A FIBER OPTIC DESIGN STUDY

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ABSTRACT

A design study was conducted to test the AM fiber backbone concept. A "typical" cable system was chosen in order to compare a fiber design to a conventional tree-and-branch architecture. Fiber's impact on end-of-line performance was investigated, and it was found that while it was possible to improve signal quality using fiber, a number of tradeoffs were involved, and the improvement was limited by distortions. A number of design and installation issues were considered, including amplifier reversal, design procedures and the location of splice points. While each system is unique, fiber designs were generally found to be more complex, and required more extensive planning for future growth. The effect of fiber systems on reliability was also studied. Fiber was determined to have little positive impact on system reliability, but it did equalize subscriber reliability across the system.

INTRODUCTION

The potential market for AM fiber optic systems in CATV applications appears to be almost limitless. Fiber's ultimate success in penetrating the cable plant will depend on several factors, including laser performance improvements and component cost reductions. However, the degree to which fiber can function as an integral part of the existing CATV distribution system will be of equal or greater importance. In order to evaluate the impact of fiber optics on the distribution plant, a detailed design study was conducted by Scientific Atlanta's Distribution Systems applications engineering group.

STUDY OBJECTIVE

The objective of the fiber design study was to test the AM fiber backbone concept, which has been proposed by James Chiddix of ATC. The concept under study involved the use of a number of nodes, each connected by fiber to the headend (or hub), and each in turn feeding cascades of four amplifiers inboth directions. The fiber backbone approach was analyzed in terms of three primary criteria: the impact on end-of-line signal quality, practical considerations for design and installation, and the effect on both system and subscriber reliability.

SCOPE OF STUDY

For the purpose of this study, a "typical" cable system was chosen in a small U.S. city, with approximately 40,000 homes passed. The system was comprised of one headend serving 530 miles of plant, which had recently been rebuilt from 300 MHz push-pull to 450 MHz using feedforward trunk and parallel hybrid feeder electronics. The majority of the plant consisted of a conventional trunk-and-feeder architecture using .750" and .875" coaxial cable. There were some coaxial supertrunks using 1.00" cable, with the longest containing 32 amplifiers in cascade.

FIBER SYSTEM DESIGN

Utilizing four amplifier maximum cascades, the fiber design was completed using a total of 51 nodes. Fiber optic cable could be overlashed to the existing aerial plant, with four main cable runs emanating from the headend. Each cable run fed a cluster of nodes, which were divided into four sectors. The first sector contained 6 nodes, with the most distant one located at 28,500 cable feet, or 8.7 kilometers from the headend. Sector 2 consisted of 5 nodes extending out to 37,310 feet (11.4 km);

sector 3, 24 nodes and 49,233 feet (15.0 km); and sector 4, 16 nodes and 70,337 feet (21.4 km). In terms of node density, 90% of the nodes fell within 16 kilometers of the headend, with 59% between 4 and 12 kilometers distant. A breakdown of node density is presented in Figure 1.

FIGURE 1

NODE DENSITY

Distance From Headend	Node Quantity	Node Percentage	Cumulative Percentage
0 - 4 km	6	11.8%	11.8%
4 - 8 km	11	21.6%	33.4%
8 - 12 km	19	37.3%	70.7%
12 - 16 km	10	19.6%	90.3%
16 - 20 km	4	7.8%	98.1%
20 - 24 km	1	1.9%	100.0%

STUDY RESULTS

1. Signal Quality

The existing coaxial system afforded good NTSC-format signal quality. The distribution plant provided a carrier-to-noise ratio (CNR) of 45.3 dB, with a 54.7 dB composite triple beat (CTB). The existing earth station provided a CNR of 50 dB, resulting in an end-of-line CNR of 44.1 dB. The desired minimum performance standards, for NTSC quality, were 43.9 dB CNR and 53.0 dB CTB. To provide picture quality comparable to Super VHS, a CNR of 46.7 dB and CTB of 54.0 dB would be needed. Achieving studio quality pictures would require minimum performance levels of 51.0 dB CNR and 56.0 dB CTB.

In the fiber design, the maximum amplifier cascade was reduced to four, which raised the coax plant performance to 58.7 dB CNR and 58.2 dB CTB. The required fiber performance for NTSC quality signals was 45.3 dB CNR and 59.9 dB CTB. In order to improve the end-of-line performance, the earth station would have to be upgraded. By increasing the earth station carrier-to-noise ratio to 52 dB, Super VHS equivalent performance could be achieved with fiber at 48.6 dB CNR and 62.3 dB CTB. To provide studio quality signals, the earth station would have to be upgraded to 55 dB CNR, with a minimum fiber performance of 54.6 dB CNR and 69.0 dB CTB. Thus, while today's AM fiber performance has brought Super VHS quality signals within reach, studio quality pictures were not yet attainable in the fiber backbone study system.

