PROGRESS IN FIBER OPTICS TRANSMISSION SYSTEMS FOR CABLE TELEVISION

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This paper reports the continuing progress achieved during the preceding year in fiber optics transmission systems applicable to CATV requirements.

Developments in transmitter/receiver design and signal conditioning are described. Also, included is a discussion of the operating experience and retrofit update of a 12 channel, eight kilometer fiber optic super trunk. A unique feature of the system described is that only one repeater location is employed in contrast with a conventional cable TV system which would require 12 repeaters to cover the same distance.

Specific fiber optic system constraints, including modal noise and carrier distortion, are discussed and the signal conditioning methodology employed to achieve exceptional CATV operational performance is outlined. The impact of these recently developed techniques on fiber optic satellite ground station links, super trunks, and office to head end transmission links is presented.

During the past 12 months, significant improvements have been made in laser transmitter modules, optical receivers, splicing techniques, signal conditioning, and optical reflectometers--all of which have contributed to increased performance, ease in construction, and improved reliability of fiber optic transportation systems. To briefly look at these various improvements, let's examine an existing system and then look at what effect these improvements have had and will have on that system in the near future.

History

The Lompoc system was installed during November and December of 1978 by Teleprompter as an expansion of their pioneering fiber optic experiment in New York City. (See Figure 1)

Figure 1 is a block diagram of the 12 channel, 2 active fiber system as installed at Lompoc. The total length of this fiber optic run is 8.4 km (27,560 ft.) and 3 repeaters were required at approximately 2.1 km intervals. The signals are F.M. modulated at 2.5 MHz deviation and feed to a passive combiner whose output is used to drive the laser module in the optical transmitter. The frequency of the 6 channels in Group A are from 30 to 230 MHz with 40 MHz spacing. Group B signals are from 50 to 250 MHz and the same spacing. These frequencies were selected to allow for the possibility of putting up all 12 channels on a single fiber whenever higher power lasers became available.

The combined F.M. signals are converted to optical signals by the optical transmitter, transported over the fiber and converted back to electrical signals by the optical receiver. A passive divider splits the signals which are then demodulated back to baseband. Transporting the signals by F.M. with 2.5 MHz deviation gives us in practice 13 to 14 dB of F.M. enhancement over received carrier/noise.

The fiber cable used in this system contained 3 fibers and was installed in 8 lengths of approximately 1 km. Fiber optic connectors were used to join the cable and, of course, to interface all electronics.

This system meets the design goal of 50 dB (EIA weighted) signal-to-noise with no visible distortion, but with essentially no margin.

Both Teleprompter and Times have learned a great deal from this experimental system. In fact, many of the developments mentioned in this paper were a direct result of the continuing work being done at Lompoc.

Optical Transmitter

Twelve months ago, the optical transmitters available from Times had a carrier/noise of approximately 42 dB at the laser module output. After approximately 4000 hours of operation in the Lompoc system, a variation of transmitted optical power which did not seem to correlate with temperature nor humidity swings was noticeable. This variation was finally traced to a corrosion forming on the laser itself. The laser drive circuitry was redesigned and the laser module repackaged into a hermetically sealed container. This, along with a general improvement in laser noise levels, has given us an improvement from approximately 42 dB carrier/noise output at the laser to 50 dB. No repetition of the corrosion has occurred in many hours of operation. Incidently, the laser module is expected to have a life expectancy of 100,000 hours which is in excess of 11 years.

Optical Receiver

A new low noise receiver amplifier has been designed, tested, and field-proven which now allows us to work with optical powers as low as 3.5 microwatts, whereas previously 6 microwatts was the lower limit. In addition, we have reduced the noise floor giving us improved signal-to-noise levels.

Fusion Splicing

Prior to 1980 all Times supplied systems used the Deutsch optical connectors for splices. These connectors are field-proven, easy to use, and reliable. Incidently, Times has standarized on Deutsch for all its fiber to electronic interfaces.

