectiveness

In evaluating an upgrade architecture, there are several key indicators which may be helpful in rating the overall cost-effectiveness of the approach. One such key indicator is the degree to which existing assets are re-used. The most valuable asset is the existing cable which; in the case of feeder cable, is present in nearly all locations where it will be needed. Other important assets that may not have been made obsolete by an upgrade include amplifier housings, AGC modules, existing power supplies (and their physical location), etc.

Another key indicator is the amount of projected variation in signal quality, or system performance, from one customer to another. Signal quality objectives should be established. Once fixed, the "constant distortion approach" of design should yield the most cost-effective plant. If the approach chosen results in a significant percentage of the customers receiving signals better than the minimum standard, the design is not fully optimized. In the past, constant distortion approaches to system design complicated plant maintenance activity, due to the number of different operating levels required for amplifiers. Later in this paper, an example of constant distortion design is shown where most amplifiers would operate with identical output levels.

Specifications for minimum tap levels also affect plant upgrade costs. If there is a single specification for the entire system, added cost savings can likely be found, since not all customers will have two television sets fed by a 150' drop (or conform to whatever criteria was used to establish a single spec). Efficient approaches would specify output levels for each of two or more drop length classifications. These level specifications would have been determined based on the number of outlets (the splitting loss) that would be fed without a drop amp, the minimum input level to the converter or customer terminal that yields the desired C/N ratio performance, and the length of drop cable to be used (perhaps in 30~50' increments). It is possible to minimize the work for the system designer by establishing tap levels based on average lot size, dwelling type, an entire street or subdivision, or a drop length classification and coding scheme noted for each pole or pedestal on the base maps.

The issue of minimum versus average tap port level is also important. If a minimum tap level is specified at 14 dBmV, 60% of the taps may actually have output levels of 16 dBmV. A money saving approach might be to specify a minimum tap level 2 dB below the target level. As a result, a small percentage of taps will have lower than target output levels. Calculations may show that it would be less expensive to equip those few customers, fed by low output taps, with a drop amplifier. In reality, the number of customers actually requiring drop amps may be less than the total number fed by these taps since some customers may have less than the expected number of outlets, or the drops may be shorter than the "average maximum" length estimated for that area of the system when the target levels were determined. It is important, of course, to add drop amplifier performance into the end-of-line performance calculations. A future option may be an architecture utilizing the active tap concept. [1] This concept uncouples the tap output level requirements from the feeder line design process.

Future Upgrade and Expansion

In order that a future upgrade would be possible for minimal additional investment, the path to reach the next bandwidth plateau must be examined today. A way to ensure low future upgrade cost is to devise a plan that will require the minimum disruption possible to the plant. That implies that the next upgrade should be considered while the current upgrade approach and architecture is being evaluated.

It is difficult to predict some of the requirements and options that may appear in the future. There are, however, some issues that we already understand quite well, such as cable attenuations and AM optical link performance at 860 MHz. Passive device performance, like that of taps and splitters, can be conservatively extrapolated from today's devices. The largest area of uncertainty is that of expanded bandwidth hybrid amplifier performance.

While 860 MHz amplifier products have been available in Europe for a decade, their performance specifications are not particularly useful given the disparity of the channel loading requirements between North American and European cable television systems. An approach that may be helpful in evaluating future plant upgrade options, is to design forward from the headend to the output of the optical node, and to design backwards from the customer's television set to an amplifier. Sensitivities to amplifier performance can then be evaluated and estimates made as to the performance improvement required over current 860 MHz European products. By assigning probabilities of success to the required improvements, a low risk plan to meet future performance and cost objectives can be developed.

Historical accomplishments in hybrid amplifier development provide some basis for conservative assumptions about future performance. While current 860 MHz hybrids are essentially single ended devices, it seems safe to assume that the development activity underway will be successful in producing an 860 MHz (or 1 GHz) true push-pull cascode hybrid. Once this activity has been completed, it follows that power doubling amplifier design can, at least, be duplicated by the "brute force" approach of physically using hybrids in a parallel configuration.

Discussions with hybrid manufacturers indicate that the development of 860 MHz or 1 GHz feedforward technology represents a significantly greater challenge. These manufacturers have also expressed doubt as to whether feedforward technology would be of value in high bandwidth systems of the future. They believe that cable operators will continue to reduce amplifier cascades through the deployment of fiber optic trunking. The complementary amplifier technologies would be ones with high output level capabilities, such as power doubling and quad power, but with lower distortion performance than is currently offered by feedforward. It is important to recall that a feedforward amplifier's output capability (compression point) is lower than that of a push-pull amplifier.

The following are guidelines that will maximize the chances that today's upgrade plan will be able to take advantage of future amplifiers.

-Where added reach from the node is needed, use 550 MHz 22 dB gain push-pull amplifiers spaced at a distance corresponding to 25 dB gain (power doubled) at 750 or 860 MHz.

-Use single cascade high output level line extenders (or distribution amplifiers) with an output split. In the future upgrade, these devices can feature dual active outputs.

-Use today's lowest technology in a way that results in high performance while meeting current cost objectives.

-Feedforward distribution amplifiers with 37 dB of gain should be used primarily where other, lower technology options are not cost effective.

If it becomes necessary to replace existing trunk amplifier or line extender housings, use new equipment featuring housing and platforms that have been designed for 860 MHz or 1 Ghz bandwidths.

Improving Reliability

The topic of improved reliability has been widely discussed in many industry forums during the last two years. One of the most straightforward means to improve perceived reliability is by shortening cascades. It is important to note that the value of shortening cascades applies not only to trunk amplifiers, but also to line extenders and even taps. The reliability improvements result from having fewer devices between the headend and the customers. The probability of an outage is proportionally reduced. Another parallel improvement in reliability comes by having fewer customers served by any critical device. A critical device could be defined as one whose failure would result in a total loss of cable television service to the customer.