2. System Design and Installation

The design objective was to site each node to feed eight amplifiers, four in each direction. This was to be accomplished by using the existing trunk locations, and reversing four amplifiers at each node. However, reversing amplifiers was workable only in certain areas, because specific RF levels were required by sub-trunk passives and terminating bridgers. In most instances, reversed amplifiers would not provide the proper levels. Also, in some cases it was not possible to implement four amplifier cascades because of physical constraints, such as the number of amplifiers in a node cluster not being evenly divisible by four. It should be noted that in the entire system, only 15 amplifiers were eliminated out of 62 supertrunk amplifiers, and all of the 224 conventional trunk amplifiers were retained.

In a traditional coaxial installation, construction begins before the final design is complete. This is possible because once the basic parameters are established, such as cable diameter, trunk and feeder spacing, and trunk cable routing, different sections of feeder plant can be designed and built independently. This means that operators have the flexibility to essentially have construction crews follow in the footsteps of the system designers, with today's strand maps being used for tomorrow's installation.

With a fiber backbone architecture, this procedure can no longer be used. Before construction of a cable run can begin, the total number of fibers leaving the headend must be known. To establish an accurate fiber count, the total number of nodes in a given sector must be known, as well as the number of fibers per node. Future expansion must be planned as well, both in terms of new nodes and additional fibers per node. A node might require additional fibers to accomodate a return path, to increase channel capacity, or even to provide services other than traditional CATV. If system expansions or increased housing densities are anticipated, allowances must be made for additional nodes. Thus, in a fiber backbone system, construction cannot begin until the final design of a node sector is complete.

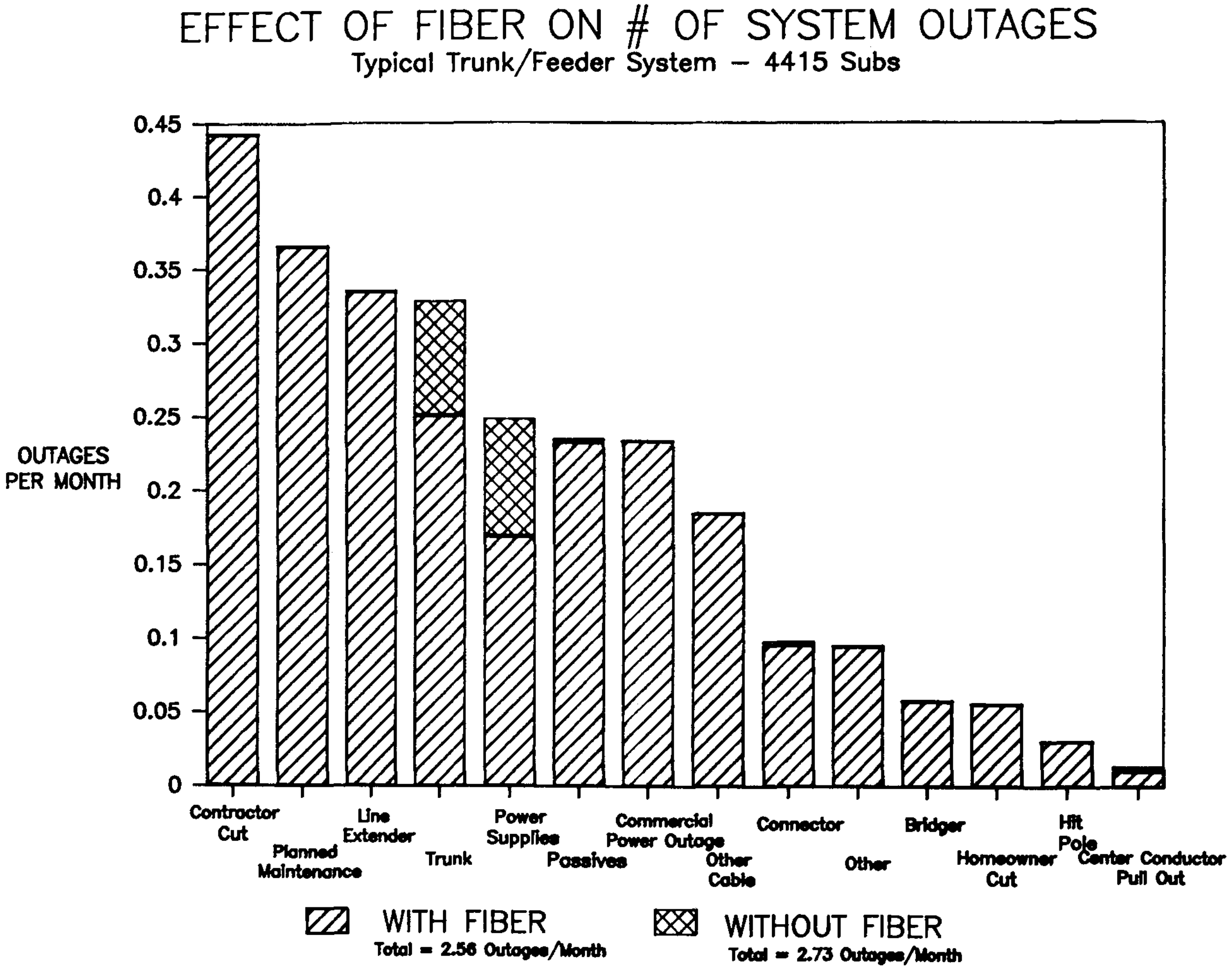
An additional level of complexity is introduced by the necessity to carefully plan the location of splice points. Since most AM fiber system designs allow only a small optical margin, splices must be kept to a minimum to reduce insertion losses and reflections. (This requirement also dictates the exclusive use of fusion splicing for installation of optical cables in CATV systems, which is beyond the scope of this study.) To minimize the number of splices required, cable span lengths must be planned carefully during the design process. Generally, the maximum reel size that can be accomodated in the construction process determines the maximum usable cable length. Up to that limit, which is usually around four kilometers, it is advisable to specify individual cable lengths as required by the design to minimize the number of splice points.