Lower loss splicing methods have been available for some time; however, they were difficult to use in the field and many methods tend to show loss variations with temperature swings.

This fusion splicer is now available from Times. It is battery operated and has been field-proven over the last six months. We consistently obtain .4 to .5 dB loss across a splice in the field, without temperature problems. This unit allows us to eliminate the use of connectors for splices with a saving of approximately 1 dB per connection.

Impact on the System

(See Figure 3). During November and December of 1979, the new laser transmitter modules and the new low noise receiver module were installed at Lompoc. The connectors used in connecting the fiber cables together were eliminated by fuse splicing. Two repeaters were eliminated making the run approximately 4.2 km (13,800 ft.) on each side of the remaining repeater. The system performance was essentially the same after this retrofit, however, as you can readily imagine, it would be easier to maintain and reliability would be improved through reduction in parts count.

Based on today's price, the original Lompoc system would have sold for $100,836 complete. The system shown in Figure 3 would have a price tag of $84,984, a 15% reduction.

Signal Conditioning

About the same time as the retrofit F.M. modulator/demodulators which would allow one to adjust the deviation from approximately 2 to 8 MHz became available, we obtained four of these units and used the full 8 MHz deviation with 4 channels up on a fiber. The F.M. enhancement experienced was 20 dB and we were able to measure (EIA weighted) signal/noise of from 54 to 58. Our Engineering Department has been evaluating and testing these new Tomco units and feel that we are ready to start using them in our systems. We have simulated the Lompoc system in our lab and have a similar system here in the hall where, if you like, you can make some signal-to-noise measurements yourself. (See Figure 4)

Our field Engineering Department has scheduled a retrofit for Lompoc the week of June 9. New F.M. modulator/demodulator pairs will be installed with 5 MHz deviation and 20 MHz spacing. Six channels at 20 MHz spacing will be transmitted on each of 2 fibers and our tests indicate we should realize 18 dB of F.M. enhancement which will give us 50 dB signal/noise with ample margin.

Earth Station Links

All the improvements covered, of course, are applicable to Earth Station links except, in some cases, the F.M. signal conditioning equipment. Since many manufacturers of satellite receivers down convert to 70 MHz I.F., we can take advantage of this fact. The 70 MHz I.F. is F.M. with a deviation of 10.75 MHz. Just what a fiber system needs. Typical of systems being quoted lately is the United Cable, Plainville, CT, system which is slated for installation in September of this year. (See Figure 5)

This system will transport 8 channels from the satellite antenna site to the headend - a total distance of 9.5 km (31,168 ft.) One repeater will be used at approximately 4 km. One of the satellite receivers will have its 70 MHz I.F. feed direct to the passive combiner. The other 3 receiver I.F. outputs will be converted by hetrodyning as shown. At the other end of the link, we down convert and feed all four 70 MHz I.F. signals to the satellite receivers demodulator which, of course, had been removed from the satellite receivers at the antenna input end of the link. By doing this, we realize 39 dB F.M. enhancement to received carriers/noise.

It might be of interest to note that if this system had been quoted 12 months ago, the system would cost $80,186 based on present prices. The price today is $60,433, a 25% reduction in 12 months.

Optical Reflectometer

(See Figure 6)

Although not directly connected with the performance of a fiber optic system, the optical reflectometer is a very necessary tool. The unit pictured here has been available for several years and is typical of many others on the market. The OR-1 like the others, for the most part, is a very accurate, reliable and easily used unit in the lab. In the field, it becomes a tremendously frustrating monster. The procedure for using this device is to clean the fiber optic and insert the bare fiber into a capillary tube located in the X-Y positioner.