Another way to improve reliability is to reduce the amount of plant where 60 Volt line power is present. Since a significant percentage of plant outages are related to powering or powering caused problems, by reducing the amount of plant required to carry line power, the probability of problems are reduced. In a short cascade node structured architecture, if power was removed from all tapped feeder lines, the reduction in the number of connectors that are required to pass power would drop to perhaps one half of the original amount.

Reducing and Simplifying Maintenance Needs

The following guidelines will reduce and simplify maintenance needs.

-Adopt a system architecture that features greatly reduced cascades (amplifiers, line extenders and taps). In this way the need for system sweeping activity can be effectively eliminated.

-Reduce the need for automatic gain control, and use exclusively amplifiers featuring plug-in pads and equalizers for level setting (ie., few or no remaining field adjustments). The need for system balancing and level set-up will be significantly reduced.

-Strive to power less of the plant. Power the rest of the plant more efficiently. With a reduction in the total number of power supplies, especially when stand-by power supplies are used (their contribution to perceived reliability is less with very short cascades), maintenance needs wil be reduced.

METHODOLOGY

Keep Options Open

In the upgrade planning process, there are no rules which require that a single architecture or approach be implemented exclusively throughout the area to be upgraded. It is important in the beginning not to exclude any options. A mix of two or three architectures, if careful planned, should not unduly complicate maintenance activities. In many systems, a single architecture simply cannot accomplish all the objectives stated earlier in this paper. The goal therefore might be to develop an upgrade plan that would result in as much plant as possible meeting all of the previously stated objectives. At the end of a 550 MHz upgrade project, if 60% of the plant can be further upgraded to 860 MHz in a simple manner (ie., a low cost amplifier module swap and a few added lasers), and the total project cost was competitive with all other 550 MHz upgrade options, capital funds will have been spent in an optimum manner.

It is useful to understand the strong points of each of the architectures listed below, and the degree to which each meets the previously stated objectives.

-Fiber Backbone (FBB)

This architecture was introduced by ATC in May 1988 at the National Cable Television Show in Los Angeles. [2] It involves the deployment of fiber optic nodes throughout the system in order to reduce amplifier cascades. A percentage of the trunk amplifiers upstream of the node location are turned around. Existing trunk bridger locations are usually retained. Feeder line rework will normally involve the re-spacing and addition of line extenders. This is probably the least costly approach if a drop-in module upgrade can be achieved that would retain existing trunk housings and locations. As a result of increased line extender cascades, and the use of feedforward trunk modules to provide the necessary gain and distortion performance to retain existing locations, this architecture will most likely require added fiber optic node locations, or major modifications to the coaxial plant when upgrading in the future.

-Cable area network (CAN)

This approach was introduced by Jones Intercable in late 1988. [3] It is similar to the Fiber Backbone Architecture except that all existing trunk amplifiers retain their original orientation (direction) in the cascade after the deployment of the fiber nodes. This gives the added benefit of an additional signal source to backup the fiber path at the node location. If the fiber optic cable feeding the node is cut, a switch in the optical node/bridger senses the loss of signal and switches from the optical detector output to the backup trunk RF signal. This architecture, which requires significantly more fiber nodes than a similar FBB approach for the same final number of trunk amplifiers in cascade, costs more to implement. Comments made regarding the ease of future upgrades to the Fiber Backbone Architecture apply equally to the CAN approach. Depending upon the distortion allocations as a result of future upgrades, the backup trunk feature of the CAN system may become ineffective due to severely degraded picture quality.

-Super distribution

This architecture was announced by Rogers Engineering in 1989. [4] A primary aspect of this architecture deals with the feeder line. It involves the adding of an express cable in parallel with the existing tapped feeder cable up to the last amplifier located at the end of the feeder line. The distribution amplifier used provides one output feeding the next amplifier in cascade and a second output for the feeder line. This second output feeds directly into a splitter which "backfeeds" and "forwardfeeds" roughly equal length tap strings. There are no requirements for power passing taps in this scenario since the feeder lines have no amplification beyond the amp located in the "express" line. The super distribution approach should allow for low cost module (or hybrid) upgrades in the future if the express line amplifiers are appropriately spaced to work with the higher bandwidth amplifiers of tomorrow. The cost for a 550 MHz upgrade using this approach may be higher than other possible solutions (550 MHz) since express cable would need to be overlashed on 60-70% of the total system distribution plant. The express line amplifiers used for 550 MHz can be relatively low performance/low cost since the spacings are quite modest at 550 MHz.

-Fiber to the feeder (FTF)

The Fiber to the Feeder architecture was first described by James Chiddix of ATC at the SCTE Fiber Optic Conference in Monterey California in early 1990. [5] The approach is a logical progression from the Fiber Backbone approach already described. An FTF architecture is a powerful option when existing trunk spacings consume a disproportionate amount of the "distortion budget". The coaxial reach after a FTF node can be increased by re-using existing trunk cable as express cable. Reach can also be increased by adding cable to allow the backfeeding of tap strings. The choice of distribution amplifier and/or line extender technology, and gain/output level capability also effects the reach from the node. The Fiber to the Feeder architecture is a very cost-effective solution for rebuilds, new builds, and those upgrades where simple drop-in amplifier module replacement is not possible. To facilitate further bandwidth expansions, without having to add additional nodes, a slightly different FTF configuration using up to three low gain distribution amplifiers in cascade followed by a single high output level distribution amplifier (DA) or line extender (LE), may be valuable. The latter configuration will be discussed in the analysis section of this document.

-Fiber to the service area (FSA)

This architecture, developed by Scientific Atlanta, [6] is similar to the FTF architecture previously described. It is essentially a multiple star approach. The homes served by a single optical node (the "service area") is limited to a specific maximum number. This number is based on future telecommunications service requirements. In the upgrade case, the optical node is the center of one distribution star. At least two other distribution stars are formed around existing trunk bridger locations. The bridger amplifiers are replaced with a distribution amplifier (with AGC) followed by an output splitter depending on the number of subsequent feeder legs. The former trunk cable is used to connect the node to the DA's at the centers of the distribution stars. As with all of the above mentioned architectures (except for super distribution and single cascade high output level LE/DA FTF), the requirement of additional fiber nodes exists when further expanding the bandwidth by a significant amount. Not unlike FTF, this is a cost-effective approach to 550 MHz upgrades.