3. Reliability

The reliability impact of fiber was examined in two dimensions, system reliability and subscriber reliability. System reliability was defined as any outage that required the operator to institute repairs. Outage data was collected and sorted according to the cause of the outage and the number of outages per month. Subscriber reliability was defined as any outage that affected a particular group of subscribers. Subscribers were grouped according to their proximity to the headend, and the number of outages per month was predicted based on the cause of the outage.

To determine the effect of a fiber backbone on system reliability, the system outage data was recalculated based on the fiber design. Since no reliability data was available on AM fiber systems, it was assumed for the purpose of this study that the fiber system did not cause incremental system outages. Because the fiber design only eliminated 15 of the 286 amplifiers, there was very little positive impact on system reliability, as shown in Figure 2.

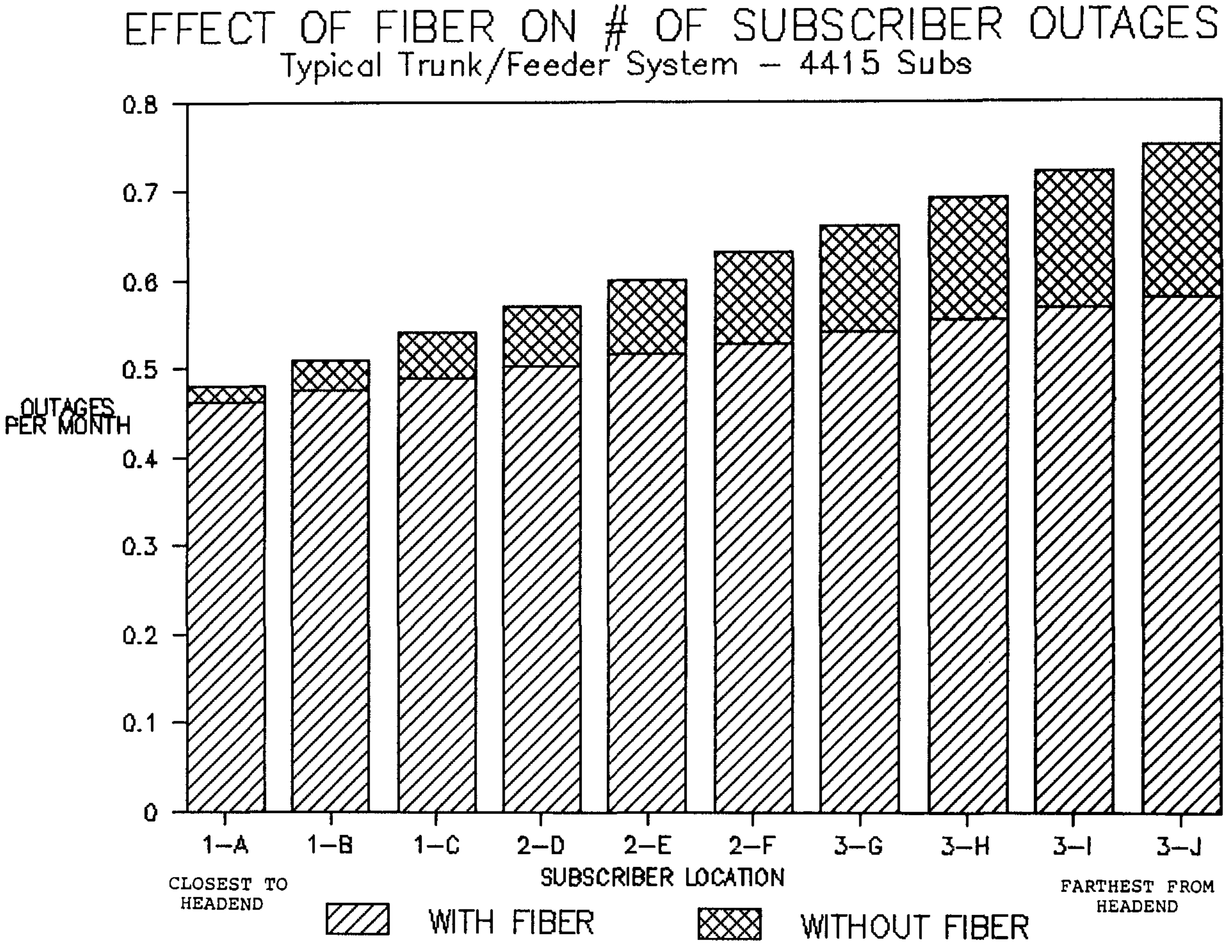
FIGURE 2



Turning to subscriber reliability, the same outage data was then applied to individual clusters of subscribers. In the conventional tree-and-branch architecture, the number of outages per subscriber increased significantly as the distance from the headend increased. This was intuitive since any system outage would be felt by all subscribers from that point on. In the fiber design, however, each subscriber was served by a maximum of four amplifiers. Subscribers located farthest from the headend would be less exposed to amplifier failure. Thus, as indicated in Figure 3, use of a fiber backbone architecture evened out reliability experience across the subscriber population.

There are two elements missing from the preceding analysis, which will require further study and additional data. First, fiber is assumed to cause no incremental system outages. This assumption is obviously not valid, and once accurate data is available, it may in fact show that fiber actually decreases overall system reliability. Second, insufficient information is available on the mean time to repair outages in a fiber system relative to a coax system. With this data and fiber system reliability information, it will be possible to determine the total system and subscriber outage time for a fiber backbone as opposed to a pure tree-and-branch architecture.

FIGURE 3



STUDY CONCLUSIONS