The problem in the field is the large amount of infrared present in sunlight plus wind. Take this unit plus a scope for readout up in a bucket truck on a windy sunny day and one can take, literally, hours to get good measurements. (See Figure 7)

This is our new field unit which can be battery-powered and comes either as a separate stand alone package or with a Tektronix scope. The big difference is the fact that the positioning device is eliminated and a fiber optic connector is used. In this case, a Deutsch bulkhead connector is mounted. Now one simply installs a connector on the fiber to be measured, plugs it in and proceeds with the readings. There is no infrared leakage and it's not affected by the wind. Measurements are now possible in minutes.

Summary

To illustrate what all of the aforementioned improvements mean, let's look at a system installed in early April of this year at Vision Cable in Fort Lee, NJ. (See Figure 8).

This system is presently in operation. It has 2 active fibers with 5 channels from the studio/microwave site to the headend and 2 channels in the opposite direction. The total distance is 8,800 feet, all of which is aerial except for 1200 feet of ductwork at the headend location. Vision Cable System's own system crew installed the fiber cable in two sections over four working days. Times Field Engineering crew fuse spliced the cable, checked out the system, and ran performance tests in 2 days - a total of 6 working days from start to integration into their CATV system by a crew with no previous construction experience with fiber cable. This system performance measurements came out as follows:

Link	EIA Weighted Signal to Noise
40 MHz	59 dB
110 MHz	55 dB
Optical Power Received	33 microwatts

Link 2	EIA Weighted Signal to Noise
40 MHz	57 dB
110 MHz	53 dB
200 MHz	54 dB
230 MHz	56 dB
250 MHz	55 dB
Optical Power Received	30 microwatts

The F.M. modulators/demodulators in this system used 2.5 MHz deviation.

In closing, continual progress is being made in fiber optic transmission systems as we have related. The improvements of the last 12 months in lasers, laser drive circuitry, laser packaging, low noise receiver amplifiers, fuse splicing, and signal conditioning equipment has allowed us to extend the distance between repeaters in some cases from approximately 6,500 feet to 16,000 feet with, of course, a reduction in system cost and improved reliability by reducing parts count.

Other companies contributing to the results mentioned in this paper are

General Optronics - Injection Laser Diodes
RCA - Avalanche Photo Detectors
Tomco Communications - F.M. Modulators and Demodulators
Power Technology, Inc. - Fuse Splicer
Deutsch - Optical Connectors