Classify The Existing Plant

By classifying the existing plant of a given system into three categories before test design begins, the designer's time can be used more efficiently. The feeder line types are defined as follows:

-Short feeder lines, or long feeder lines where perpendicular access, in order to "break up" the feeder line into short feeder lines, is possible (the good)

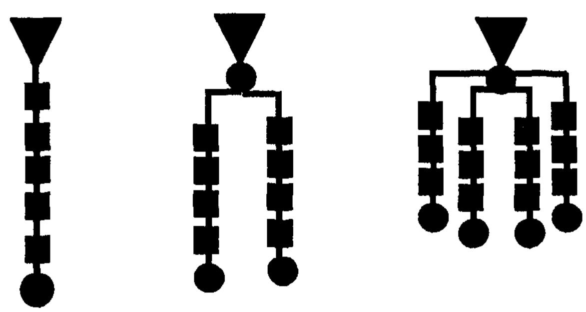
-Long aerial feeder lines (eg. already three plus line extenders in cascade at 300 MHz) with no perpendicular access (the bad)

The Benefits of Output Splitting

-This diagram shows how output splitting after the line extender lowers amplifier cost per mile. This savings can pay for added express cable using single cacade high ouput LE FTF architecture, or for added backfeed cable in other approaches.

Key Parameters

- **Cable- .412 Standard**
- **150' tap spacing**
- **Power Doubled Line Extender**
- **40/49 dBmV Output Level**
- **55/550 MHz**
- **11 dBmV min. tap output**



# Tap Ports	20	36	56
Total Footage	750	1,500	2,400
Amplifier Cost/Tap Port	$ 11.50	$ 6.38	$ 4.10
Amplifier Cost/Mile	$ 1,619	$ 809	$ 506

LE cost = $230 # tap ports/ mile = 126 ==> 100 homes/mile

Diagram 1

-Long underground feeder lines (eg. already three plus line extenders in cascade at 300 MHz) with no cost-effective perpendicular access (the ugly)

It is also important to note the amount of trunk cable present in different parts of the system. While a poor trunk to feeder ratio may have added to the initial construction costs, the presence of "extra" trunk cable today can further reduce the implementation costs of an FTF or FSA type architecture. All of the existing trunk cable can be used either as express cable, or in some cases, a low loss feeder cable.

Use Of A Building Block Approach

It may be useful in the analysis to segment each major component of the system into layers. Possible layers might include:

-The AML microwave link

-An AM fiber super trunk out to a secondary hub (or optical repeater site)

-The AM fiber optic distribution system

-The coaxial trunk, or dedicated express cable, and its amplifiers (if used)

-The distribution amps or line extenders

-The tapped feeder line

Once the layers have been defined, one should establish a first cut performance requirement. One can then confirm that each piece will fit together in a way that meets end of line objectives. Plant cost components may then be analyzed for each scenario, or architecture approach. In this way, cost sensitivities can be developed for the various plant components.

