AM OPTICAL BRIDGER NETWORKS FOR CATV

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Abstract

In its application of AM fiberoptic technology to supertrunks and to segmentations of trunk cascades, the cable TV industry has gained an appreciation for the performance and reliability features of this technology. It has become increasingly clear, however, that CATV distribution architectures other than the traditional tree and branch might be needed in order to fully exploit the advantages of fiber technology. This paper describes and discusses one of the most promising of these new architectures -- optical bridgers -- which permit widespread deployment of fiber in new-builds and substantial rebuilds without incurring a cost penalty. In an optical bridger network the CATV trunk is completely eliminated and each fiber receiver feeds a multiple-output RF bridger directly. With no trunk cascade, wide-area distribution can be made through four or five high-level amplifiers without compromising end-of-line performance. Using specific examples, this paper will review the properties of optical bridger architectures and will discuss hardware implications, such as selection of hybrid amplifier type.

BACKGROUND

Following the lead of a few key individuals, the CATV industry has embraced fiberoptic technology and has caused a remarkably rapid development of the components needed for AM transmission of video over glass fiber. Thus, at the beginning of 1990 there were only a small number of AM fiberoptic nodes in place within our industry, but by the end of the year the number in service was between 500 and a thousand. To a CATV industry accustomed to coax systems having RF amplifiers approximately every 3000 feet, the attractiveness of a transmission medium that offered ten to twenty mile unrepeatered spans was obvious. Prior to the development of the AM technology, however, those spans were achievable only by FM techniques, whose conversion costs were so high that widespread usage was unthinkable.

In the initial AM fiber transmission installations, of course, the equipment was also expensive, as is the case for most new technologies. Hence those installations tended to have specific attributes that made them more tolerant of high equipment costs. Typical of these first applications were supertrunks to combine headends in adjacent franchises or to break up conventional trunk cascades that had grown overly long and unreliable due to extensions. In addition a number of installations were pursued in part to test the emerging AM fiber technology and to develop experience, which in turn tacitly assumed that as time went on the AM fiber equipment would become more and more cost-effective.

In actuality, with increasing volume and manufacturing experience, the cost of an AM fiberoptic link has decreased dramatically during the past year. The price of an AM laser transmitter, which dominates the link equipment, has decreased from around $25,000 to the vicinity of $15,000. At the same time the distortion performance and output power of these transmitters has improved significantly, thus making high quality links more and more commonplace. Notwithstanding these strides, however, the costs of an AM optical link remain greatly out-of-line for an industry that generally measures equipment unit costs in tens and hundreds of dollars. Hence widespread deployment of AM fiber within the industry's traditional tree and branch network architecture was questionable.

Approximately one year ago, however, the industry began to give serious consideration to non-traditional architectures for CATV. In particular, multi-level star architectures were proposed by ATC at last year's SCTE fiberoptics conference in Monterey[1]. Soon afterwards our company announced its Flamethrower optical bridger and all at once it appeared that everyone was talking Fiber-to-the-Feeder, Fiber-to-the-Bridger or some other variant on the same theme. In any of these systems the conventional trunk amplifier cascade is eliminated and is replaced by multiple optical fiber links that feed coaxial cable stars, which provide extensive distribution to subscribers. At the heart of the excitement generated by these systems is the fact that the multi-level RF star distribution spreads the laser transmitter cost over a large number of households. Thus the per-subscriber cost of the optical link becomes much less of a barrier to deployment and the advantages of AM fiber performance and reliability become more generally accessable.

This paper will describe several optical bridger networks and will indicate the reasons for their cost-effectiveness. In addition, options for the choice of amplifier hybrids to be used in this equipment will be discussed.