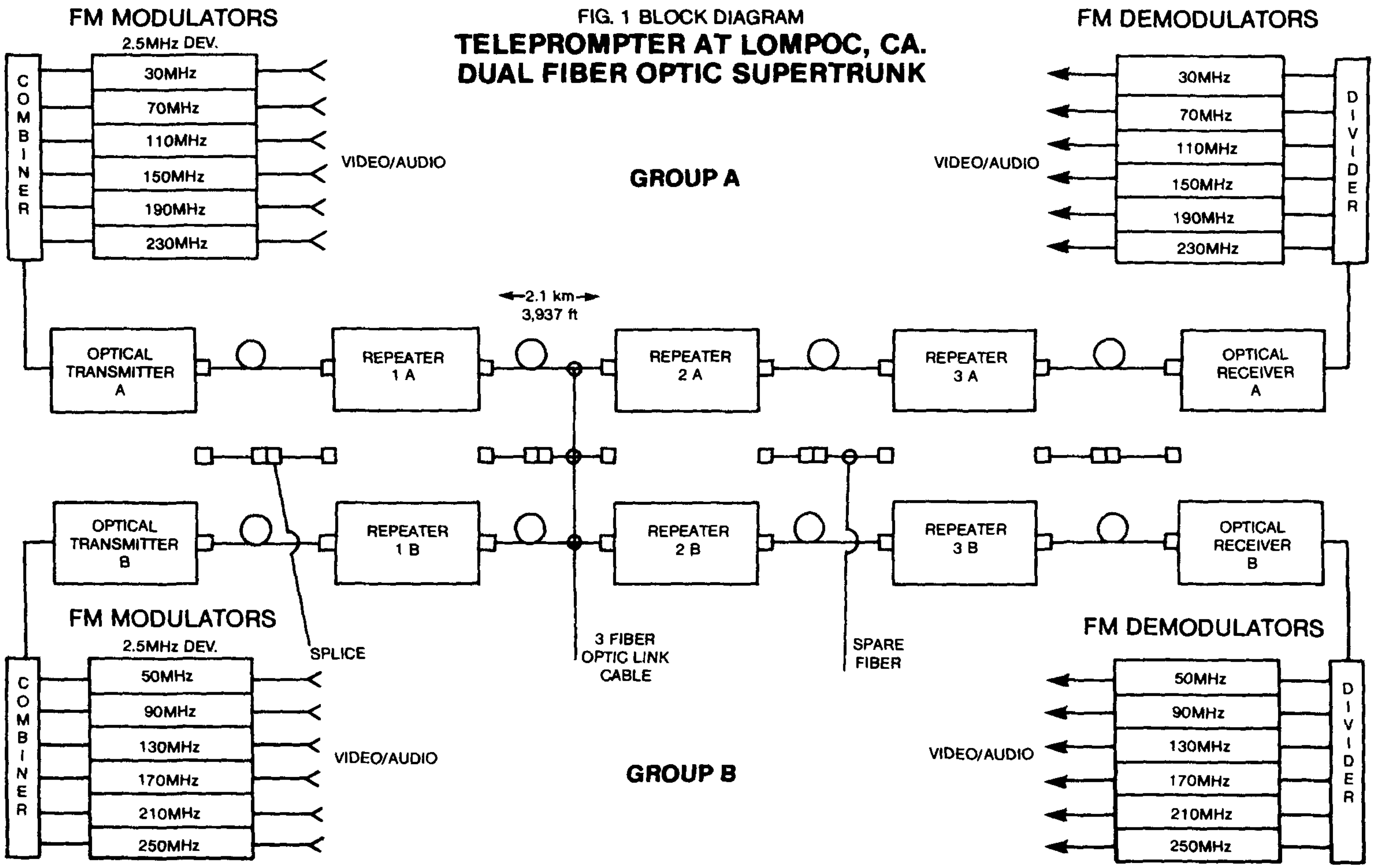


FIG. 1 BLOCK DIAGRAM

TELEPROMPTER AT LOMPOC, CA.
DUAL FIBER OPTIC SUPERTRUNK

FIG. 3 BLOCK DIAGRAM