ANALYSIS

Design Observations

Diagram 1 illustrates the potential savings

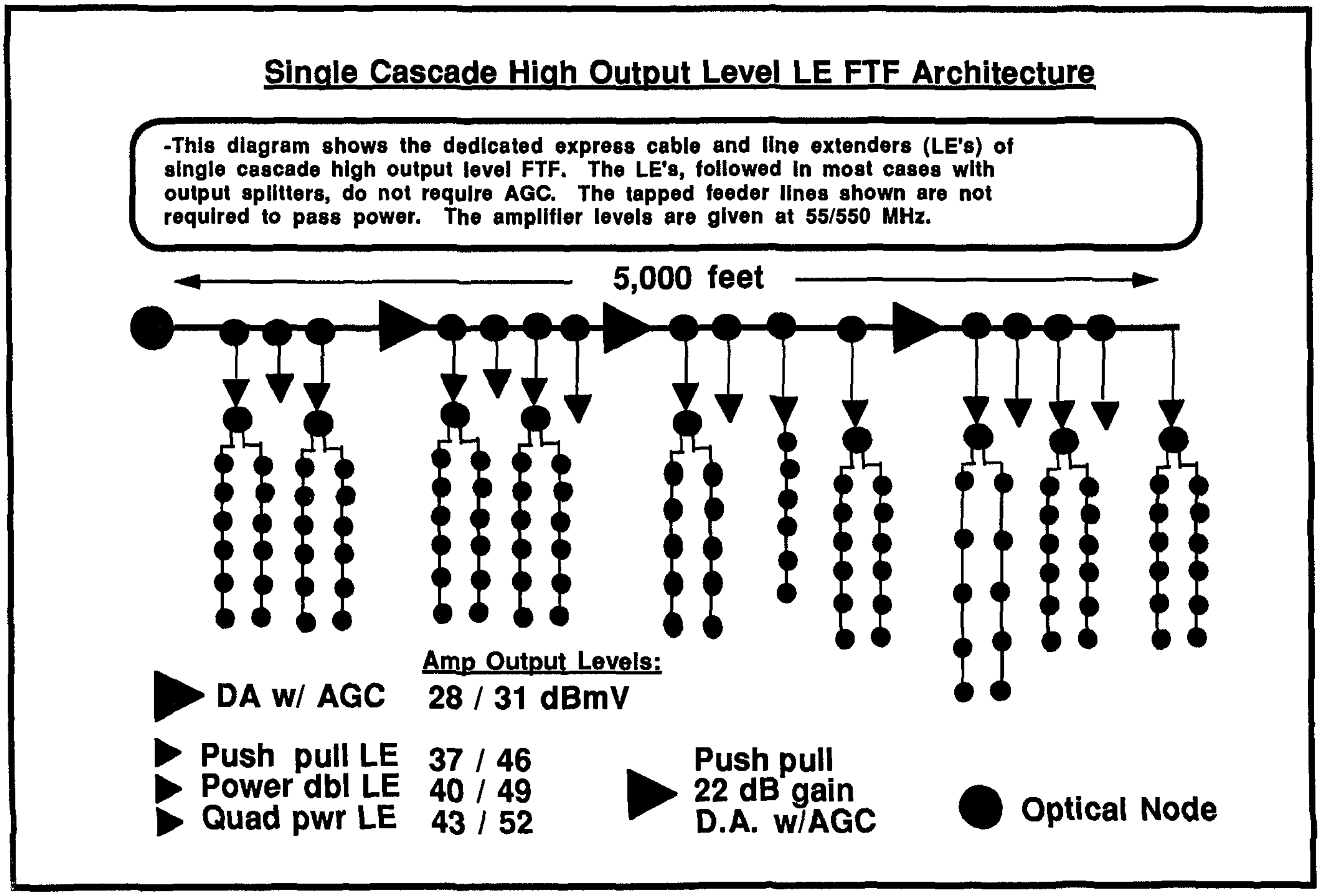


Diagram 2

offered by output splitting of a line extender. Feeder line backfeeds in an FTF or FSA architecture take advantage of this concept to improve reach, and/or minimize feeder electronics. This idea is a key component of the super distribution architecture. Diagram 1 shows three line extenders each operating with the same 49 dBmV output level at 550 MHz. The feeder cable used in each of the feeder strings was .412" standard cable, which has a 550 MHz attenuation specification (measured) of 2.9 dB/100'. The cost of the line extender was assumed at $230. The line extender costs per mile associated with each of the three scenarios are indicated in the bottom row of the diagram. The benefit of using feedforward distribution amp plus a power doubled line extender. If complete stations must be replaced as part of the upgrade plan, there may be ways to save money using a different approach.

A factor to be considered is the price performance ratio of distribution amplifiers versus line extenders. Distribution amplifiers typically have added features and higher prices when compared to line extenders. Where ouput splitting is not required, and the amplifier does not need AGC, the added cost of a DA may offer little in return.

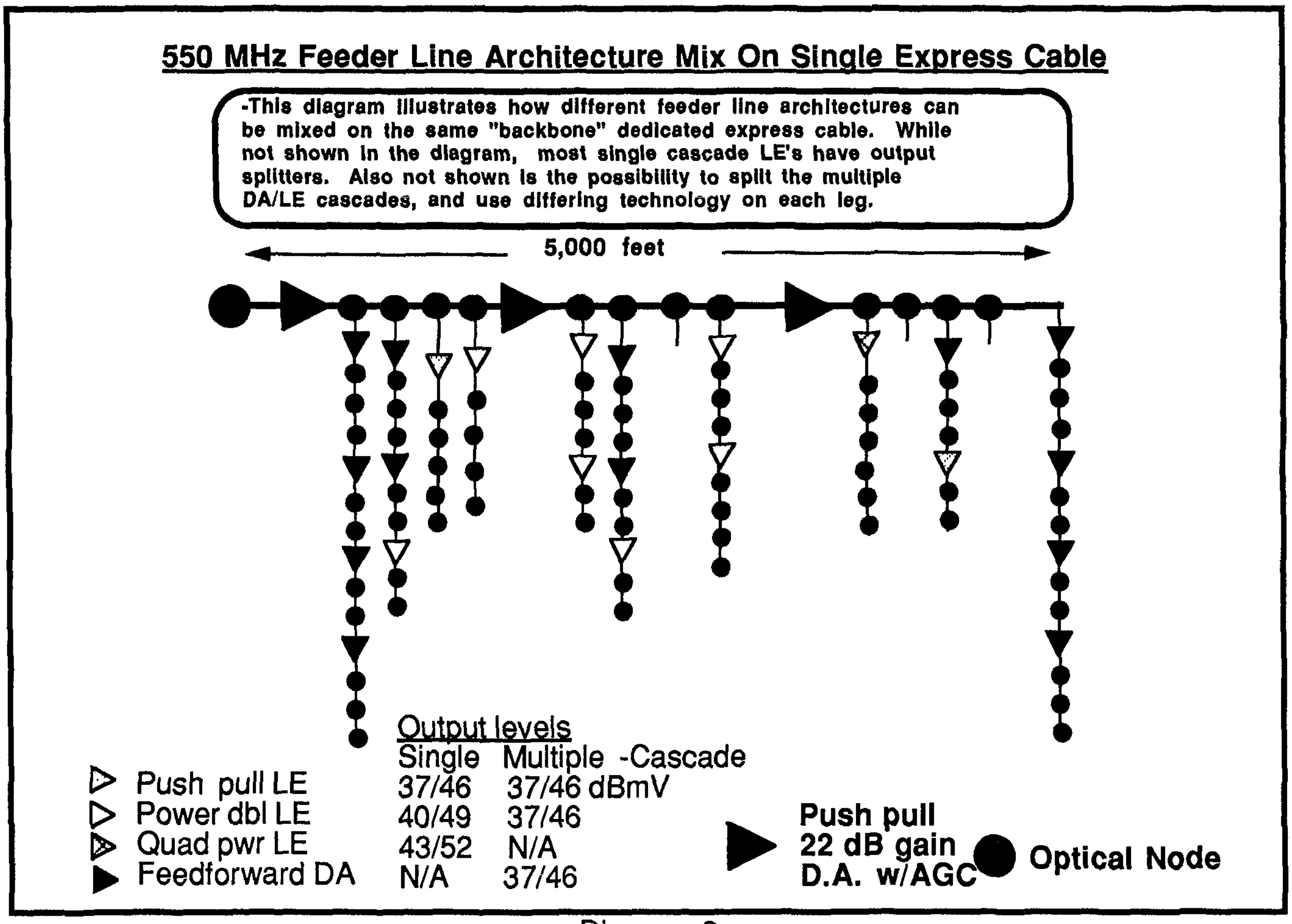


Diagram 3

output splitting is evident.