OPTICAL BRIDGERS

Four-amplifier

As an introduction to the subject, we will consider a 4-amplifier optical bridger network, as shown schematically in Figure 1. One notes immediately the multiple-star arrangement: numerous optical fiber runs radiate out from the headend to various neighborhoods (A, B, C, etc), terminating in optical bridger node stations. Each optical bridger station consists of an optical receiver and a multiple-output rf bridger amplifier, which is a hub of one of the secondary stars. Multiple strings of up to three line extender amplifiers radiate out from each bridger.

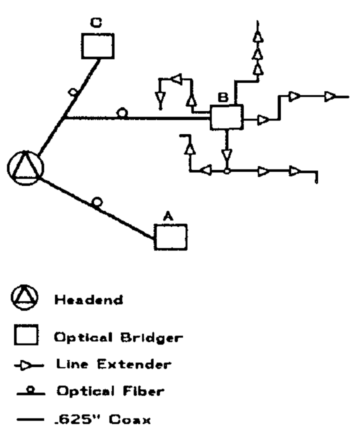


Figure 1. Four-amplifier Optical Bridger Distribution Network

In the 4-amplifier network no subscriber is more than four active devices away from the headend (one bridger and three line extenders). If we look in detail at one complete path between headend and end-of-line, as diagrammed in Figure 2, we can evaluate the performance of this network (Table 1). This performance assumes power doubler hybrid technology and does not utilize roll-back from the line extenders (using more than 150' of cable in the last tap span before a line extender). Since the optical link can provide 52 dB CNR over a 10 dB optical loss budget, the optical bridger node can be as much as 16 miles from the headend, which means that it can deliver end-of-line performance far in excess of that which could be achieved with a conventional trunk and feeder architecture -- even with feedforward trunk amplifiers (Table 2). Since the signal distortions resulting from the optical link are better than from a typical long cascade, one is able to feed three line extenders rather than the conventional two, thereby increasing the radial reach out from the optical node to approximately 3150 feet. In comparing Tables 1 and 2 one should note how the noise and distortion build-up is more or less equivalent from each segment of the optical bridger path, whereas in the long cascade tree-and-branch the trunk predominates in both signal degradations.

In this example one can see how the multiple-star architecture with optical fiber provides high signal quality and generous reach.

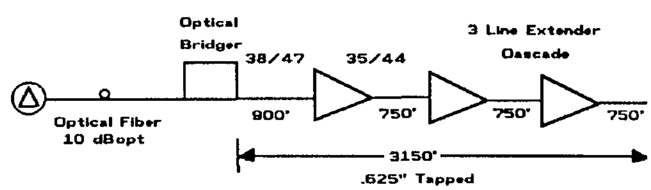


Figure 2. Four- amplifier String

Five-amplifier

In order to gain an added appreciation for the potential of the optical bridger type of architecture we can examine what happens when an additional star layer is inserted in the form of express feeder legs between each optical receiver and multiple-output bridger (Figure 3).

Table 1. Four-amplifier Optical Bridger Performance (550 MHz Power Doubled Amplifiers)

	CNR @ 50 MHz	CNR @ 550 MHz	CTB	XMOD
Fiber Receiver (10 dB loss budget, 40 channels/fiber	52	52	-65	-65
Optical Bridger	63	67	-64	-67
Line Extenders (3 Cascade)	56	56	-61	-64
End-of-line	50	50	-54	-56

Table 2. Trunk and Feeder (550 MHz Feedforward Trunk and Power Doubled Distribution)

	CNR	CTB	XMOD
Trunk Amplifiers (33 Cascade)	44	-58	-60
Bridger	65	-65	-66
Line Extenders (2 Cascade)	57	-67	-70
End-of-line	44	-53	-55

Table 3. Five-amplifier Optical Bridger Performance (550 MHz Power Doubled Amplifiers)

	CNR @ 50 MHz	CNR @ 550 MHz	CTB	XMOD
Fiber Receiver	52	52	-65	-65
Optical Bridger	64	62	-70	-71
High Output Bridger	60	62	-65	-68
Line Extenders (3 Cascade)	56	56	-61	-64
End-of-line	50	50	-53	-55

This is accomplished by operating the optical bridger node at somewhat reduced output levels, and feeding a second multiple-output bridger with nearly 2700 feet of untapped .875" coaxial cable (the "express feeder"). By comparing the performance of this 5-amplifier system (Table 3) with the 4-amplifier optical bridger (Table 1), one can see that the half-mile increase in reach has been achieved with nearly imperceptable degradation to end-of-line performance.

