A TECHNICAL ANALYSIS OF A HYBRID FIBER/COAXIAL CABLE TELEVISION SYSTEM

Perry Rogan, Raleigh B. Stelle III, Louis Williamson

American Television and Communications

Abstract - Improvements in the quality of the delivered NTSC signal in CATV systems may be obtained by the application of fiber backbone technology.

These signal improvements will be the result of decreased cascades of traditional cable television amplifiers following the fiber node. These improvements are measurable in terms of carrier-to-noise ratio, and intermodulation products.

The resulting improvement in system overhead may be exchanged for additional bandwidth, for increased system reach, or for improved quality of the delivered signal.

This paper presents the evaluation we performed for one of our existing systems. We show the improvements in performance which are obtained with fiber backbone. We also show how the same system can be upgraded from 270 MHz to 550 MHz, without changing trunk cable, trunk locations, or using microwave hubs. The 270-550 MHz upgrade example focuses on the exchange of performance for additional bandwidth.

SCOPE

American Television and Communications (ATC) management directed the engineering staff to undertake the analyses described herein because of its belief that our future depends on six primary operational considerations.

1. Delivery of signal quality directly comparable to present and perceived future sources, while providing economics comparable to, or better than, alternatives now available to our systems.

2. The ability to transport to the home, any enhancement which may be forthcoming in the art of television systems.

3. The ability of our systems to offer ancillary services which may become desirable to our subscribers.

4. The ability of our systems to meet competitive situations in a cost effective manner.

5. The ability of our systems to operate in a more reliable fashion.

6. The ability of our systems to take advantage of a more flexible evolutionary architecture.

This paper will deal only with the technical performance aspects of the application of the fiber backbone concept. Financial modeling which is an inherent part of any decision making process will be presented by other members of the ATC Engineering staff in a separate paper.

FIBER BACKBONE

The fiber backbone concept requires that conventional amplifier cascades be reduced to a small number, such as 2, 3, 4, or 5. In order to create such short cascades, a number of "fiber nodes" must be created. Each node is connected to the headend by single mode optical fiber which transmits the optical signal from the headend to the node.

In the headend, the radio frequency (RF) signals are converted to optical frequencies, and coupled onto the fiber.

The multi-fiber cable follows traditional trunk routings and is likely to be overlashed to existing cable. As the fiber proceeds toward the furthest node point, it is split, and spliced many times. Examples of these routes are included in the appendix.

At the fiber node location, we believe the equipment required will be housed in an enclosure similar to existing trunk amplifiers. The purpose of the node is to terminate the optical fiber cable, and convert the optical signal on that fiber to RF for transmission to the home via traditional cable television trunk and line extender amplifiers.

How good must the node RF performance be?

We believe the signals recovered from the fiber must have at least 55 dB carrier-to-noise, -65 dB composite triple beat and -65 dB composite second order performance.

OPTICAL LINK PERFORMANCE

ATC staff engineers began active experimentation in fiber optic transmission systems in the spring of 1987. While our focus is directed primarily at broadband amplitude modulated, vestigial sideband (AM-VSB) transmission, we also closely monitor the progress being made in the area of FM transmission on fiber. Either modulation technique (AM, or FM) may be applied to the fiber backbone approach.

Several vendors of lasers, fiber, and detectors were contacted with requests for product information and sample items. The initial results were disappointing, yielding carrier-to-noise ratios of 47 dB, and composite triple beat ratios of 50 dB. With these devices, the second order performance was unacceptable. The composite second order beat products were eliminated from the band of interest by choosing an octave of bandwidth from 200-400 MHz for the initial experiments. In practical application, it may be necessary to convert the 55-550 spectrum to 605-1155 MHz prior to modulating the laser. Two advantages are expected from this process. One advantage is that all second order products will fall outside the band of interest, and may be removed by filtering. The second advantage is that this frequency range allows the laser to function in a more favorable region of its operating characteristics.

This performance was initially perceived as disappointing because it was so far from the performance required to make the fiber backbone concept a reality. The disappointments did not last very long, however.

The following graph, Fig. 1, indicates the performance improvements we have been able to observe from the various components of fiber systems to date.

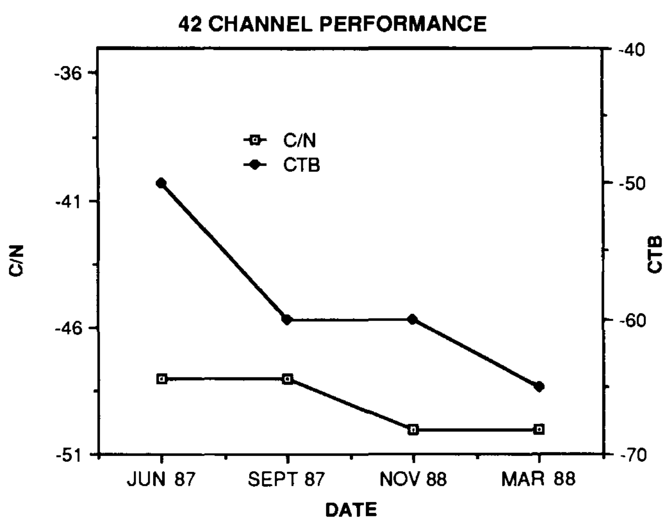

Figure 1. Link Performance over 15 KM

The best performance observed so far produces 48 dB carrier-to-noise ratios and -65 dB composite triple beat dB with 42 channel loading, through 15 Km of fiber.

A future element of the fiber experiment is to block convert the 42 channel spectrum (55-330 MHz) to 605-935 MHz. At these frequencies the signals occupy less than an octave of bandwidth and we will be better able to determine the second order performance. Experiments are presently in progress on this phase of the project, and will be reported as they produce meaningful data.

The progress made in laser technology over the past year makes us very optimistic that the required node performance goals of 55 dB carrier-to-noise, -65 dB composite triple beat, and -65 dB composite second order over 15 Km of single mode fiber are goals which will be achieved in the near future, at acceptable prices.

An especially significant item of note is that in our discussions with various manufacturers of lasers and detectors, we have learned that there are no known physical limits preventing the laser and detector manufacturers from creating devices with the parameters required to deliver the performance we expect.

Assuming that the required node performance is obtainable, we analyzed the performance improvements which can be expected in the sample 270 MHz system. We then performed an analysis on this same system to determine the performance achievable if the system were to be upgraded to 550 MHz.

In the 550 MHz upgrade, we decided to attempt to use the same trunk cable and amplifier locations, and to "drop-in" appropriate 550 MHz amplifiers, if possible.