TELEPROMPTER AT LOMPOC, CA.
DUAL FIBER OPTIC SUPERTRUNK

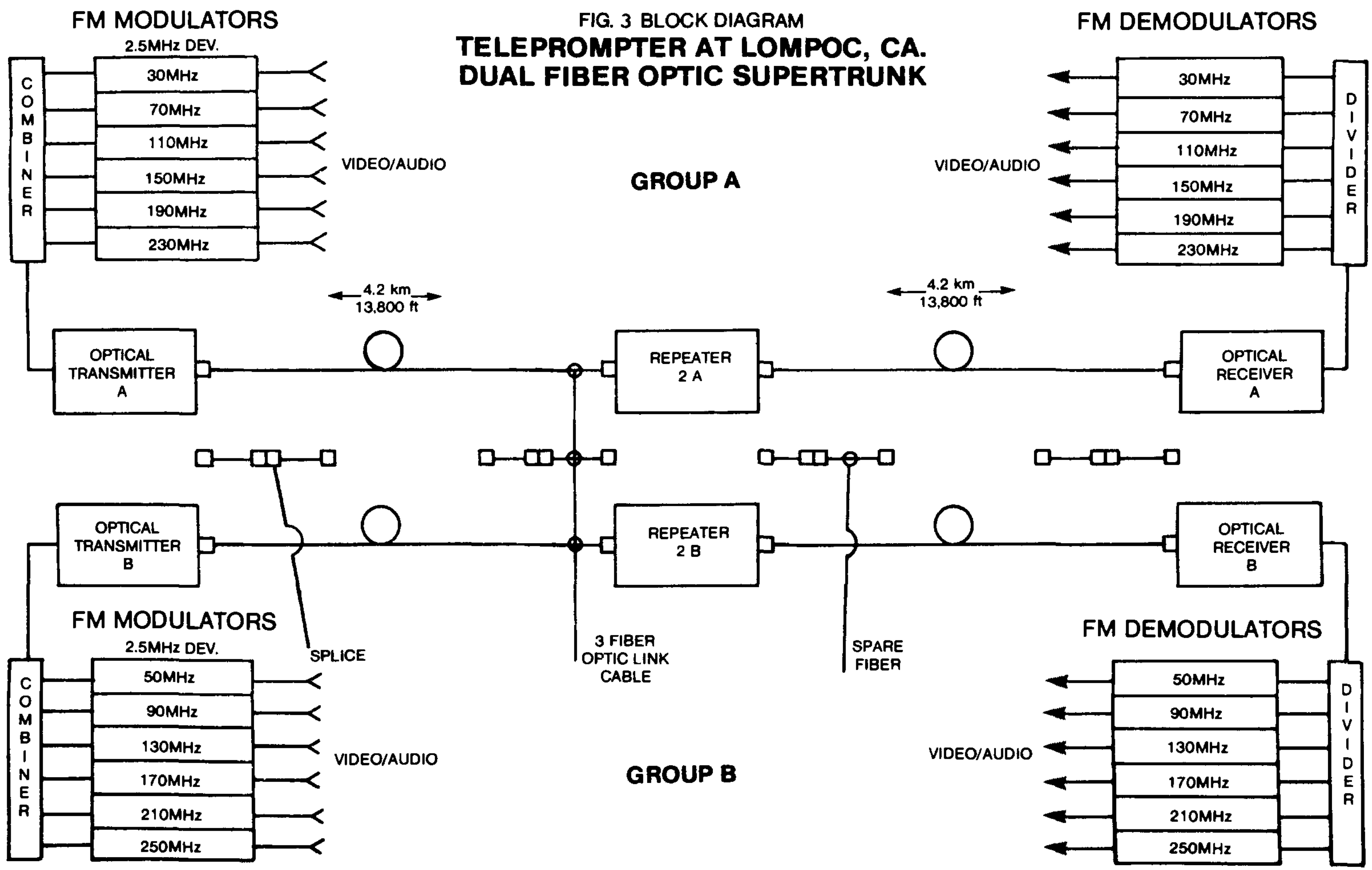


FIG. 4 BLOCK DIAGRAM
TELEPROMPTER AT LOMPOC, CA.