Since that reach extends in a number of different directions (limited, of course, by the local distribution of subscribers) one can see that each optical receiver node has access to all homes within a radius of approximately 1.1 miles. Alternatively one can view this system as covering areas of almost four square miles that are located as much as 16 miles away from the headend.

ECONOMICS

As has already been stated, one of the key aims of the optical bridger architecture is to minimize the cost impacts of the relatively expensive optical link by maximizing the number of end-users served by each node. Optical bridgers can do this well when the multiple output capabilities can be used to fan-out effectively. Thus a realistic economic evaluation of this architecture must be system-specific and can be done only with actual system maps.

In one sample system design performed recently for a 90 sub/mile operator, nearly 25 miles of plant (2200 subscribers) could be served from a single optical bridger node, with 50 dB CNR, 53 dB CTB and 59 dB CSO at the tap. If a single fiber link were devoted to that node (i.e., there were no optical splits to other nodes) then the optical transmitter and receiver would cost less than $7 per sub. Note, as well, that the amount of large cable for express feeder (750" in this case) was less than 9% of the cable used, so there were no unusual costs buried in the design.

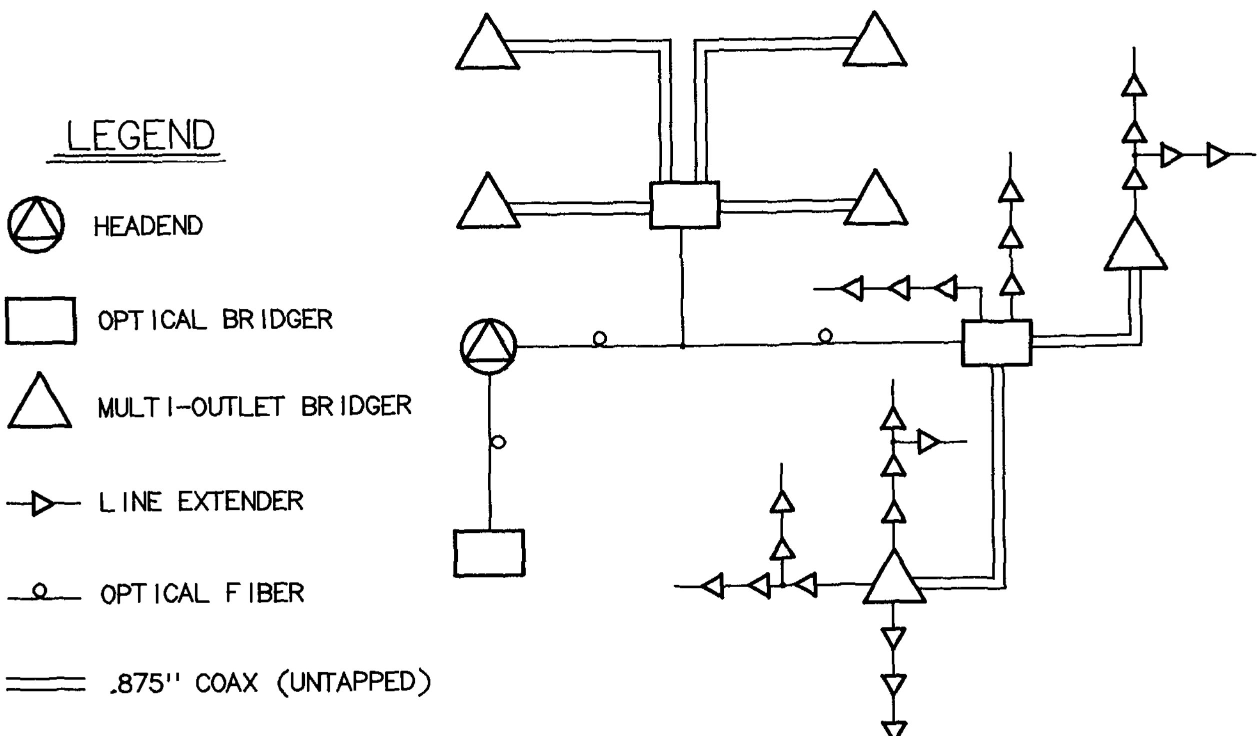


FIGURE 3
FIVE-AMPLIFIER OPTICAL BRIDGER DISTRIBUTION NETWORK

Clearly not all systems will be as fertile for optical bridger network designs as that one. Experience indicates that relatively dense operations (approximately 50 subs/mile or greater) offer the most ready opportunities for exploiting the multiple star achitectures. Furthermore one must recall that one of the early attractions of optical fiber was its ability to segment a CATV system for reasons of customer service and marketing. Thus there are extremes of fan-out that may be undesirable despite their attractively low equipment costs.

AMPLIFIER HYBRIDS