Another observation concerns the cost of a trunk amplifier station, and its alternatives. With many vendors, the price of a feedforward trunk power doubled bridger station is approximately 50% more expensive than the combined cost of a

Express cable size can significantly influence the maximim reach from the node, there by driving the maximum amount of distribution plant fed by the node. It is important to understand all of the associated cost trade-offs when selecting express cable sizes or types.

In lower density construction, the potential cost savings as a result of using low fiber count optical cable, as compared to "trunk" size coaxial cable may be suprising.

Flexible Architecture and Design

After spending considerable time evaluating how different architectures would fit in a "severe" upgrade, it became apparent that while a given approach was cost effective for one portion of the system, something else worked better in other areas. A severe upgrade in this case is defined as one where even three power doubled line extenders could not reach the end of existing feeder lines. (Remember the good, the bad, and the ugly types of feeder lines mentioned earlier).

Conceptually, it seemed as though an architecture met all of the objectives outlined at the beginning of this paper. The architecture that held the most promise was the single high output level DA/LE version of FTF, shown in Diagram 2. While this approach worked well for the areas of plant consisting of "good" feeder lines, it became apparent that it would not work at all with long underground ("ugly") feeder lines. Implementing this approach on long aerial feeder lines where no perpendicular access was available, would result in a feeder line that resembled the super distribution approach. As previously mentioned, the super distribution approach is somewhat more expensive today as a result of the amount of added cable. Like single cascade high output level DA/LE FTF, super distribution allows cost-effective, minimally disruptive upgrades in the future .

To address the challenges presented by different types of feeder lines in close proximity to one another, the mixing of single cascade high output level LE's (or DA's) with multiple LE (or DA) cascades was considered. Both the single