COMPUTER ANALYSIS

All of the analyses presented are performed with various computer programs which permit the entry of all necessary variables, and calculate performance accordingly. Several of the exhibits are the printouts from these programs. The programs require the entry of the equipment operating parameters in the area designated "Manufacturer's Specifications". The operating parameters, as the equipment is applied in the system, are entered in the "System's Specifications" area. Included in this area is the data for the number of each type of amplifier in cascade. In the area labeled "Calculated Equipment Specifications", the program calculates the performance which is expected from the contribution of each of the elements cascaded (i.e., trunk, bridger, line extender, and converter), derating appropriately for the operational parameters chosen. The "Calculated System Specifications" area indicates the expected performance of the elements in cascade, indicating "end of the line" performance. Using a program simplifies the repetitive process necessary to arrive at optimum solutions to diverse system applications.

The following material represents our progress to date in the process of arriving at an optimum solution to the problem of implementing the fiber backbone concepts.

SIGNAL QUALITY IMPROVEMENTS

As stated in the abstract, one of the goals of our project was to improve the performance of an existing 270 MHz system. The following section describes the processes we used, and the results obtained from applying the fiber backbone to this system.

The system chosen for analysis is one of ATC's older 270 MHz systems which has been in operation for more than 15 years, and which requires improved operational performance to meet competitive pressures, and market demands. The system segment analyzed consists of 375 miles of plant, serving approximately 10,000 subscribers. The longest cascade consists of 28 trunk amplifiers, one bridger, and two line extenders. The trunk spacing is 21 dB, and the cable is .750" P-3. The distribution levels are 48/41 dBmV for the bridger, and 43/37 for the line extenders. The end of the line performance of this system is: 46.7 dB carrier-to-noise, -56.2 dB composite triple beat, and -60.3 dB composite second order.

The system performance is shown in the cascade analysis, Exhibit 1 of the appendix.

Implementation of a fiber backbone in this system will yield an improvement in carrier-to-noise of 4.8 to 5.7 dB, depending on the number of amplifiers cascaded after the fiber node. In this example, the intermodulation products were slightly worse after implementing the fiber backbone. These intermodulation products are the result of the high tap levels required in the distribution portion of the system, to meet end of the line tap levels. See Fig. 2, below, and Exhibits 1, 2, 3, and 4 of the appendix.

SYSTEM END PERFORMANCE DATA

	C/N	CTB	CSO	NODES
BEFORE FIBER BACKBONE	46.7	-56.1	-60.3	0
AFTER FIBER BACKBONE 2 TRUNK IN CASCADE	52.4	-55.2	-61.3	61
AFTER FIBER BACKBONE 3 TRUNK IN CASCADE	51.9	-55.1	-61.2	41
AFTER FIBER BACKBONE 4 TRUNK IN CASCADE	51.5	-55	-61	29

Figure 2. end of the line performance calculations based on trunk cascade and "quad power" line extenders.

Fig. 2 shows the end of line comparisons for different cascades after the fiber node. Exhibit 1 shows the present system performance. Exhibit 2 shows the performance with the fiber backbone with four trunk amplifiers cascaded after the node. Exhibit 3 shows the performance with two trunk amplifiers cascaded after the node.

This range of improvements is made possible by the flexibility of system architecture produced by implementing the fiber backbone concept.

In this example, our goals were:

1. Reuse as much of the existing plant as possible to minimize the complexity of any future upgrade which might be undertaken. Existing equipment was reused, and only direction reversals on approximately half the trunk locations were required.

2. Provide performance improvements which will allow this system to meet present market pressures, and permit future bandwidth expansion as necessary. The goal of improved carrier-to-noise was met. (4.8-5.7 dB).

As the system design for the quality improvement example evolved, it was necessary to consider the number of fiber node locations to be used. Several alternatives were evaluated with emphasis on the system performance with various cascades after the fiber node. An analysis of the number of nodes required is contained in Figure 3 below. It can be seen that in each of the 209 existing trunk amplifiers is a node location; the number on nodes required is 209. Similarly, if the number of amplifiers cascaded rises to 28 (the original cascade), the number of nodes is one. Between these values, we selected the numbers 2, 3, and 4 for cascade and fiber route evaluation.

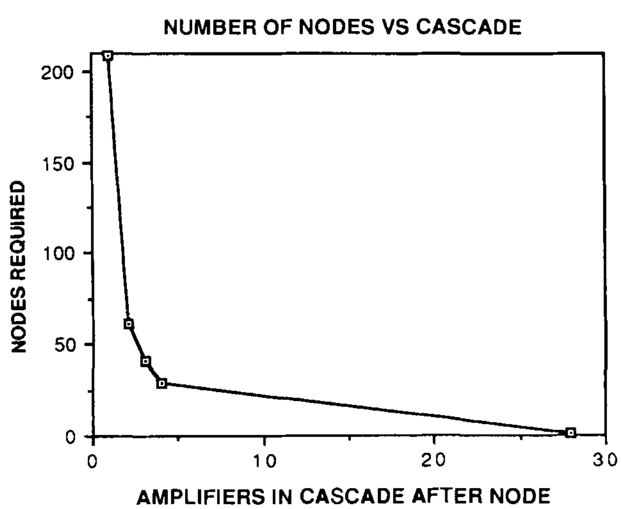

Figure 3. The relationship between cascade selected, and fiber nodes required.

Due to this system's architecture, and the curve from Figure 3, it appears there is no apparent advantage to continuing beyond the four in cascade point. To do so would defeat our purpose because of the buildup of noise and distortion in longer cascades.

As a preamble to the next section, two terms to be used require definition. They are: route miles, and fiber miles. A "route mile" is total linear distance which will require lashing of the fiber bearing cable to the existing plant. The "total fiber mileage" is the sum of the distances from each node to the headend, with one fiber run per node.

For each of the analyses presented we have calculated the route mileage to provide an indication of the magnitude of the overlashing required, and the fiber mileage to indicate the possible fiber costs.

The node location data, and fiber mileages for the system analyzed, are shown below.

For four in cascade after the node: (miles)
1. Route mileage = 43.7
2. Fiber mileage = 128.6
3. Nearest node = 1.13
4. Furthest node = 8.99

For three in cascade after the node:
1. Route mileage = 45.3
2. Fiber mileage = 174.6
3. Nearest node = .9
4. Furthest node = 8.61

For two in cascade after the node:
1. Route mileage = 50.9
2. Fiber mileage = 248
3. Nearest node = .9
4. Furthest node = 8.99

The fiber routings for the three cascade examples tested (2, 3, and 4 after the node) are shown in Exhibits 6, 7, and 8 respectively. These exhibits are located in the appendix.