All of the optical bridger designs described so far have employed power double hybrid technology. In this final section we will discuss the relative advantages of using feedforward technology for the amplifiers in these multiple-star networks. Three single string designs are shown schematically in Figure 4, representing one maximal coax path in optical bridger networks employing different hybrid types. All of these stri ngs will deliver the same end-of-line performance: 50 CNR, 53 CTB and 54 XMOD. (The fiber link is omitted from the diagrams but not from the performance calculations.) In each case, the express feeder cable is .875" and all other cable is .750" . Tap separations are a uniform 150' and no roll-back is included.

The first diagram shows that a five-amplifier string using feedforward bridgers can attain a 6250' length (1.2 miles) with 25 tap locations. When power addition technology is used, as in Figure 4b, the maximum reach drops by 6.6% and has four fewer taps. Interestingly, Figure 4c shows that a four-amplifier string utilizing feedforward bridgers can actually reach nearly as far as the five-amplifier string in 4a -- by virtue of its very long express feeder leg -- but has only 18 tap locations.

In many actual system designs, however, single-string reach is likely to be a misleading measure of value. This is because the cost-effectiveness of the optical bridger architecture is based largely on the number of fan-outs that it makes possible. Because of the cost and the power dissipation of feedforward amplifier hybrids, it is not possible to install numbers of these modules within one CATV amplifier housing.

Thus multiple branches can be provided only by splitting the output of a single hybrid, which decreases the operating levels. Power addition hybrids, on the other hand, can be associated on a one-for-one basis for each output port, thus permitting multiple high-level outputs.

Furthermore, it has been shown[2] that distortion performance of feedforward hybrids degrades rapidly and unpredictably at levels approaching 50 dBmV (Figure 5). This is not surprising since those hybrid modules were designed for application to trunk amplifiers, which operate in the vicinity of 36 dBmV. The importance of this observation, however, is that the end-of-line distortion performance of the high level feedforward amplifiers will be very sensitive to operating level changes. This, in turn, may mandate the use of AGC circuits for the feedforward units. This is unfortunate because one of the features of the optical bridger architecture is the lack of a clear need for AGC, due to the short cable lengths involved. These considerations are summarized in Table 4.