DUAL FIBER OPTIC SUPERTRUNK

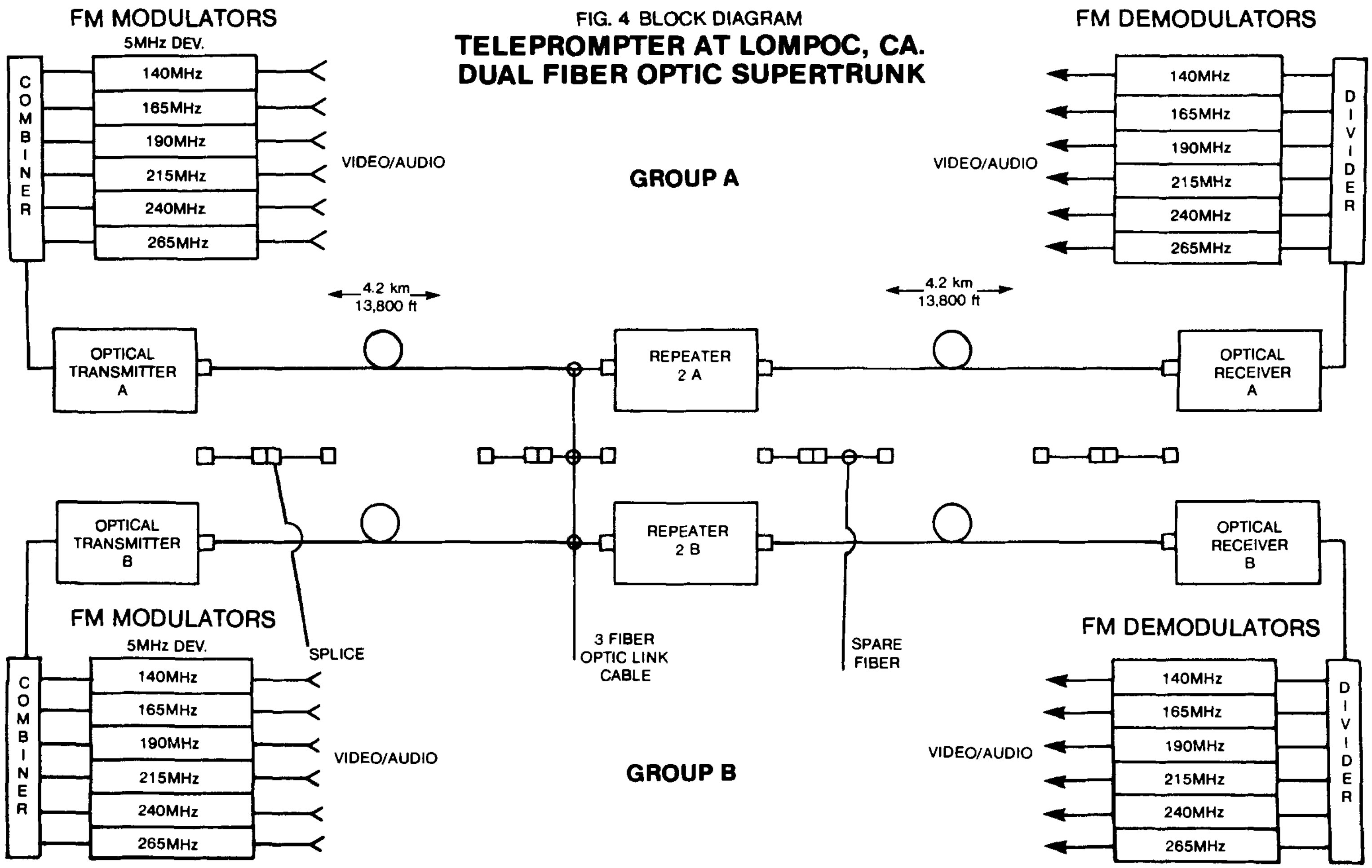


FIG. 5 BLOCK DIAGRAM

FIBER OPTIC SYSTEM
UNITED CABLE
PLAINVILLE, CT.