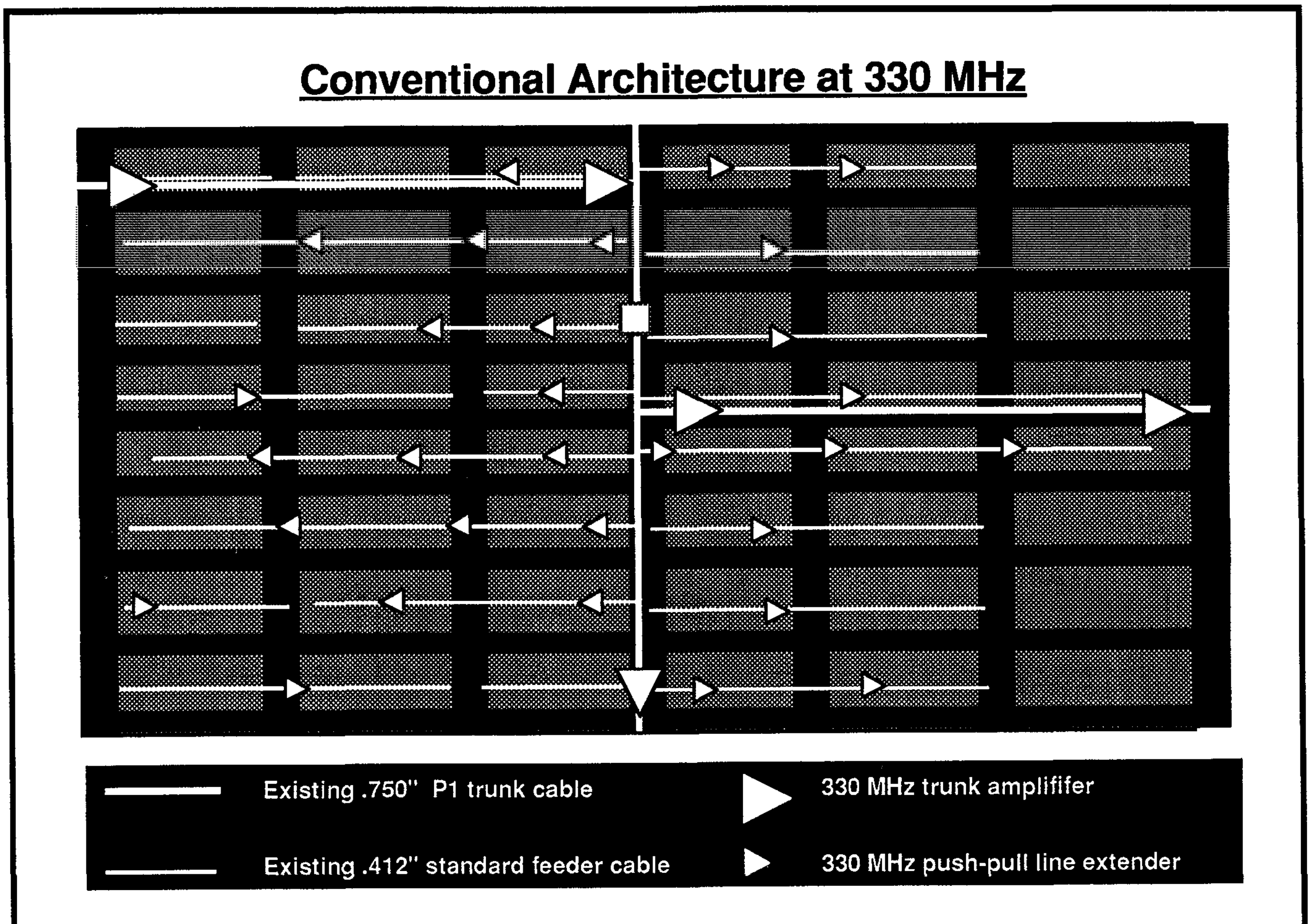


Diagram 4

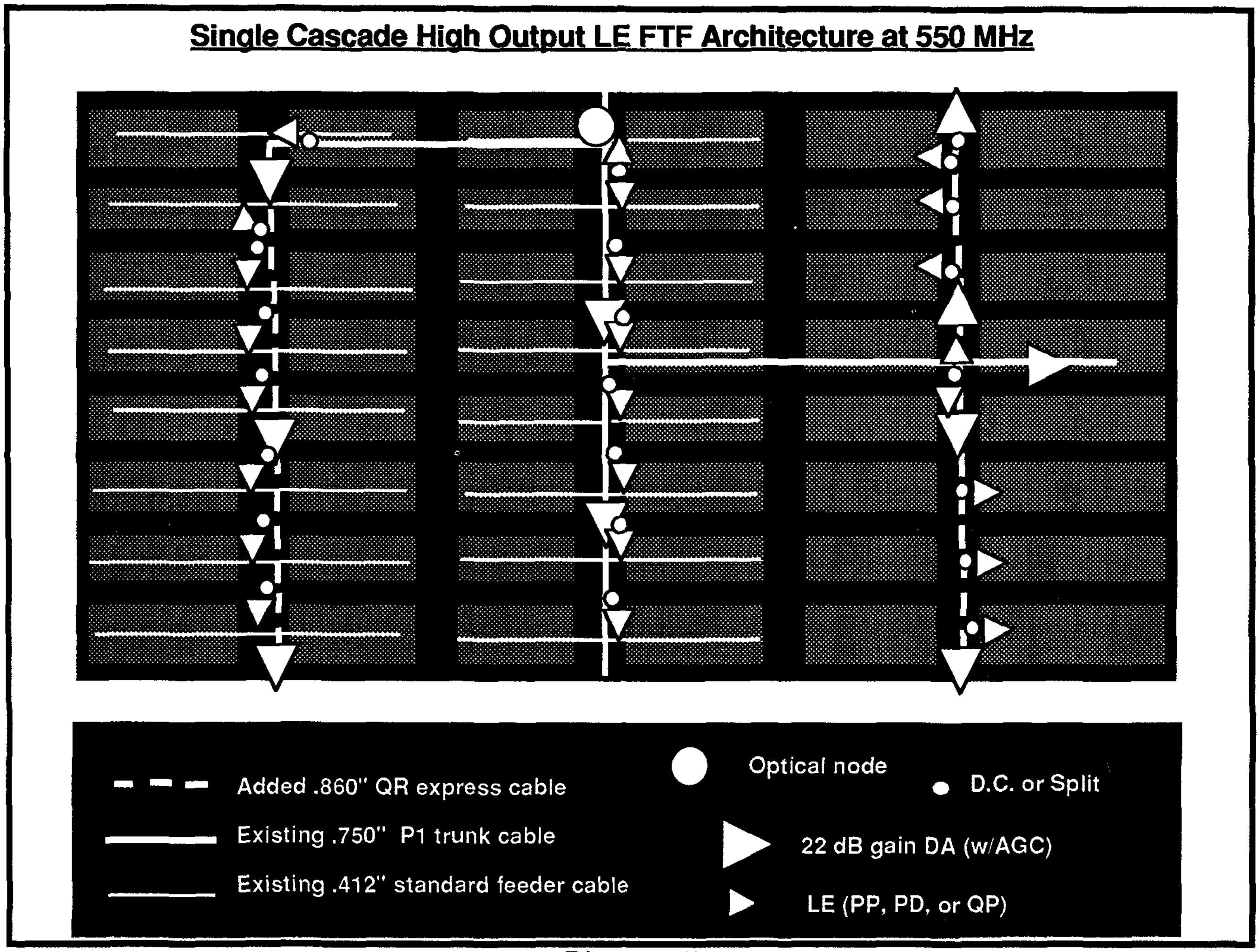


Diagram 5

cascade DA/LE and the multiple DA/LE cascades would be fed by directional couplers from a "backbone" type dedicated express cable (or former trunk cable). This approach is shown in Diagram 3. The option of having up to four LE/DA's in cascade would have allowed the longest underground feeder line (currently three power doubled LE's in cascade at 330 MHz) to be upgraded to 550 MHz in a most cost-effective manner.

In a significant number of cases, however, it was both cost-effective and possible to break existing feeder lines in half by adding an express cable perpendicular to the tap string. At the intersection of the express cable and the feeder line, a line extender (fed by a DC on the express cable) with a two way output splitter would have been installed. Diagram 4 shows the plant layout before the upgrade. Diagram 5 shows the plant after the implementation of single cascade FTF design.

In examining how to upgrade the long aerial feeder lines (the "good"), several conclusions were reached. Backfeeding offered a cost-effective means to reduce the number of line extenders required. In the absence of backfeeding, a cascade of four feedforward DA's would have been requied. Upon closer examination, however, the amount of cable to be added at each of the DA locations was equal or greater than the amount of added express cable required to "break-up" the feeder line. In some cases, strand was available on the future perpendicular express cable runs. In other cases, pole lines were available but stranding would have been required.

Diagram 6 compares the cost of a four feedforward DA cascade with two output split single cascade power doubled LE's. By using the latter of the two approaches, the savings in feeder line electronics cost would clearly pay for some additional express cable. The amount of express

Feeder Line Electronics Cost Comparison at 550 MHz

Parameter	Feeder A	Feeder B
Reach	3,000'	3,000'
Tap Ports	72	72
Tap Output	11 dBmV	11 dBmV
Cable Type	.412 STD	.412 STD
Amp Type	FdFwd	Pwr Dbl
Amp O/P	37/46	40/49 dBmV
Qty. Used	4	2
Unit Cost	$ 450	$ 230
Amp. Cost	$ 1,800	$ 460
Cost/Mile	$ 3,168	$ 810

By using the distribution architecture depicted in feeder line B, as opposed to that in feeder line A (conventional approach), the reduction in LE/DA cost

= $ 2,358 per mile

The savings in electronics pay for the added express cable in single cascade high output level LE FTF designs.