FIBER ANALYSIS VS CASCADE

	ROUTE MILES	FIBER MILES	NODES (FIBERS)	NEAREST NODE, MI.	FARTHEST NODE, MI.
2 CASCADE	50.9	248	61	.9	8.99
3 CASCADE	45.3	174.6	41	.9	8.61
4 CASCADE	43.7	128.6	29	1.13	8.99

Figure 4. Fiber requirements versus cascade chosen.

Figure 4 is a tabulation of the number of nodes, fiber miles, and route miles for each cascade evaluated.

Design samples were performed to determine the architecture of the system after application of the fiber backbone. The typical trunk routings for each cascade evaluated are shown in Exhibits 8, 9, and 10 of the appendix. While it was not necessary to physically relocate any of the trunk stations, 50% of them will require reversal.

The distribution portions of the original system remain unchanged.

Another point of interest is that the same node locations will be used regardless of whether the plan is to simply upgrade the system performance, or to increase the bandwidth. This condition occurs because the same trunk locations and cascades will be used in either situation.

The preceding information shows the performance improvements which can be achieved with existing plants. As can be seen, the performance improvements in themselves are significant. Even more significant is with this performance in place, the stage is set at any time in the future to upgrade this system to 550 MHz. Not only can this system be upgraded, it can be upgraded for a relatively low cost compared to the alternative of a total rebuild.

270-550 Upgrade

The performance improvements generated by the fiber backbone approach and very short amplifier cascades permits an exchange of end of the line performance for expanded bandwidth. Adding improved technologies permits the upgrading of this 270 MHz system to 550 MHz, while maintaining adequate end of the line performance, with no change in trunk cable, distribution cable, or trunk locations.

The test design for the upgrade of the system was a sample of 15.8 miles of plant, with areas selected to represent an average sample of the densities in existence. Three areas of five miles each were designed, with densities ranging from less than 75 homes per mile, to densities exceeding 130 homes per mile.

DISTRIBUTION ANALYSIS

The analysis process of this upgrade began with the end of the line performance criteria established for our systems. It was determined that these parameters would be met or exceeded in the 550 MHz upgrade.

The major performance specifications to be met are:

1. 46 dB carrier-to-noise
2. -53 dB composite triple beat
3. -53 composite second order
4. +15/10 dBmV at the tap (drops are 150 ft. RG-6)

These specifications forced the levels required, and the distribution distortion values.

Various line extender and bridger technologies were evaluated to determine which would offer the most economical upgrade while meeting the performance required. It was possible to meet end of the line performance with either two "quad power" line extenders in cascade, or three power doubling line extenders. Three conventional line extenders in cascade failed to meet the required performance criteria. The use of three line extenders in cascade requires the addition of up to 147% more line extenders than the "quad power" choice, and in that case, 46% of the distribution system required the use of three line extenders in cascade.

END OF LINE PERFORMANCE	QUAD LE (2)	P.D. LE (3)	CONV LE (3)
C/N	48.4	-47.9	-48.3
CTB	-52.5	-52.3	-49.0
CSO	--59.8	-59.8	-49.0

Figure 5. End of line performance versus line extender technology..

Fig. 5 shows the distribution end of the line performance of the line extenders evaluated. Complete 550 MHz cascade analysis is shown for each of the line extender technologies evaluated. These analyses appear as Exhibits 5, 12, and 13 of the appendix.

TRUNK ANALYSIS

The next phase of the analysis was to examine the trunk from the fiber node to the bridger input. The P-3 cable in use on the example system has a 270 MHz loss of .85 dB/100. At 550 Mhz, this same cable has 1.21 dB loss/100 ft., or 29.97 dB per span at 550 MHz. Fig. 6 shows the attenuation versus frequency for this cable.

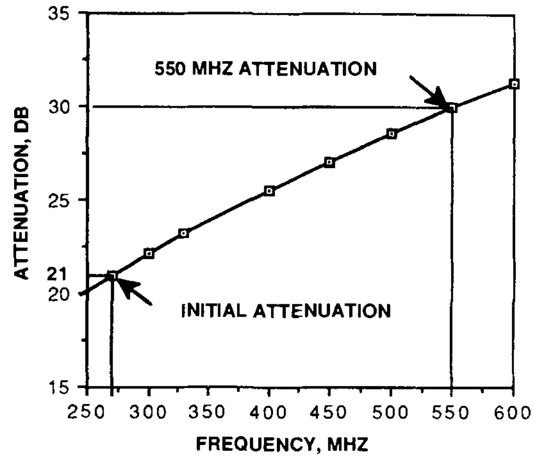

Figure 6. Operational gain required when upgrading from 270 - 550 MHz.

Since 30 dB gain trunk stations are available in several technologies, it appeared possible to "drop-in" the new amplifiers in the existing locations.

Utilizing feed forward technology, trunk cascades of 2, 3, and 4 were analyzed for headroom. The headroom graphs display the carrier-to-noise and composite triple beat limits which are achieved with the output levels chosen. The graphs of these performances are shown in Fig's. 7, 8, and 9. Exhibits 5, 12, and 13 of the appendix provide full cascade analysis.