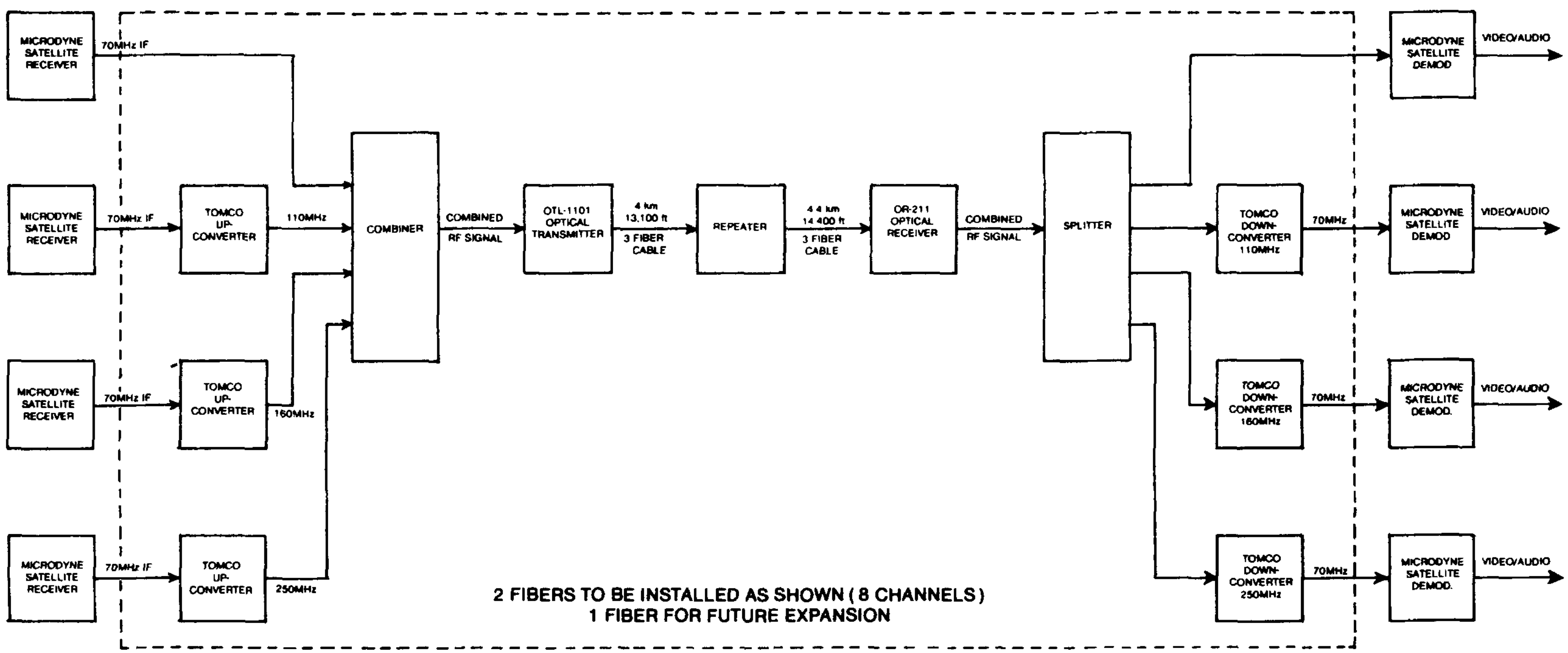


FIG. 6

TIMES FIBER COMMUNICATIONS, INC.

