A DISCUSSION OF A FIBER OPTIC OFF-PREMISES TWO-WAY ADDRESSABLE CONVERTER SYSTEM INSTALLATION: THE SUCCESSES AND LESSONS OF ALAMEDA

Lawrence W. Engdahl
Manager Mechanical Engineering

Times Fiber Communications, Inc.
Wallingford, Connecticut

ABSTRACT

United Cable Television Company's Alameda California cable system is an application of fiber-optic technology in a dual-cable, two-way franchise. The 24,000 homes passed in the star-switched Mini-Hub I system provided new lessons and solutions that previous French and Japanese developments attempted to solve with smaller subscriber bases.

Times Fiber Communications, Inc. (TFC) electronic developments incorporated commercial quality components into outdoor off-premises equipment. Micro-computer technology was incorporated into two-way, FSK, high traffic fiber-optic links between subscribers and the local hubs. Important lessons on trunk amplifier tuning and constructing the two-way coaxial link between the headend to the local hubs were also learned.

The world's most extensive aerial and burial fiber-optic distribution system contains patentable developments in fiber connections, junctions, and weatherproofing. Two new fiber optic connectors were introduced that reduced fiber connector costs by five times.

INTRODUCTION

The purpose of this report is to review the details of the design and installation of the fiber-optic subscriber distribution portion of the system, and put it in perspective with other phases of the Alameda construction. Each part of the link will be discussed with regard to the initial design and related theoretical decisions, lab test results, and an explanation of field experiences.

COAXIAL TRUNK PLANT

Star-switched systems greatly affect the design of the trunk and feeder portion of one- and two-way systems. The amplifiers in the Alameda system (Jerrold JN Series) were spaced 21 dB to satisfy a maximum cascade requirement of 14 amplifiers for the Cable A and Cable B downlinks. This short cascade is a benefit of star-switched designs. Long cascades used fused-disc to achieve the 14 amplifier design goal and 1.0 inch diameter and .750 inch diameter semiflex cables were used in the remainder of the lines.

Two-way addressing required rigorous enforcement of standard industry quality measures to ensure performance. Unterminated cable ends at future hub sites created severe noise ingress problems during activation of the two-way link to the first fully initialized hub sites. Trunk line connectors and splices required extensive reworking to reduce noise ingress during the hub-to-headend link activations.

COMPUTER CONTROL

User-friendly is a term most computer system engineers apply to software/operator interfaces; however, a star-switched system with computer diagnostics is very "user-friendly" to the radio-equipped service technician. When hub sites were activated or customer complaints were troubleshot, the field technician received confirmation within minutes that his actions had or had not resulted in success. As the system size expanded beyond previous system sizes (30 to 40 sites) during construction, new control requirements necessitated enhancements to the digital hardware in the hub.

THE SUBSCRIBER LINK

In Mini-Hub I the subscriber link (Figure 1) between the off-premises hub and the home contains two fibers--one for delivering video to the TV and the other to return the keypad encoded channel requests to the hub. The converter output originates from an LED to which one end of the optical fiber is directly connected. The subscriber end of the optical fiber is terminated in a receiver (RIU) which converts this optical signal to an electronic video signal. This video link of the fiber can carry channels 3, 6, and the FM band simultaneously. The return or uplink is similar, encoded FSK keypad commands are converted to optical pulses (9600 baud) at the RIU which then transmits them to the converter for channel selection.

LED AND FIBER

The Motorola LED (SFOE 101B) supplied in a TO-52 can was a design match to TFC's 200-250 micrometer step-index fiber; this resulted in the availability of 200 to 400 microwatts of launched optical power into each subscriber link. A performance minimum of 30 microwatts delivered to

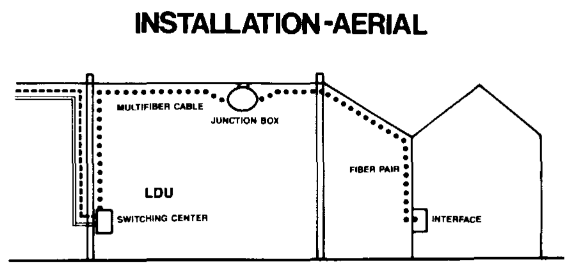


Figure 1

the subscribers' receivers required link losses no greater than 8 dB and an installation budget of 6 dB to allow for aging. Factory testing and selection of the LED resulted in very high converter light outputs that provided excellent reliability in the converter section. A field problem was keeping the optical ports of the transmitters and receivers clean enough to maintain high optical power transmission. This was accomplished with plastic caps.