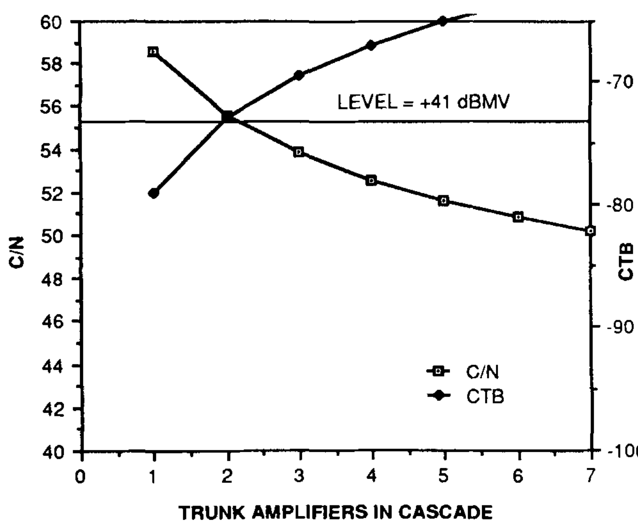

Figure 7

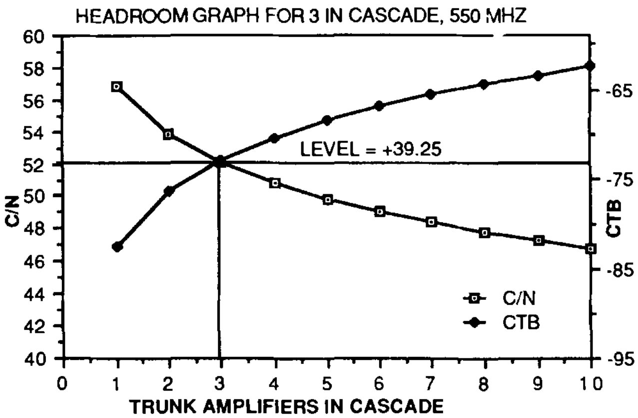

Figure 8

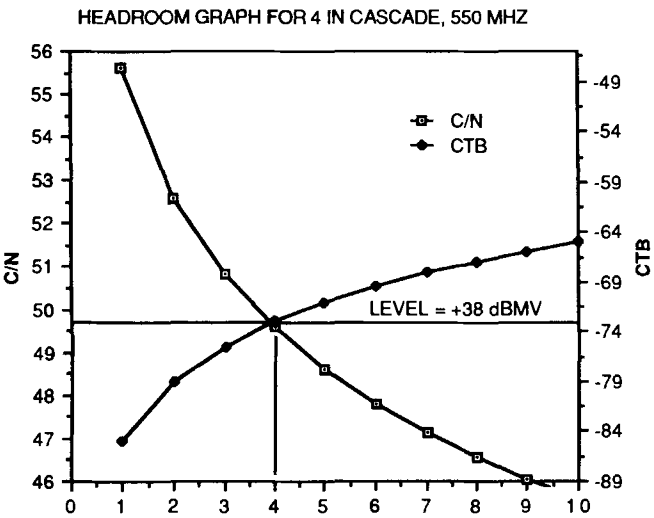

Figure 9

From the preceding graphs and exhibits, one can see that the improvement to be expected from shortening the cascade after the node is in the area of carrier-to-noise. The example system required high distribution levels and in this example, at least, it was not possible to make the usual exchange of carrier-to-noise for distortion. The distribution of this system is the limiting distortion factor, and the trunk contribution is relatively minor. Even so, it is possible to deliver a signal with 51.9 dB carrier-to-noise, to the subscriber's TV set. This performance may well be what is required to make enhanced television systems a reality.

ALTERNATE SOLUTIONS

Analysis was performed to establish whether the proposed upgrade could be accomplished without the use of AML, or other hub techniques.

Further headroom analysis graphs were prepared to determine what performance could be expected with "normal" 22 dB spacing after replacement of the trunk cable. The results appear in Fig's. 10 and 11.

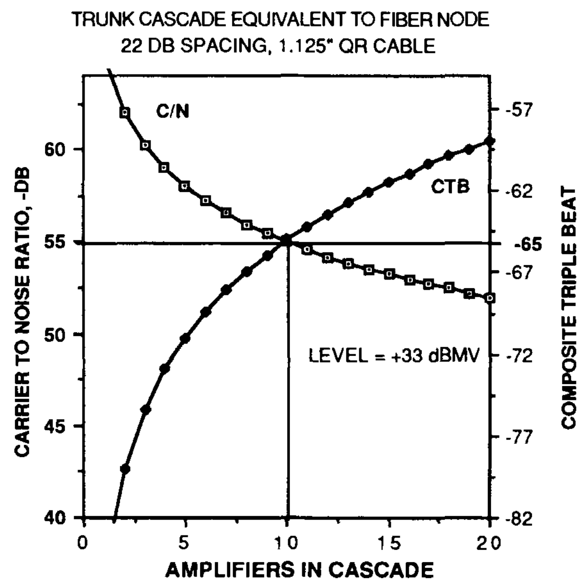

Figure 10

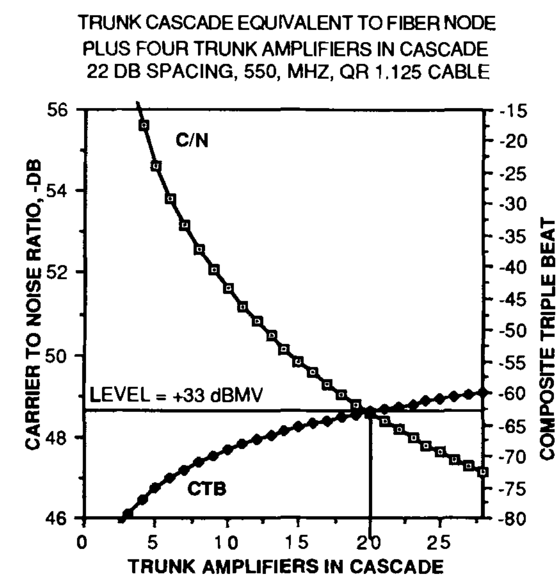

Figure 11

Fig. 10 shows that performance equal to that of the fiber node was reached after a cascade of 10 feed forward trunk amplifiers.

Fig. 11 shows that performance equal to the fiber node plus four trunk amplifiers in cascade was reached after a cascade of 20.

Since replacing the trunk cable permitted the direct replacement of the amplifier locations, one can see that the "reach" is inadequate to replace the original 28 in cascade, and some sort of hub network will be required to complete the upgrade from 270 to 550 MHz.

This section of the paper shows that an upgrade from 270 MHz to 550 MHz can be accomplished using the fiber backbone concept. It has further demonstrated that this upgrade cannot be accomplished otherwise without resort to hub techniques.

SUMMARY

In this paper, we demonstrated the following:

1. The improvement in signal quality which may be obtained by application of the fiber backbone concept to an existing 270 MHz system.
2. The potential to upgrade our example system to a greater bandwidth, by trading improved performance for that bandwidth.
3. The upgrade of a 270 Mhz system to 550 MHz while preserving trunk cable and trunk locations, and without resorting to AML or other hub techniques.
4. The application of the fiber backbone concept will provide new opportunities for the cable television community to take advantage of performance technologies as they occur.
5. As will be seen in the financial models to be presented later, the expense of the fiber backbone is less than a total rebuild, and it appears possible that this technology will permit upgrades which are not possible with any amplifier technology available today, or in the foreseeable future.

It is the authors' opinion that the ideas and concepts set forth in the abstract have been proven. We have shown that quality improvements can be attained; and that these improvements are not only measurable, but substantial; and we have shown a working upgrade example from 270 to 550 MHz which in the worst case not only betters original system performance, but a 550 MHz system which has the performance to transport enhanced television systems or other services.

Our peers, in a parallel effort, have shown that the fiber backbone concept is economically viable as we have proven its technical feasibility.