MODEL OR-1

OPTICAL REFLECTOMETER

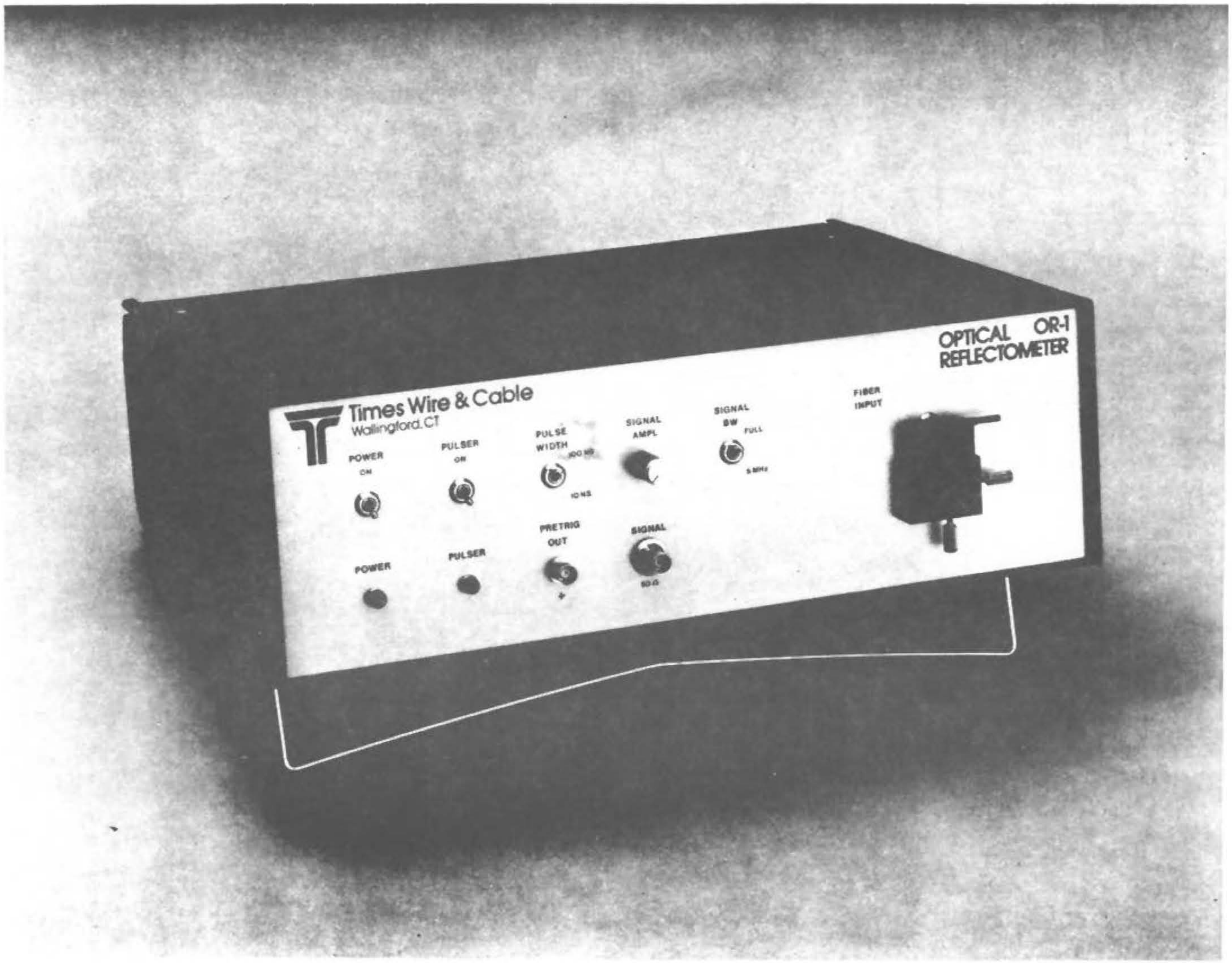
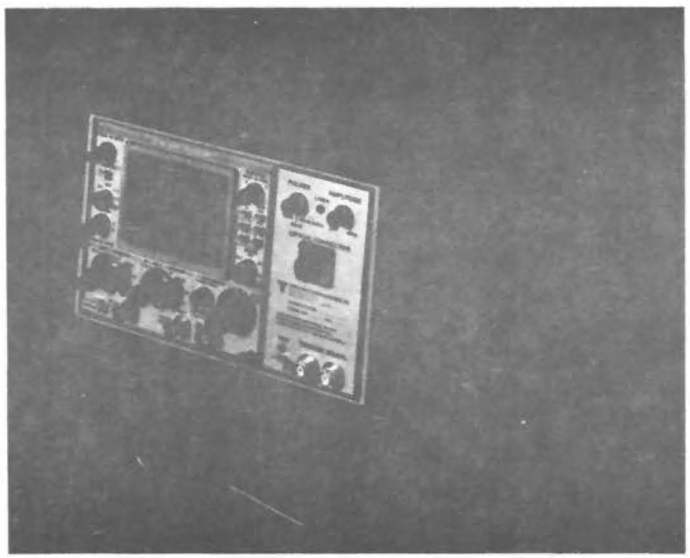


FIG. 7

TIMES FIBER COMMUNICATIONS, INC.

OPTICAL REFLECTOMETER



MODEL: SYSTEM 53

MODEL: SYSTEM 51

FIG. 8 BLOCK DIAGRAM
VISION CABLE
FORT LEE, NJ
STUDIO ---- HEADEND