Table 4. Comparison of Hybrid Amplifier Technology for Optical Bridgers

	Feed Forward	Power Double
Cost	≈$100 addition per hybrid	--------
Coverage	Longer reach in straight-line with single string	Larger span, due to multiple high level outputs
AGC	Needed	Optional

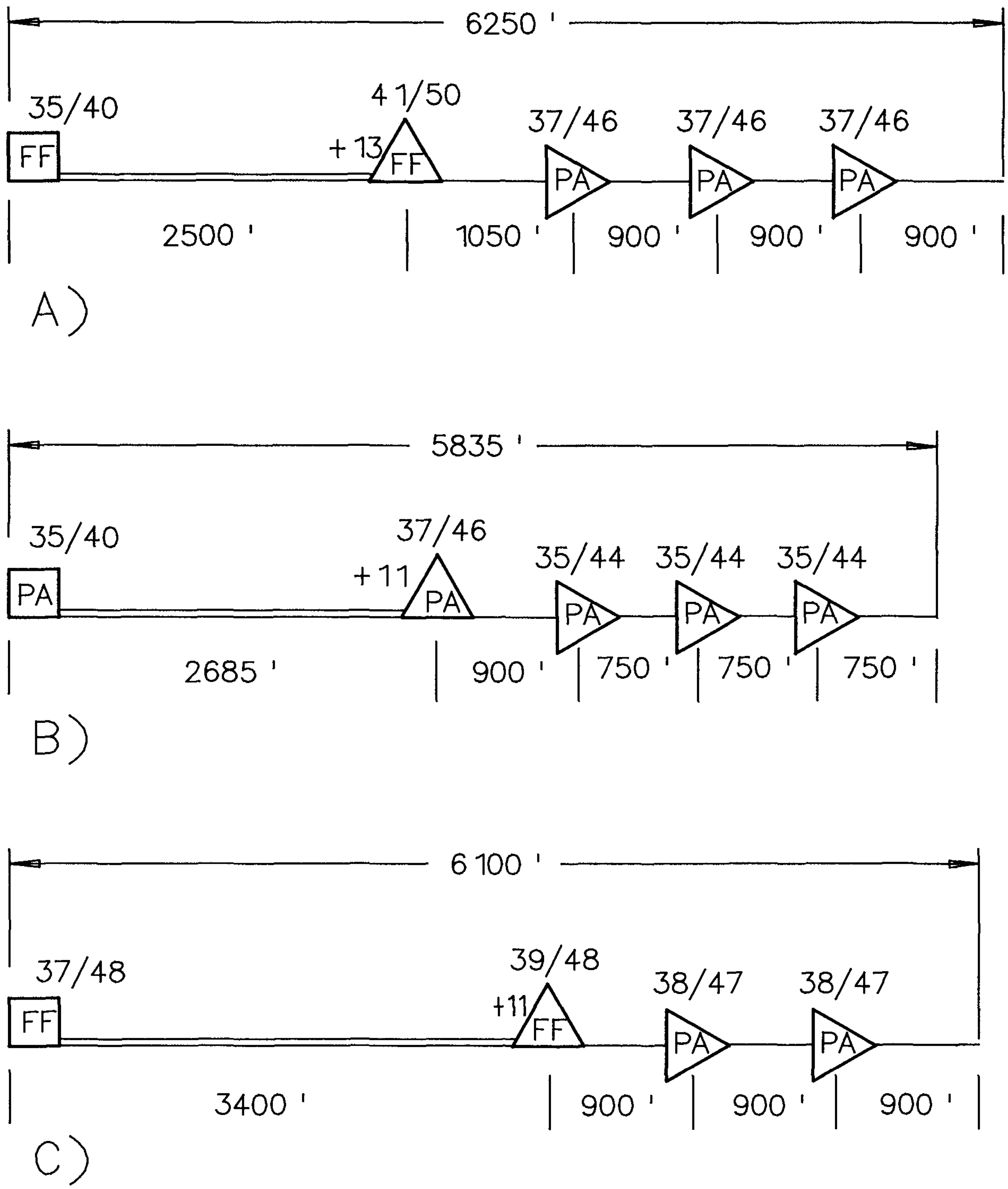
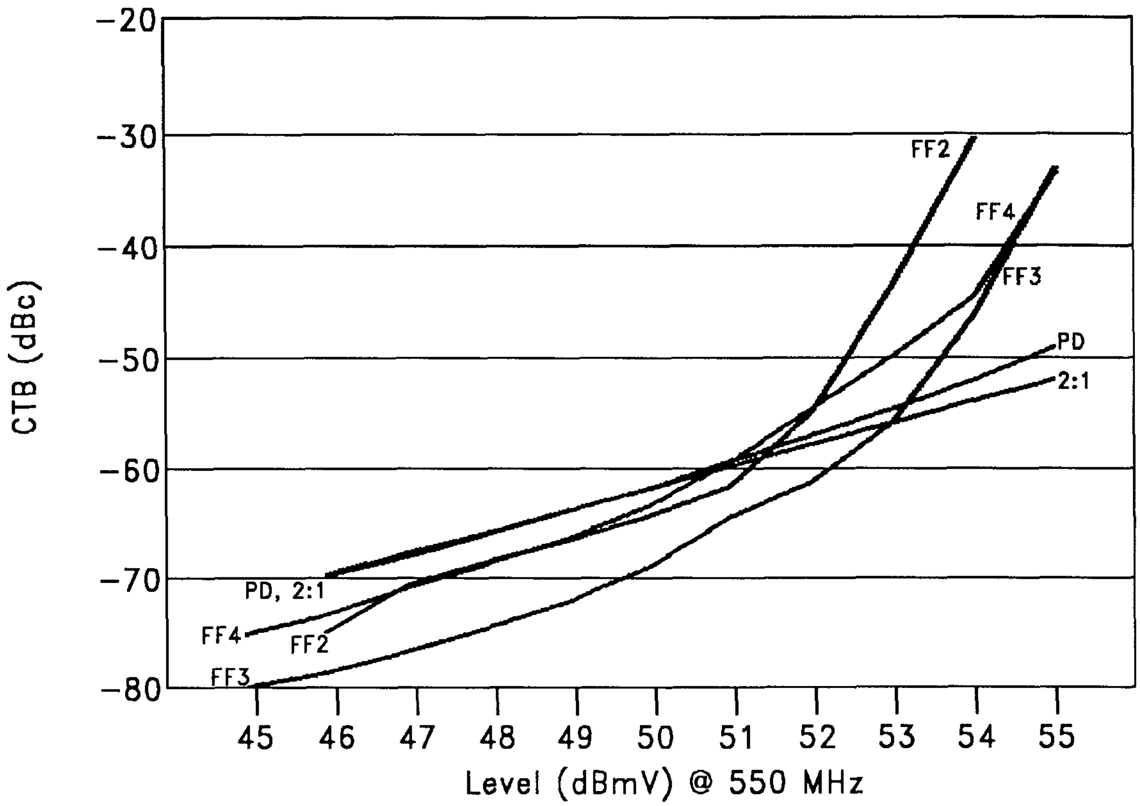


FIGURE 4

AMPLIFIER HYBRID SINGLE-STRING
MAXIMUM REACH

Measured Hybrid CTB
77 Channel, 8 dB Tilt, 547.25 MHz
Figure 5



CONCLUSIONS

The optical bridger type of distribution architecture provides a cost-effective means for deploying AM fiberoptic technology on a wide scale for cable TV. The multiple high-level output capabilities offered in the RF distribution equipment that is becoming available will be both a boon and a challenge to the system designer. This equipment provides the designer with new opportunities for efficient designs, but will also test his or her ingenuity and flexibility. The choices between specific amplifier units will depend on the details of the system maps, on cleverness of the designer and on the inherent costs of those units.

REFERENCES

1. J. Chiddix, "The Strategic and Business Value of Fiber," SCTE Fiber Optics 1990, Monterey, CA, March 1990.

2. D. Jubera and J. Hernandez, "CATV Hybrid Distortion in High Level Distribution Systems," Technical Report, Texscan Corporation, El Paso, TX, June 1990.