Installation and Performance of An 18-Channel Fiber Optics TVRO Link

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ABSTRACT

This paper reports on the design, construction and performance of a 32-channel Earth Station downlink installed by Times Fiber Communications and Falcon Cable TV in Monterey Park, California.

INTRODUCTION

Falcon Cable TV has built a master headend with 54-channel capacity at Monterey Park which will interconnect subsystems in Montebello, Temple City, Alhambra, Norwalk, Huntington Park and La Canada, California. The satellite antenna site is approximately 4 km (13.125 ft.) from the headend. A total capacity of 32 channels from the headend to the antenna site was required with a minimum degradation of signal quality so that the largest possible geographic area could be serviced with acceptable quality signals. (Eighteen channels were to be activated during startup with the remainder for future expansion.)

Fiber Link Design

The earth station downlink design used at Falcon has been successful in several other installations. At Falcon, Scientific Atlanta satellite receivers were utilized, while Microdyne receivers have also been used in other installations such as United Cable's installation in Plainville, Connecticut. Any satellite receiver having 70 MHz IF output and input ports can be utilized in this method. The receiver is purchased as a split site type; that is, one complete receiver is divided between two housings. The down-converter and 70 MHz IF circuits are installed at the antenna site and the FM demodulator, video and audio circuits are located at the headend site.

The fiber link "up converters" receive up to four 70 MHz IF receiver outputs. One remains at 70 MHz and the other three are converted to higher frequencies. The four frequencies are then frequency division multiplexed and fed to the laser transmitter. The laser transmitter converts the RF signals by intensity modulation of the laser to light signals and transmits them down the fiber.

At the receiver end of the link, an avalanche photodiode (APD) converts the optical power back to RF signals which is split and down-converted to four 70 MHz IF signals. These are then fed to the split site receiver demodulators which give us baseband video and audio out.

Figure 1. System Block Diagram

In the Falcon system, two (4-fiber) fiber optic cables were lashed to a strand along with coaxial cables from the headend. The fiber used was Times Fiber Communications, Inc. graded index fiber with an average bandwidth of 800 MHz/km and 5.0 dB/km loss at 840 nm. Five fibers are presently activated with four channels on four fibers and two channels on the fifth fiber for a total of 18 channels. The system capacity is four channels on eight fibers or 32 channels. The upconverters convert three of the four 70 MHz IF signals to 110, 160, and 250 MHz. 70, 110, 160, and 250 MHz signals are transported on each fiber.

Design Calculations

SNR

In a four channel earth station downlink of this configuration, the signal-to-noise ratio is dependent upon:

1. CNR of the laser output (typically 45 dB).
2. Noise factor of the APD receiver (NR_X = 9 dB).
3. Cascade factor 10 log N (N = No. of repeaters plus receiver.
4. Receiver input level Vin (typically 5 dBmV).

Since this system does not exceed 4 km in length, optical attenuation and bandwidth are not a problem so a repeater is not required.

System CNR = CNR Laser - NR_X + Vin -10 log N

$$CNR = 45 - 9 + 5 - 10 \log 1$$
$$CNR = 41 \text{ dB}$$

The FM improvement in signal-to-noise over carrier-to-noise for this wide deviation FM link is 39 dB.

$$SNR = CNR + \text{improvement}$$
$$SNR = 41 + 39$$
$$SNR = 80 \text{ dB}$$

This SNR indicates that the fiber link will be transparent. By transparent we mean that no signal parameter will change within the accuracy of the test equipment utilized. See actual measured performance section.

Link Loss

In selecting the optical fiber loss required for the system, the following have to be considered:

1. Minimum received optical power.
2. Laser transmitter output.
3. Connector losses.
4. Splice losses.
5. Operating margin.

$$\text{Fiber Loss} = \frac{\text{Max link loss + connector loss}}{\text{length}} + \frac{\text{splice loss + margin}}{\text{length}}$$

$$\text{Allowable link loss} = 10 \log \frac{\text{received power}}{\text{transmitter output}}$$

$$= 10 \log \frac{1 \text{ uw}}{1000 \text{ uw}}$$

$$= -30 \text{ dB}$$

Connector loss = 2 x 1.5 dB /connector = 3 dB

Splice loss = 3 x .3 dB /splice = .9 dB

$$\text{Fiber loss} = \frac{30 + 3 + .9 + 6}{4 \text{ km}}$$

$$= \frac{20.1}{4}$$

$$= 5 \text{ dB/km}$$

AM Coaxial Cable

An AM coaxial system would be possible and we could calculate its SNR as follows:

- o Assume 1" coaxial cable with 0.85 dB/100' at 400 MHz
- o Amplifier spacing 20 dB
- o Amplifier noise of 9 dB
- o Assume input level (Vin.) of 10 dBmV

$$\text{No. of Amp} = \frac{\text{Dist.} \div 100 \times \text{Loss (dB/100)}}{\text{Amp Spacing (dB)}}$$

$$= 13{,}120 \div 100 \times 0.85 \div 20$$

$$= 5.58 \text{ or } 6 \text{ amplifiers}$$

CNR = +59 -N.F. +Vin -10 log N
CNR = +59 -9 +10 -10 log 6
CNR = 52.2 dB
SNR = CNR -4dB
SNR = +48.2 dB

FM Coaxial Cable

Using conventional FM over coaxial cable would be an alternative method; however, cost of such a system would be greater than a fiber link with considerably more electronics including strand mounted electronics in the system. One could also use the same up/down conversion method used over fiber. This would mean eight times as many outdoor electronics locations since eight coaxial cables would be required. (See cost comparisons.) FM in either configuration would produce a transparent link. The SNR calculations are as follows:

CNR = +59 - N.F +Vin - 10 log N
CNR = +59 - 9 +10 - 7.8
CNR = +52.2 dB

The FM improvement for conventional FM links would be 6 to 9 dB or a SNR = 58.2 to 60 dB and the conversion technique gives us a 39 dB improvement which makes both methods transparent.

In summary, we can readily see that if we had a satellite channel at the antenna site of 54 dB weighted SNR, we would obtain, at the headend, in the case of the fiber link or FM link, a SNR of 53.96 dB by combining the two signals on a power basis. In the case of the AM link we would have a 54 dB input signal on a 48.2 dB system with a resultant SNR = 47.19 dB. Transporting the satellite signals at 70 MHz IF and 10.75 MHz deviation gives us an advantage over an AM system of 6.75 dB in SNR. This means that when we use this fiber link, we can extend our system by the number of amplifiers that it replaced, which in this case is six amplifiers.

System Planning

With aerial construction, fiber optic cable splicing must be performed from a bucket truck. Therefore, all splice points must be accessible from a bucket truck. Much of the Falcon installation was along backyard easements which prohibited the use of a bucket truck except at street crossings and short distances along streets as can be seen in the route map below.

Figure 2. Route Map

Because of this, the cable lengths had to be selected carefully so as to have the splice points come out at accessible places with a minimum of excess cable. Once the cables were selected and the splice points located, construction began.

System Installation

The installation of the Falcon cables was accomplished by a contracted cable installation company under the supervision of Times Fiber personnel. Construction was started at the headend working toward the earth station. Because the system was a new installation, coaxial cables were being installed at the same time, all lashed to strand. The first length of cable to be installed was 1.3 km (4200 ft.). This length had seven 90° corners, (three vertical, four horizontal) and three 45^{o} bends. No special equipment or techniques were required beyond good coaxial cable installation practices. Hanging and lashing of the fiber and coaxial cables was accomplished in approximately three weeks without any problems.

Fiber Cable Splicing

After the cable installation was complete, Times' splicing crew proceeded to splice the cables. Fiber splicing is accomplished using a fusion splicer which melts the ends of the glass fiber together. One person makes the actual splices while a second person advises him of the quality of the splice by observing using an optical TDR.

The 24 splices required for this system were completed in three days with an average splice loss of less than 0.3 dB.

System Interconnection

The optical components (transmitters and receivers) are then hooked up and received power measurements made. Actual received power measurements and meas- ured system attenuation was very close to the predicted values. See actual system measurements.

After the optical power measurements are made, the remaining equipment is hooked up and system performance is measured. System performance attests to the fact that this fiber optic satellite downlink is truly a transparent system.

Actual System Measurements

All 18 active channels were measured, and the signal-to-noise figures are given below. The HBO channel was examined in detail as the photos below show. In all cases, the Fig.(n)A is the antenna site and Fig. (n)B is at the headend. HBO transmits, during the vertical interval, a composite combination test signal, modulated stairstep, and a field square wave which were utilized.