We must stress that while there is, today, no equipment commercially available which supplies all the desired performance at the price necessary to transform the fiber backbone concept into reality, the authors' are confident that the performance predicted herein will be attainable in the foreseeable future.

ACKNOWLEDGEMENT

We would like to thank George Salvador, and the ATC Design Department for their assistance with the design analysis for this paper, and we would also like to thank the other members of the Engineering and Technology staff at ATC for their valuable assistance.

APPENDIX

CATV SYSTEM DISTORTIONS

SYSTEM NAME.		FWD. BW	4.0	FWD. NOISE	-59.2
DATE	1-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	TRUNK	BRIDGER	L.E.
NOISE FIGURE	9.5	10.5	11.0
CTB OUTPUT CAP	33.0	50.0	50.0
CTB RATING(-dBmv)	-93.0	-59.0	-59.0
XMOD OUTPUT CAP	33.0	50.0	50.0
XMOD RATING(-dBmv)	-92.0	-59.0	-59.0
2nd OUTPUT CAP	33.0	50.0	50.0
2nd RATING(-dBmv)	-85.0	-70.0	-70.0
CHANNEL CAPACITY	42.0	35.0	35.0
MANUFACTURER TILT	3.0	6.0	6.0
HUM SPECIFICATION	-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT	12.0	13.0	17.0
GAIN OR BR DC LOSS	21.0	-20.0	26.0
DESIRED TILT	6.0	6.0	6.0
AMPLIFIER OUTPUT	33.0	48.0	43.0
CHANNEL LOADING	35.0	35.0	35.0
CASCADE LENGTH	30.0	1.0	2.0

CALCULATED EQUIPMENT SPECIFICATIONS		TRUNK	BRIDGER	L.E.
	C/N......	-46.9	-61.7	-62.2
	CTB......	-67.6	-63.0	-67.0
	XMO.....	-66.2	-63.0	-67.0
LOG..15.0	2ND.....	-62.8	-72.0	-72.5
	HUM.....	-40.5	-70.0	-64.0

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-46.9	-46.8	-46.7	...C/N
CTB......	-67.6	-59.0	-56.1	...CTB
XMO.....	-66.2	-58.4	-55.7	...XMO
2ND.....	-62.8	-61.4	-60.3	...2ND
HUM.....	-40.5	-40.2	-39.6	...HUM

NOTES: CURRENT OPERATING PERFORMANCE.

EXHIBIT 1

CATV SYSTEM DISTORTIONS

SYSTEM NAME.		FWD. BW	4.0	FWD. NOISE	-59.2
DATE	1-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
NOISE FIGURE			9.5	10.5	11.0	
CTB OUTPUT CAP			33.0	50.0	50.0	
CTB RATING(-dBmv)			-93.0	-59.0	-59.0	
XMOD OUTPUT CAP			33.0	50.0	50.0	
XMOD RATING(-dBmv)			-92.0	-59.0	-59.0	
2nd OUTPUT CAP			33.0	50.0	50.0	
2nd RATING(-dBmv)			-85.0	-70.0	-70.0	
CHANNEL CAPACITY			42.0	35.0	35.0	
MANUFACTURER TILT			3.0	6.0	6.0	
HUM SPECIFICATION			-70.0	-70.0	-70.0	
SYSTEM SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
AMPLIFIER INPUT			12.0	13.0	17.0	
GAIN OR BR DC LOSS			21.0	-20.0	26.0	
DESIRED TILT			6.0	6.0	6.0	
AMPLIFIER OUTPUT			33.0	48.0	43.0	
CHANNEL LOADING			35.0	35.0	35.0	
CASCADE LENGTH			4.0	1.0	2.0	
CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
	C/N.....	-55.0	-55.7	-61.7	-62.2	
	CTB.....	-65.0	-85.1	-63.0	-67.0	
	XMO.....	-65.0	-83.7	-63.0	-67.0	
LOG..15.0	2ND.....	-65.0	-76.0	-72.0	-72.5	
	HUM....	-70.0	-58.0	-70.0	-64.0	
CALCULATED SYSTEM SPECIFICATIONS		FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)		
	C/N.....	-52.3	-51.8	-51.5		...C/N
	CTB.....	-64.2	-57.6	-55.0		...CTB
	XMO.....	-64.0	-57.5	-55.0		...XMO
	2ND.....	-63.9	-62.2	-61.0		...2ND
	HUM....	-56.0	-54.4	-51.9		...HUM

NOTES: PERFORMANCE IMPROVEMENT ONLY.
FOUR TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 2

CATV SYSTEM DISTORTIONS

SYSTEM NAME.		FWD. BW	4.0	FWD. NOISE	-59.2
DATE	1-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
NOISE FIGURE			9.5	10.5	11.0	
CTB OUTPUT CAP			33.0	50.0	50.0	
CTB RATING(-dBmv)			-93.0	-59.0	-59.0	
XMOD OUTPUT CAP			33.0	50.0	50.0	
XMOD RATING(-dBmv)			-92.0	-59.0	-59.0	
2nd OUTPUT CAP			33.0	50.0	50.0	
2nd RATING(-dBmv)			-85.0	-70.0	-70.0	
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DESIRED TILT			6.0	6.0	6.0	
AMPLIFIER OUTPUT			33.0	48.0	43.0	
CHANNEL LOADING			35.0	35.0	35.0	
CASCADE LENGTH			3.0	1.0	2.0	
CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
	C/N.....	-55.0	-56.9	-61.7	-62.2	
	CTB.....	-65.0	-87.6	-63.0	-67.0	
	XMO.....	-65.0	-86.2	-63.0	-67.0	
LOG..15.0	2ND.....	-65.0	-77.8	-72.0	-72.5	
	HUM....	-70.0	-60.5	-70.0	-64.0	
CALCULATED SYSTEM SPECIFICATIONS		FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)		
	C/N.....	-52.9	-52.3	-51.9		...C/N
	CTB.....	-64.4	-57.6	-55.1		...CTB
	XMO.....	-64.3	-57.8	-55.1		...XMO
	2ND.....	-64.2	-62.4	-61.2		...2ND
	HUM....	-58.0	-56.0	-53.1		...HUM