The fiber design study provided useful data regarding the implementation of an AM fiber backbone system in a CATV plant. In particular, the results of the study demonstrated that fiber can be used to improve end-of-line signal quality. In doing so, however, the operator has to trade off the performance of the fiber system against those of the earth station and the coaxial distribution plant. The required performance of the fiber system can be reduced by increasing the antenna size, by upgrading the distribution electronics, or by reducing the number of amplifiers in cascade from the node. These options involve obvious cost implications, which must be addressed in future studies.

There will be a number of design and installation issues in any fiber backbone implementation, many of which will be unique to that particular system. However, it appears that some general conclusions can be drawn. It will be difficult to reverse amplifiers without extensive reconstruction of feeder plant, and few amplifiers will be completely eliminated. The design of a fiber backbone will be more complicated than that of a conventional coax system. Planning for future growth must be done at the outset, and construction must wait until the final design is complete. A variety of cable lengths will be required, since care must be taken to minimize the number of splice points.

A critical factor in determining how successful fiber will be in penetrating the CATV plant will be its impact on overall reliability. In terms of system reliability, since few amplifiers are eliminated, it is apparent that fiber will not have a positive impact. Thus, from the operator's standpoint, it is important to have extremely reliable fiber electronics, and to protect fiber optic cables as much as possible. Close to the headend, where total fiber counts are relatively high, it may be advisable to bury optical cables to protect them from problems with downed lines or pole rearrangements.

In terms of subscriber reliability, fiber does tend to even out performance across the system, so that the most distant subscribers no longer experience every system outage. However, it is not yet clear what impact fiber will have on overall subscriber reliability. The two major unknowns are the reliability of the fiber system and the time required to repair fiber cable and electronics as opposed to coax. If amplifiers are not reversed, operators may choose to retain existing coaxial trunk runs in addition to a fiber backbone. This would provide them the capability to utilize the coax as a backup to the fiber system.

This study has shed light on a number of issues concerning the impact of fiber optics in the CATV distribution plant. Future studies will undoubtedly uncover other issues to be considered in implementing a fiber backbone in a CATV system. Once fiber optic technology becomes an integral part of the CATV distribution system, fiber will have a key role to play in the future of cable television.