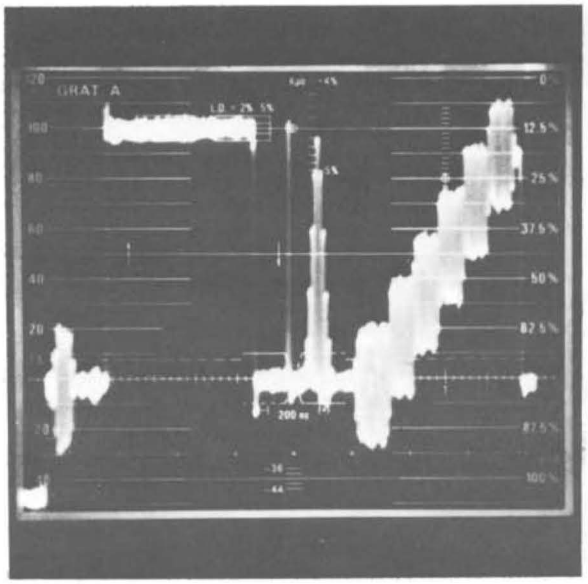
The following table is a comparison of the predicted system loss to the measured loss. For the five lines in use:

Predicted loss = Cable loss + Connector loss + Splice loss:

	I	II	III	IV	V
Cable loss-dB	20.3	19.2	20.2	19.7	19.6
Connector loss-dB	3.0	3.0	3.0	3.0	3.0
Splice loss-dB	0.9	0.9	0.9	0.9	0.9
Total - dB	24.2	23.1	24.1	23.6	23.5

$$\text{Actual Loss} - 10 \log \frac{\text{Transmitter output}}{\text{Receiver input}}$$

	I	II	III	IV	V
Transmitter Output-μW	1000	1000	1050	995	1075
Receiver Input-μW	6.1	4.7	5.5	4.65	4.2
Actual Loss-dB	22.1	23.5	22.8	23.3	24.1



Earth Station
Fig. 3A

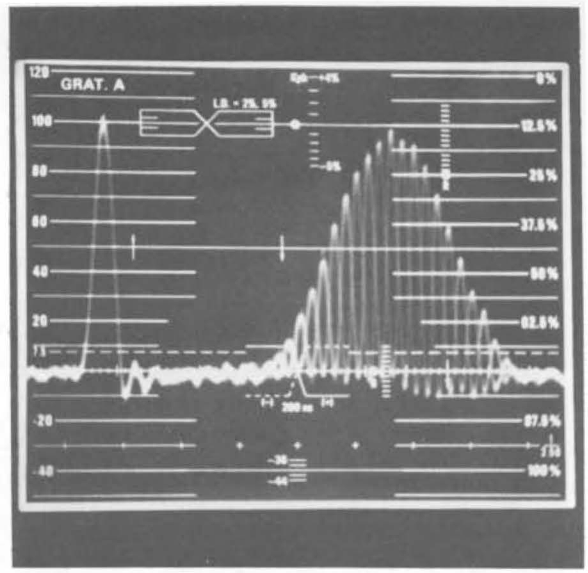


Fig. 4A
Earth Station

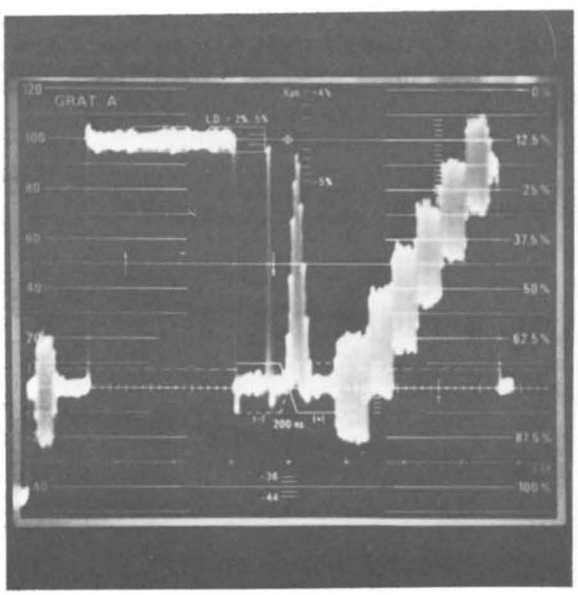


Fig. 3B
Headend

The above composite signal shows insertion gain is zero, and line time distortion is zero.