NOTES: PERFORMANCE IMPROVEMENT ONLY.
THREE TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 3

CATV SYSTEM DISTORTIONS

SYSTEM NAME.		FWD. BW	4.0	FWD. NOISE	-59.2
DATE	1-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
NOISE FIGURE			9.5	10.5	11.0	
CTB OUTPUT CAP			33.0	50.0	50.0	
CTB RATING(-dBmv)			-93.0	-59.0	-59.0	
XMOD OUTPUT CAP			33.0	50.0	50.0	
XMOD RATING(-dBmv)			-92.0	-59.0	-59.0	
2nd OUTPUT CAP			33.0	50.0	50.0	
2nd RATING(-dBmv)			-85.0	-70.0	-70.0	
CHANNEL CAPACITY			42.0	35.0	35.0	
MANUFACTURER TILT			3.0	6.0	6.0	
HUM SPECIFICATION			-70.0	-70.0	-70.0	
SYSTEM SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
AMPLIFIER INPUT			12.0	13.0	17.0	
GAIN OR BR DC LOSS			21.0	-20.0	26.0	
DESIRED TILT			6.0	6.0	6.0	
AMPLIFIER OUTPUT			33.0	48.0	43.0	
CHANNEL LOADING			35.0	35.0	35.0	
CASCADE LENGTH			2.0	1.0	2.0	
CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
	C/N.....	-55.0	-58.7	-61.7	-62.2	
	CTB.....	-65.0	-91.1	-63.0	-67.0	
	XMO.....	-65.0	-89.7	-63.0	-67.0	
LOG..15.0	2ND.....	-65.0	-80.5	-72.0	-72.5	
	HUM....	-70.0	-64.0	-70.0	-64.0	
CALCULATED SYSTEM SPECIFICATIONS		FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)		
	C/N.....	-53.5	-52.9	-52.4		...C/N
	CTB.....	64.6	-57.7	-55.2		...CTB
	XMO.....	64.5	-57.7	-55.1		...XMO
	2ND.....	64.4	-62.7	-61.3		...2ND
	HUM....	-60.5	-58.0	-54.4		...HUM

NOTES: PERFORMANCE IMPROVEMENT ONLY.
TWO TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 4

CATV SYSTEM DISTORTIONS

SYSTEM NAME:	FIBER TEST	FWD. BW	4.0	FWD. NOISE	-59.2
DATE	7-Mar 1987	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS		FIBER	TRUNK FF	BRIDGER CP	L.E. XCLE	
NOISE FIGURE			11.5	9.5	12.0	
CTB OUTPUT CAP			38.0	48.0	47.0	
CTB RATING(-dBmv)			-85.0	-65.0	-69.0	
XMOD OUTPUT CAP			38.0	48.0	47.0	
XMOD RATING(-dBmv)			-85.0	-65.0	-69.0	
2nd OUTPUT CAP			38.0	48.0	47.0	
2nd RATING(-dBmv)			-87.0	-71.0	-73.0	
CHANNEL CAPACITY			77.0	77.0	77.0	
MANUFACTURER TILT			6.0	10.0	10.0	
HUM SPECIFICATION			-70.0	-70.0	-70.0	
SYSTEM SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
AMPLIFIER INPUT			8.0	18.0	19.0	
GAIN OR BR DC LOSS			30.0	-20.0	29.0	
DESIRED TILT			6.0	9.0	9.0	
AMPLIFIER OUTPUT			38.0	48.0	48.0	
CHANNEL LOADING			77.0	77.0	77.0	
CASCADE LENGTH			4.0	1.0	2.0	
CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.	
	C/N......	-55.0	-49.7	-67.7	-63.2	
	CTB......	-65.0	-73.0	-64.3	-60.3	
	XMO......	-65.0	-73.0	-64.3	-60.3	
LOG..15.0	2ND......	-85.0	-78.0	-71.0	-87.5	
	HUM.....	-70.0	-58.0	-70.0	-64.0	
CALCULATED SYSTEM SPECIFICATIONS		FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)		
	C/N......	-48.6	-48.5	-48.4		...C/N
	CTB......	-62.1	-57.1	-52.5		...CTB
	XMO......	-62.1	-57.1	-52.5		...XMO
	2ND......	-64.2	-62.2	-59.8		...2ND
	HUM.....	-56.0	-54.4	-51.9		...HUM

NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
FOUR TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 5