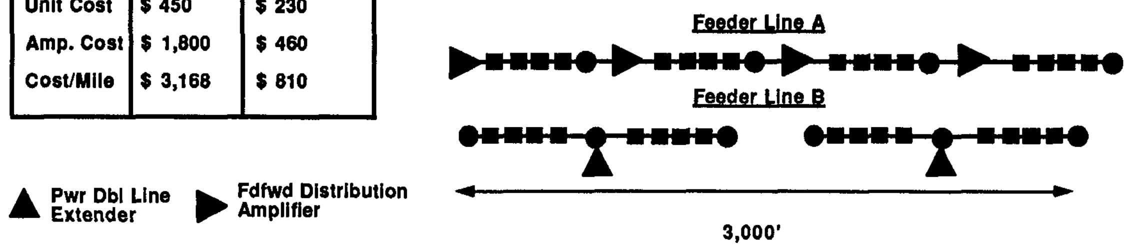


Diagram 6

cable required to implement the single cascade FTF design must be determined in order to compare the total cost of each option. In one upgrade study, approximately 1,000' of .750" express cable per plant mile would have been required.

Design tests with both backfeeding and dedicated express cable/single cascade FTF should be performed on feeder lines in different areas of the system to determine if cost savings are available over conventional approaches.

The goal of the single cascade high output line extender was to feed taps located in the blocks on either side of the added express cable, as shown in Diagram 5. Designing backwards from the end of each block revealed the output level requirement for the line extender. The next step was to select a line extender/DA that would provide the output level required with the lowest technology and cost. The last three rows in Diagram 7 show the output level of a single cascade LE/DA based on a given technology. All output level and cummulative performance specifications shown in Diagram 7 assume an AM fiber optic link and a three DA cascade preceeding the listed amplifier(s). The optical trunk performance used was C/N = 50 dB, CTB = 65 dB, and CSO = 62 dB. The three distribution amplifiers used in the dedicated express cable were 550 MHz, 22 dB gain, push-pull type amplifiers with AGC, operating with an output level of 31 dBmV.

The first four rows of Diagram 7 show the output levels for some of the possible combinations of differering technology LE/DA's. It is important to note that an output level of 46 dBmV was possible for one single LE/DA as well as for two, three, and four DA's in cascade. In addition to the consistant output levels, the end of line performance specifications were almost identical. By selecting the lowest technologies possible for the required cascade, the cost of feeder line electronics (LE's and DA's) can be held to a minimum.

In the version of single cascade high output level DA FTF shown in Diagram 8, the dedicated express cable was fed by a high output level optical bridger. The maximum reach (between the node and the last LE), with the directional couplers installed to feed the single cascade LE's, was approximately 2,500'. As a result of this reach, the amount of plant fed by this node was less than required to be truly cost-effective. Another drawback was the significant

Mixed Feeder Line Architecture Amplifier Output Level Table (550 MHz)

Equipment cascaded	O/P 1	O/P 2	O/P 3	O/P 4	C/N	CTB
FF+FF+FF+FF	37/46	37/46	37/46	37/46	47	53
FF+FF+PD	37/46	37/46	37/46		47.3	53
FF+PP	37/46	37/46			47.6	53
PD+PD	37/46	37/46			47.6	53
PUSH-PULL (PP)	37/46				48	53
POWER DBL (PD)	40/49				48	53
QUAD PWR (QP)	43/52				48	53
FEEDFORWARD (FF)	N.A.					

The output levels shown for each type of amplifier and for its position in cascade, as well as the cummulative carrier to noise ratio (C/N) and CTB performance indicated, assume that the feeder line is attached to the end of a three DA cascade which is fed by a fiber optic node with the output specifications of C/N = 50 dB, CTB = 65 dB, and CSO = 62 dB. The three DA's in cascade are 22 dB gain, 550 MHz , push-pull type amplifiers with AGC, and with a nominal output level of 31 dBmV.

Diagram 7

cable spacing between the node and the last LE. Depending on the range of temperature variations, it may have been necessary to use a DA with AGC to keep output levels within the desired window. This cable spacing would also have created difficulties when upgrading to 860 MHz or 1 GHz. By using a trunk output level from the node, and up to three 22 dB gain DA's (with AGC) in cascade in the dedicated express cable, the requirement for AGC in the single cascade line extenders has been eliminated, and the cable spacing issue at higher bandwidths resolved.

CONCLUSIONS

It is hoped that the reader will have drawn two primary conclusions from this paper. The first conclusion being that it is possible to intermix at least two different types of feeder line architecture, fed by the same dedicated express cable, without requiring 20 different output levels. The resulting product can be one that is cost-effective today, while minimizing tomorrow's upgrade cost for a significant portion of the plant.

The second conclusion relates to the inherent advantages offered by the single cascade high output level DA/LE FTF architecture. To summarize the advantages offered by this architecture:

Unpowered, Short Tap Cascades

By removing the power passing chokes from current taps, the bandwidth can be increased to 860 MHz or 1 GHz with low development costs. In this process, the maximum tap insertion losses are expected to drop back to those specifications currently found at 400 MHz. These taps, if available today, would allow a future upgrade to 860 MHz with little disruption to the feeder line. By simplifying the taps, it is hoped that pricing will decrease, or at least, remain constant.