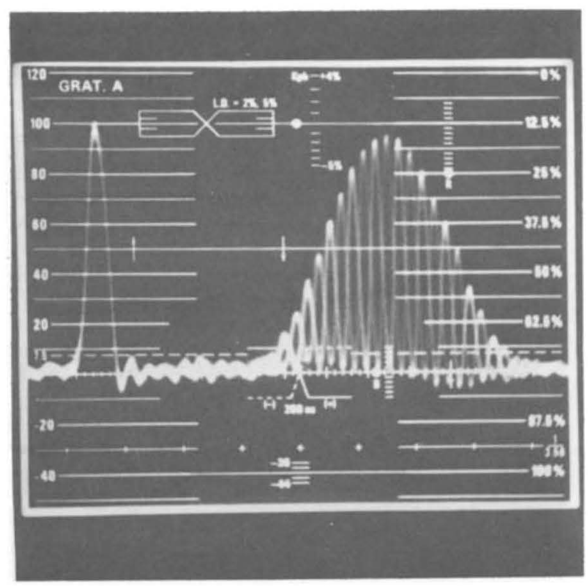


Fig. 4B
Headend

The above expanded view of the 2T and 12.5T pulses show some short time distortion and chrominance-luminance given inequality and some chrominance-luminance delay inequality, however, they are virtually the same at the earth station and the headend.

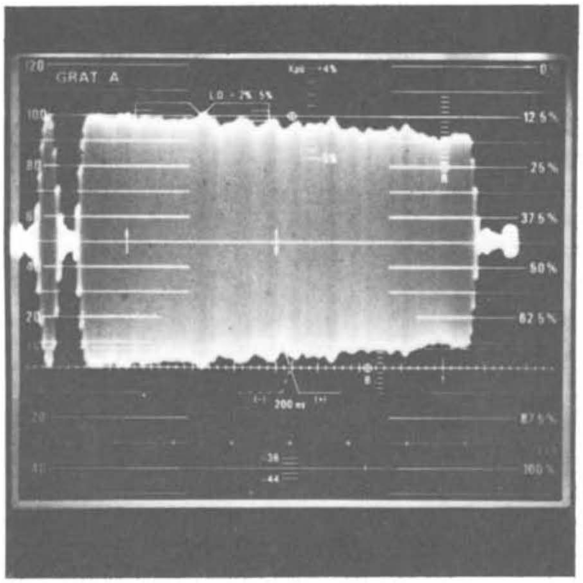


Fig. 5A
Earth Station

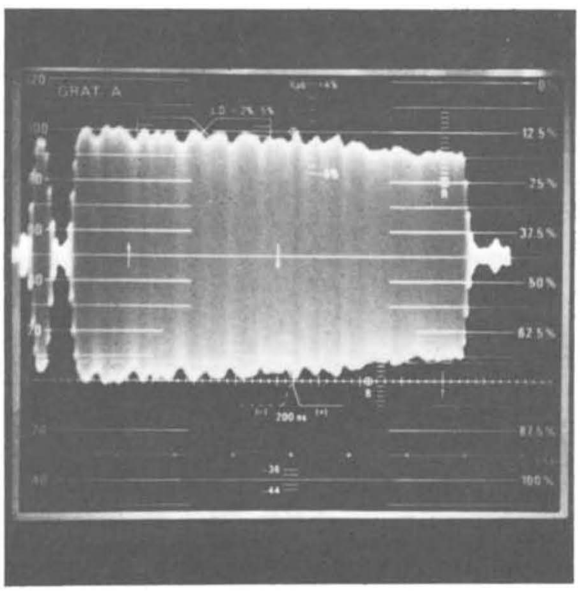


Fig. 5B
Headend

The above pictures of the 5 step staircase passed through a high pass filter show some differential gain, however, it is the same from Earth Station to Headend.