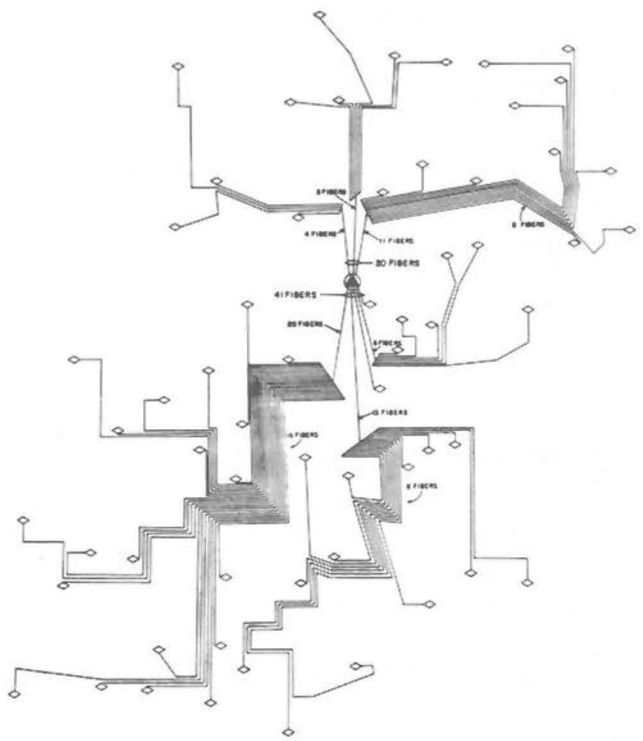

EXHIBIT 6, NODE LOCATION AND FIBER ROUTING FOR TWO IN CASCADE

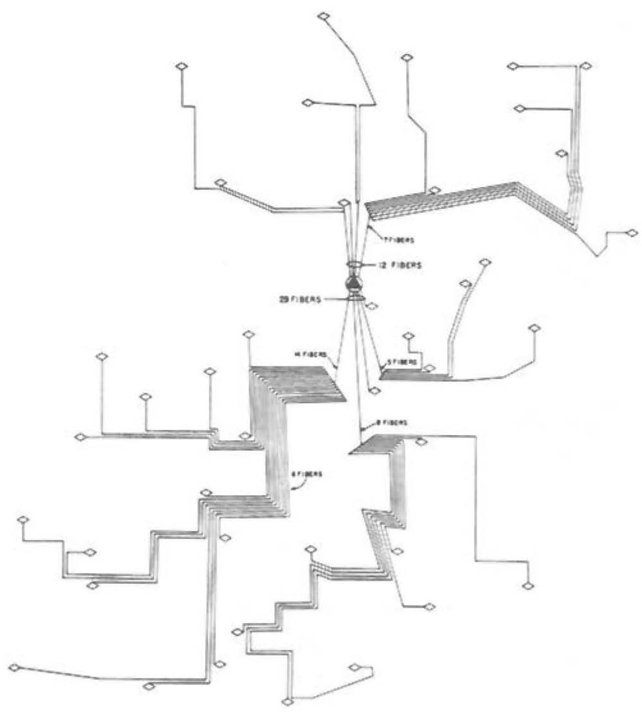

EXHIBIT 7, NODE LOCATION AND FIBER ROUTING FOR THREE IN CASCADE

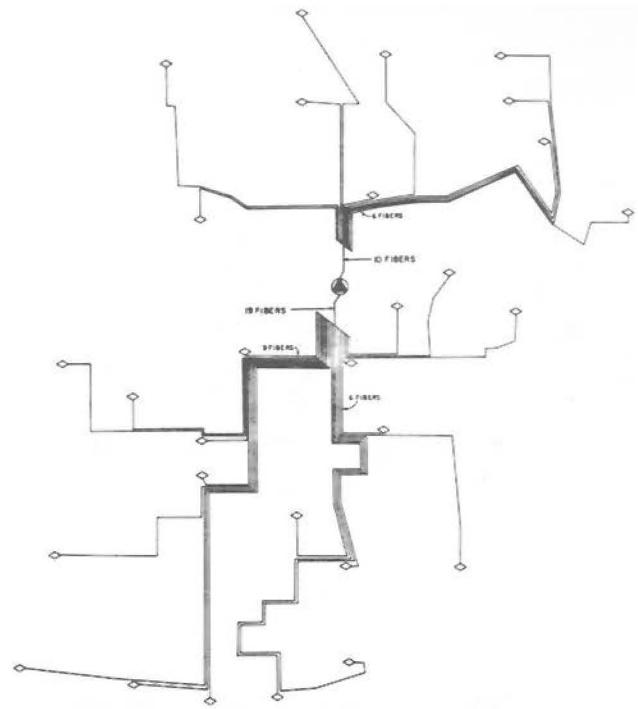

EXHIBIT 8, NODE LOCATION AND FIBER ROUTING FOR FOUR IN CASCADE

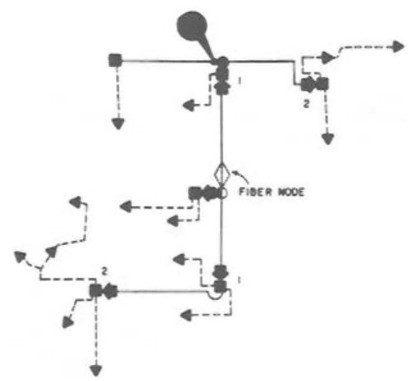

EXHIBIT 9, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS TWO IN CASCADE

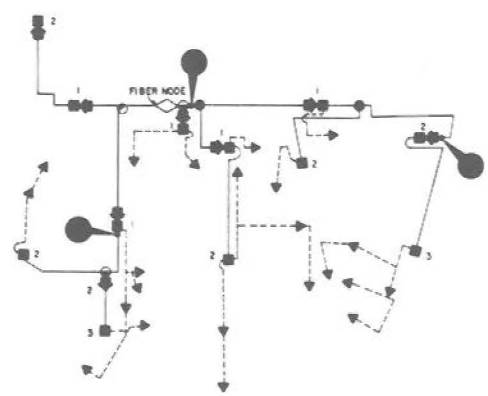

EXHIBIT 10, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS THREE IN CASCADE

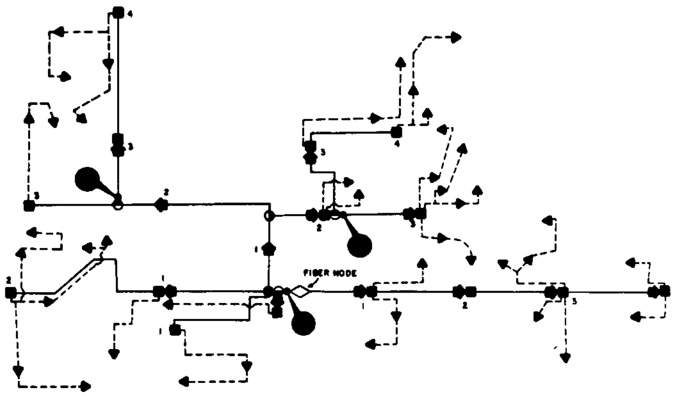

EXHIBIT 11, TYPICAL TRUNK DIAGRAM FOR FIBER NODE PLUS FOUR IN CASCADE

CATV SYSTEM DISTORTIONS

SYSTEM NAME:	FIBER TEST	FWD. BW	4.0	FWD. NOISE	-59.2
DATE	7-Mar 1987	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	FIBER	TRUNK FF	BRIDGER QP	L.E. XQLE
NOISE FIGURE		11.5	9.5	12.0
CTB OUTPUT CAP		38.0	48.0	47.0
CTB RATING(-dBmv)		-85.0	-65.0	-69.0
XMOD OUTPUT CAP		38.0	48.0	47.0
XMOD RATING(-dBmv)		-85.0	-65.0	-69.0
2nd OUTPUT CAP		38.0	48.0	47.0
2nd RATING(-dBmv)		-87.0	-71.0	-73.0
CHANNEL CAPACITY		77.0	77.0	77.0
MANUFACTURER TILT		6.0	10.0	10.0
HUM SPECIFICATION		-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	FIBER	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT		9.3	19.3	19.0
GAIN OR BR DC LOSS		30.0	-20.0	29.0
DESIRED TILT		6.0	9.0	9.0
AMPLIFIER OUTPUT		39.3	48.0	48.0
CHANNEL LOADING		77.0	77.0	77.0
CASCADE LENGTH		3.0	1.0	2.0

CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.
	C/N......	-55.0	-52.2	-69.0	-63.2
	CTB......	-65.0	-73.0	-64.3	-60.3
	XMO......	-85.0	-73.0	-64.3	-60.3
LOG..15.0	2ND......	-65.0	-78.6	-71.0	-67.5
	HUM......	-70.0	-60.5	-70.0	-64.0

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-50.3	-50.3	-50.1	...C/N
CTB......	-62.1	-57.1	-52.5	...CTB
XMO......	-62.1	-57.1	-52.5	...XMO
2ND......	-64.2	-62.3	-59.8	...2ND
HUM......	-58.0	-58.0	-53.1	...HUM

NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
THREE TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 12