The Single Cascade High Output Amplifier

In the proposed FTF configuration, the requirement for amplifier AGC would be eliminated except for the few low gain express cable Distribution Amplifiers. Not only will this increase

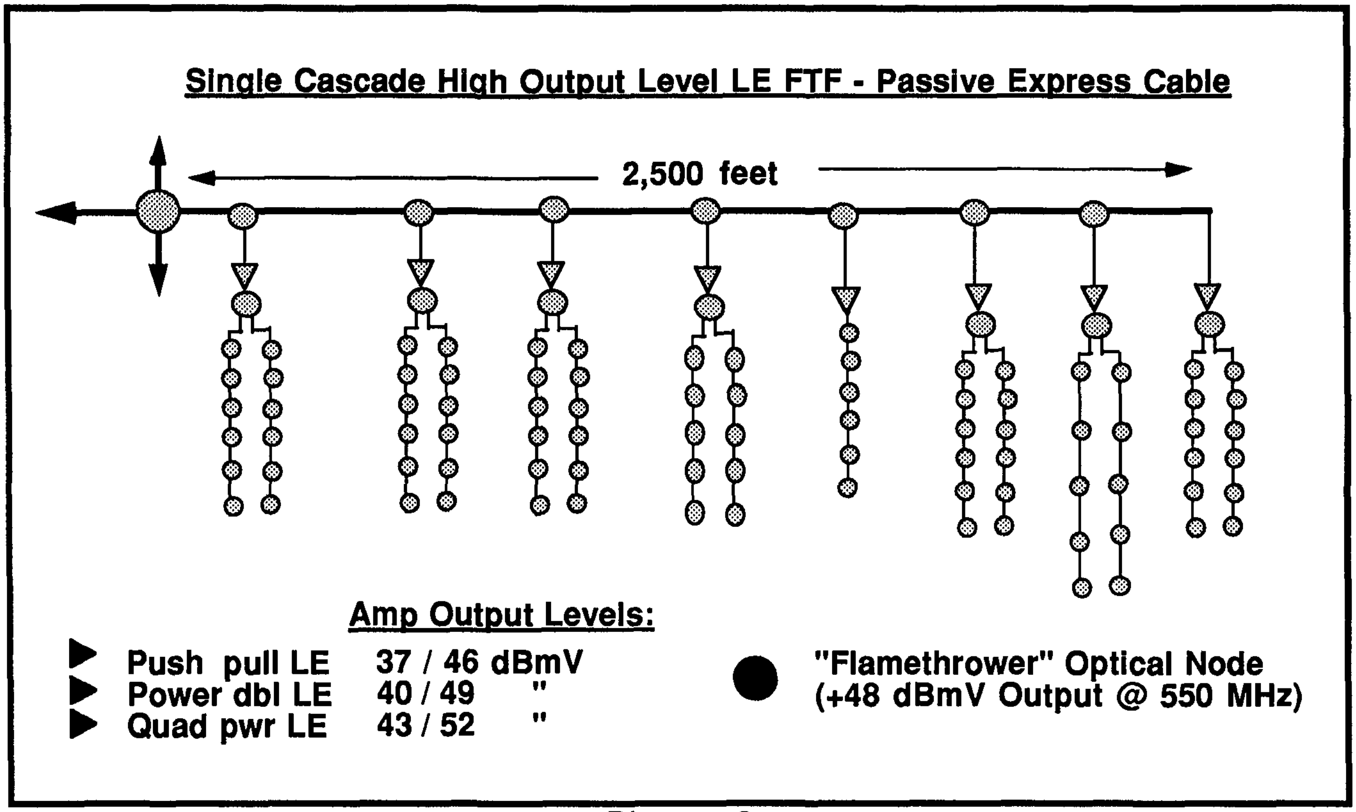


Diagram 8

amplifier performance and gain as a result of lower interstage losses, it will also improve amplifier stability thereby reducing maintenance requirements. By eliminating most LE/DA AGC requirements, the total cost of feeder line electronics can be significantly reduced.

With the LE's or DA's fed directly by a .750 or larger express cable, the power consumption should be less than in conventional plant. In addition, since relatively high output levels can be obtained from push-pull technology amplifiers, further reductions in power consumption can be obtained.

The fact that the express cable spacings are targeted at 22 dB (550 MHz) in addition to using low technology amplifiers whenever possible, this architecture ensures a low cost, minimally disruptive path to higher bandwidths.

Cable Use

Significant amounts of fiber optic cable would be installed when using this FTF architecture in a system upgrade. A moderate amount of coaxial cable, for dedicated express runs or backfeeding purposes, will also be added. By allocating more of the upgrade funds to the purchase of these "unlimited" bandwidth passive components, which can be reused for many years, the percentage of plant assets that may become technically obsolete (in the event of further upgrades) before being fully depreciated is reduced.

SUMMARY

When specifying how to best use available capital to upgrade a system to 550 MHz, the engineer will be faced with many options. Given the increasingly competitive nature of our industry, the long term impact of today's decisions must be carefully evaluated.

The challenge is to select an architecture that will assure the smooth, low cost evolution of today's cable television systems into tomorrow's high performance communications networks, while conserving the shrinking supply of capital funds.

References-

[1] J. A. Chiddix and J.A. Vaughan, "Upgrading Coaxial Distribution Networks with Amplified Taps," *NCTA '91 Tech. Papers*, 1991.

[2] J.A.Chiddix and D.M. Pangrac, "Fiber Backbone: A Proposal for an Evolutionary CATV Network Architecture," *NCTA '88 Tech. Papers*, 1988.

[3] Robert Luff, "The Broward Cable Area Network fiber model," *Communications Engineering Digest*, February 1989, Page 27.

[4] G. Hart and N. Hamilton Piercy, "Rogers fiber architecture," *Communications Engineering Digest*, July 1989, Page 44.

[5] David M. Pangrac, "Fiber trunk and feeder: ATC's new architecture," *Communications Engineering Digest*, May 1990, Page 28.

[6] Robert C. Loveless, "Fiber to the Feeder: A Star Architecture," *SCTE 1991 Fiber Optic Conference Tech. Papers*, 1991.

Biography

Jay A. Vaughan currently holds the position of Senior Project Engineer with American Television and Communications. In September 1990 Mr. Vaughan returned to the United States after a two year assignment in France where he was involved in the engineering and construction of 860 Mhz cable television systems.

Prior to his overseas assignment he held the position of Project Engineer with ATC. Mr. Vaughan has also worked for Rogers Communications, Jerrold Electronics, and others during his fourteen years in the cable television industry. He received his BSEE in Electrical Engineering from the University of Texas in Austin in 1981.