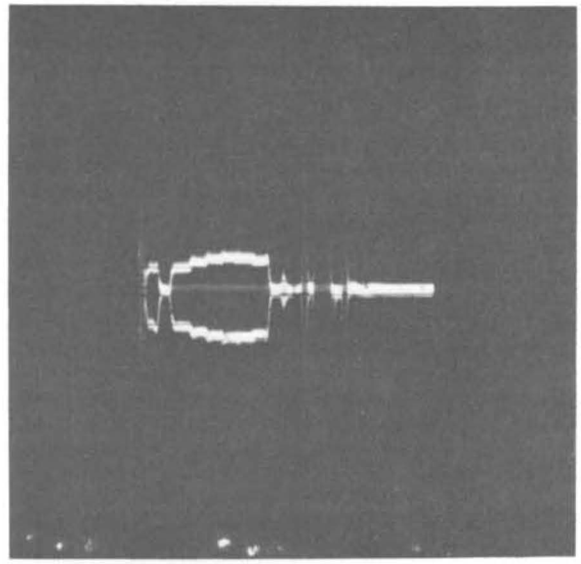


Fig. 6A
Earth Station

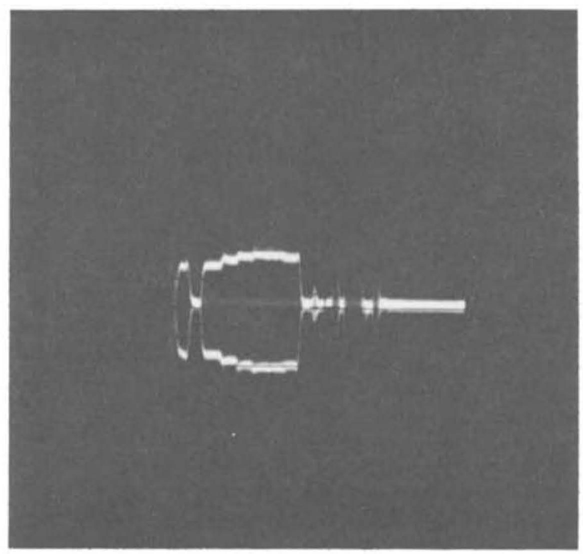


Fig. 6B
Headend

The above pictures show some differential phase distortion, however, it is the same at both ends of the fiber link.

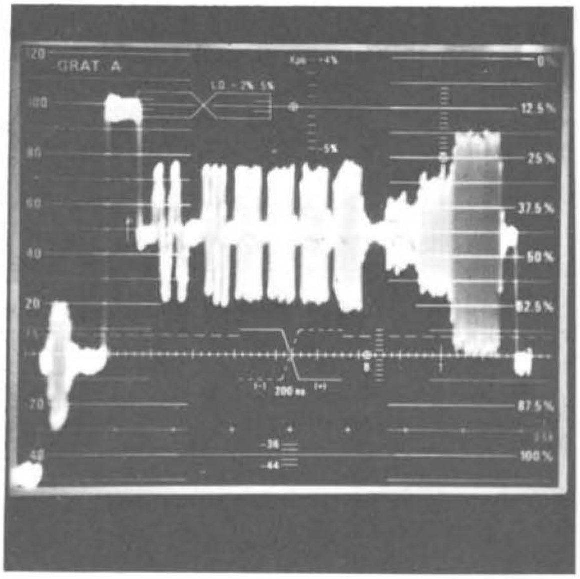


Fig. 7A
Earth Station

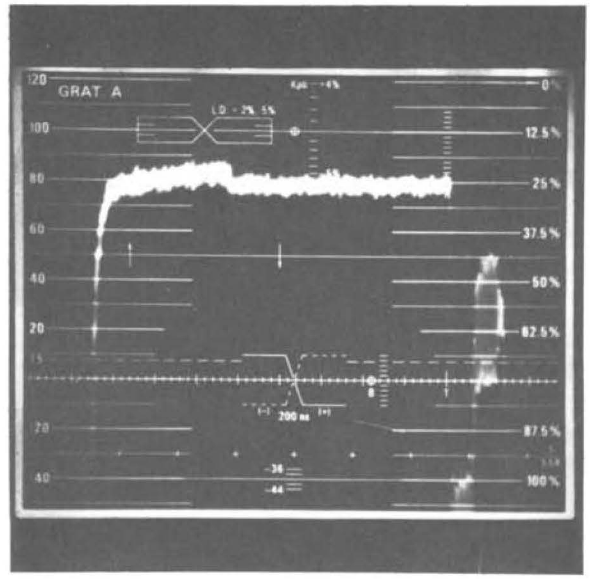


Fig. 8A
Earth Station

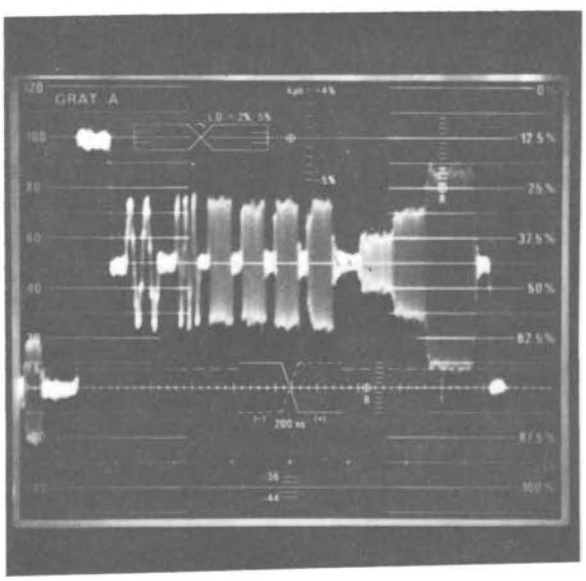


Fig. 7B
Headend

The above pictures show that gain/frequency distortion is zero at both ends of the link.