CATV SYSTEM DISTORTIONS

SYSTEM NAME:	FIBER TEST	FWD. BW	4.0	FWD. NOISE	-59.2
DATE	7-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	FIBER	TRUNK FF	BRIDGER QP	L.E. XQLE
NOISE FIGURE		11.5	9.5	12.0
CTB OUTPUT CAP		38.0	48.0	47.0
CTB RATING(-dBmv)		-85.0	-65.0	-69.0
XMOD OUTPUT CAP		38.0	48.0	47.0
XMOD RATING(-dBmv)		-85.0	-65.0	-69.0
2nd OUTPUT CAP		38.0	48.0	47.0
2nd RATING(-dBmv)		-87.0	-71.0	-73.0
CHANNEL CAPACITY		77.0	77.0	77.0
MANUFACTURER TILT		6.0	10.0	10.0
HUM SPECIFICATION		-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	FIBER	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT		11.0	21.0	19.0
GAIN OR BR DC LOSS		30.0	-20.0	29.0
DESIRED TILT		6.0	9.0	9.0
AMPLIFIER OUTPUT		41.0	48.0	48.0
CHANNEL LOADING		77.0	77.0	77.0
CASCADE LENGTH		2.0	1.0	2.0

CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.
	C/N......	-55.0	-55.7	-70.7	-63.2
	CTB......	-65.0	-73.0	-64.3	-60.3
	XMO......	-65.0	-73.0	-64.3	-60.3
LOG..15.0	2ND......	-65.0	-79.5	-71.0	-67.5
	HUM......	-70.0	-64.0	-70.0	-64.0

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-52.3	-52.2	-51.9	...C/N
CTB......	-62.1	-57.1	-52.5	...CTB
XMO......	-62.1	-57.1	-52.5	...XMO
2ND......	-64.3	-62.3	-59.9	...2ND
HUM......	-60.5	-58.0	-54.4	...HUM

NOTES: 550 MHz UPGRADE/FIBER BACKBONE.
TWO TRUNK AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 13

CATV SYSTEM DISTORTIONS

SYSTEM NAME:	FIBER TEST	FWD. BW	4.0	FWD. NOISE	-59.2
DATE	7-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	FIBER	TRUNK FF	BRIDGER QP	L.E. PD
NOISE FIGURE		11.5	9.5	13.0
CTB OUTPUT CAP		38.0	48.0	45.0
CTB RATING(-dBmv)		-85.0	-65.0	-67.0
XMOD OUTPUT CAP		38.0	48.0	45.0
XMOD RATING(-dBmv)		-85.0	-65.0	-67.0
2nd OUTPUT CAP		38.0	48.0	45.0
2nd RATING(-dBmv)		-87.0	-71.0	-73.0
CHANNEL CAPACITY		77.0	77.0	77.0
MANUFACTURER TILT		6.0	10.0	10.0
HUM SPECIFICATION		-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	FIBER	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT		8.0	18.0	15.0
GAIN OR BR DC LOSS		30.0	-20.0	29.0
DESIRED TILT		6.0	9.0	9.0
AMPLIFIER OUTPUT		38.0	47.0	44.0
CHANNEL LOADING		77.0	77.0	77.0
CASCADE LENGTH		4.0	1.0	3.0

CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.
	C/N......	-55.0	-49.7	-67.7	-56.4
	CTB......	-65.0	-73.0	-66.3	-58.8
	XMO......	-65.0	-73.0	-66.3	-58.8
LOG..15.0	2ND......	-65.0	-78.0	-72.0	-66.8
	HUM......	-70.0	-58.0	-70.0	-60.5

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-48.6	-48.5	-47.9	...C/N
CTB......	-62.1	-57.9	-52.3	...CTB
XMO......	-62.1	-57.9	-52.3	...XMO
2ND......	-64.2	-62.5	-59.8	...2ND
HUM......	-56.0	-54.4	-50.9	...HUM

NOTES: 550 MHz UPGRADE WITH THREE PD LINE EXTENDERS.
FOUR AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 14

CATV SYSTEM DISTORTIONS

SYSTEM NAME:	FIBER TEST	FWD. BW	4.0	FWD. NOISE	-59.2
DATE	7-Mar 1988	REV. BW	4.000	REV. NOISE	-59.2

MANUFACTURER SPECIFICATIONS	FIBER	TRUNK FF	BRIDGER CP	L.E.
NOISE FIGURE		11.5	9.5	9.5
CTB OUTPUT CAP		38.0	48.0	46.0
CTB RATING(-dBmv)		-85.0	-65.0	-59.0
XMOD OUTPUT CAP		38.0	48.0	46.0
XMOD RATING(-dBmv)		-85.0	-65.0	-59.0
2nd OUTPUT CAP		38.0	48.0	46.0
2nd RATING(-dBmv)		-87.0	-71.0	-70.0
CHANNEL CAPACITY		77.0	77.0	78.0
MANUFACTURER TILT		6.0	10.0	10.0
HUM SPECIFICATION		-70.0	-70.0	-70.0

SYSTEM SPECIFICATIONS	FIBER	TRUNK	BRIDGER	L.E.
AMPLIFIER INPUT		8.0	18.0	16.0
GAIN OR BR DC LOSS		30.0	-20.0	28.0
DESIRED TILT		6.0	9.0	9.0
AMPLIFIER OUTPUT		38.0	47.0	44.0
CHANNEL LOADING		77.0	77.0	77.0
CASCADE LENGTH		4.0	1.0	3.0

CALCULATED EQUIPMENT SPECIFICATIONS		FIBER	TRUNK	BRIDGER	L.E.
	C/N......	-55.0	-49.7	-67.7	-60.9
	CTB......	-65.0	-73.0	-66.3	-52.9
	XMO......	-65.0	-73.0	-66.3	-52.9
LOG..15.0	2ND......	-65.0	-78.0	-72.0	-64.8
	HUM.....	-70.0	-58.0	-70.0	-60.5

CALCULATED SYSTEM SPECIFICATIONS	FWD. TRUNK PLUS FIBER	FWD. TRUNK PLUS BRIDGER	FWD. SYSTEM TR+BR +LE(S)	
C/N......	-48.6	-48.5	-48.3	...C/N
CTB......	-62.1	-57.9	-49.0	...CTB
XMO......	-62.1	-57.9	-49.0	...XMO
2ND......	-64.2	-62.5	-59.0	...2ND
HUM.....	-56.0	-54.4	-50.9	...HUM

NOTES: 550 MHz UPGRADE WITH THREE PD LINE EXTENDERS.
FOUR AMPLIFIERS IN CASCADE FROM FIBER NODE.

EXHIBIT 15