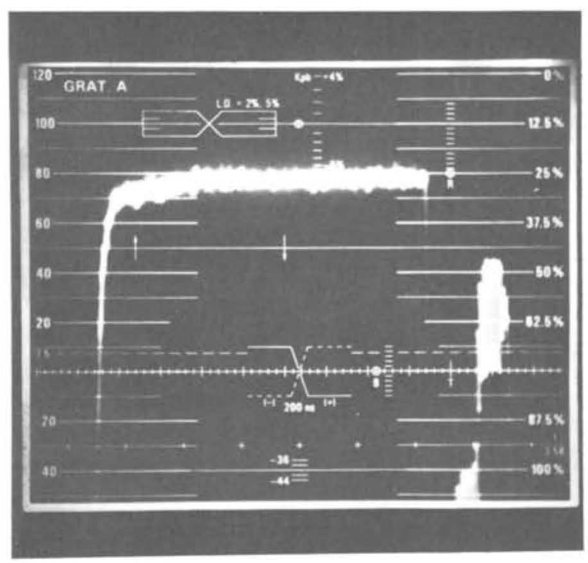


Fig. 8B
Headend

The above pictures are of the line bar of the composite waveform with noise inserted. The weighted signal-to-noise measurement of both ends of the system indicate 52 dB signal-to-noise.

The actual EIA weighted SNR measurements at the Earth station site and after the fiber link at the headend were measured. It should be noted that a time interval of several hours elapsed between the measurements at either end and some change in transmission or reception quality can enter into the measurements, consequently one should not consider a difference of 1 dB significant. In the following table under station, a statement such as ------blank (HBO) means there was no signal on the assigned frequency so an agile receiver was used to put up another signal (in this case, HBO) to make the fiber system measurements.

Fbr. #	Rx #	Station	S/N Anten.	S/N Hdend
1	1	WGN	53 dB	52 dB
	2	ESPN	52 dB	52 dB
	3	USA	52 dB	51 dB
	4	Ncklodeon	52 dB	52 dB
2	5	WOR	51 dB	50 dB
	6	Blnk (ESPN)	52 dB	52 dB
	7	Cinemax	52 dB	52 dB
	8	Movie Chan	52 dB	51 dB
3	9	CBN	52 dB	52 dB
	10	CNN	51 dB	51 dB
	11	ACSN	50 dB	51 dB
	12	Gala-vision	51 dB	50 dB
4	13	HBO	52 dB	51 dB
	14	WTBS	51 dB	50 dB
	15	BRAVO	49 dB	48 dB
	16	Blnk (Gala)	51 dB	50 dB
5	17	Blank (HBO)	52 dB	51 dB
	18	Blnk (WTBS)	51 dB	50 dB

Cost Comparison

32-Channel-8-fiber Earth Station Link

8 ea. Transmitters and Receivers (Optical)	$ 31,500
8 ea. Up/down Converter Sets	38,224
8 fiber optic cable 13,125'	31,500
Total System Price	$101,224

Note: This price includes all connectors, hardware, etc., except racks for the electronics.

32-Channel FM Coaxial Link

For cost effectiveness 1/2" coaxial cable was used with 9 amplifiers in this calculation. Two cables required with 16 channels/cable.

32 ea. FM Modems @ 3,000/modem	$ 96,000
18 ea. Trunk Amp. @ 900/amp	16,200
26,250' 1/2" cable @ 210/1000'	5,538
Total Cost	$117,738

Note: This price is for the electronics and cable only. No interconnections, connectors for the coaxial cable or rack mounts for electronics are included.

SUMMARY

The fiber optic system installed by Falcon and Times at the Monterey Park facility is transparent, has no electronics on the strand outdoors, and is the least costly method of transporting quality signals to the headend. There is no question but that they can now extend their trunk lines by at least the number of amplifiers saved over the AM method with the same SNR that would have provided. This ability to extend their trunks another 6 amplifiers deep means a great increase in geographic area covered.