The video receiver used was a Motorola SFOD133 and the FSK subscriber uplink which required much less performance than the video downlink utilized a Honeywell SE4342 with an SD4342-2 detector that had a 13 dB loss budget. Therefore, choices were available to the installer to utilize the lowest power loss link for the video downlink.

The 200 micrometer core fiber was made to a 250 micrometer ±3 micrometer outer diameter size with fiber attenuation of 7.0 dB per kilometer (or approximately .21 dB/100 ft). Connectors were fabricated with a 253 micrometer minimum bore. Most measuring instruments or wire gauges are made in increments of 2.5 micrometer (0.0001 inch) scale resolution; therefore, oversized fiber or undersized connectors can't be detected. To remedy these situations, the installers were provided with oversized connectors.

FIBER CONNECTORS

From the very beginning of the Mini-Hub I concept, the problem of fiber optic connector choices was a major issue. Optical fiber connector design, now as then, was based on low-cost epoxy fastened requiring high installation cost, or high-cost mechanical clamp technologies, both unsuitable for a CATV fiber star network. New development goals were needed. Three targets were chosen as connector design development goals.

1. The connector was to be manufactured for less than $1.00 per unit.
2. The connector was to be able to be field-installed in less than 5 minutes.
3. The connector had to possess an optical power loss of less than 1.0 dB.

The efforts took two directions--one, to develop a connector internally and two, to support a similar effort by an outside vendor. By the time Alameda construction was started, a third TFC-developed connector, the Three Pin Connector II or TPC II, had been developed. It could be installed in less than 2 minutes, had a mean loss of 0.9 dB, and cost slightly more than $1.00 per plug. Figure 2 shows a statistical compilation of loss measurements of five readings per connector-pairing for many connectors.

A second development contributed by AMP, Inc. was the crimpable Optimate SFR, which only required a one-step polish. The AMP Optimate could be installed in 2.5 minutes, had a mean loss of 0.8 dB, and a cost of $2.50 per plug. Figure 3 represents a statistical compilation of the results of five readings made on each connector.

The TPC II connector exhibited a better optical loss change over different temperatures and therefore it was preferred for outdoor use. It was estimated that over 150,000 connectors would be required for the Alameda system, so two production sources were needed to meet their needs.

The installation of connectors required the training of new people in a skill with which they were not familiar. Of particular importance is the cleaving operation on the TPC II connector. The use of simple crimping tools quickened the connector installation and one-step fiber polishing posed little problems.

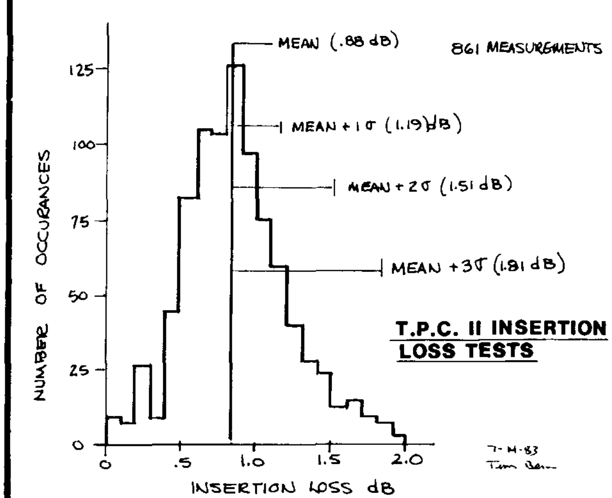


Figure 2

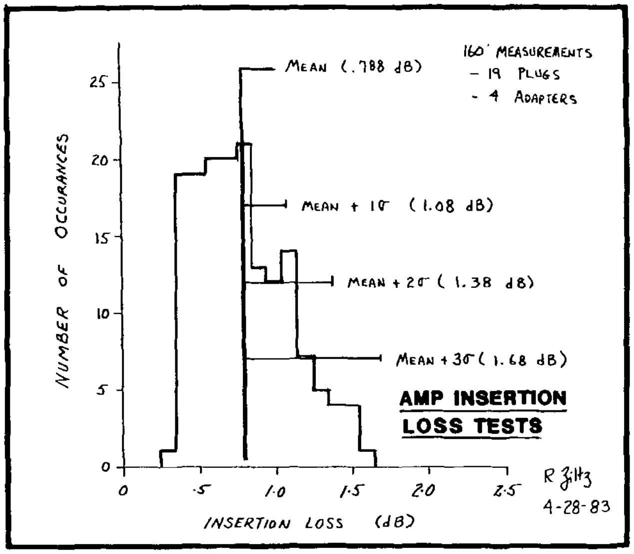
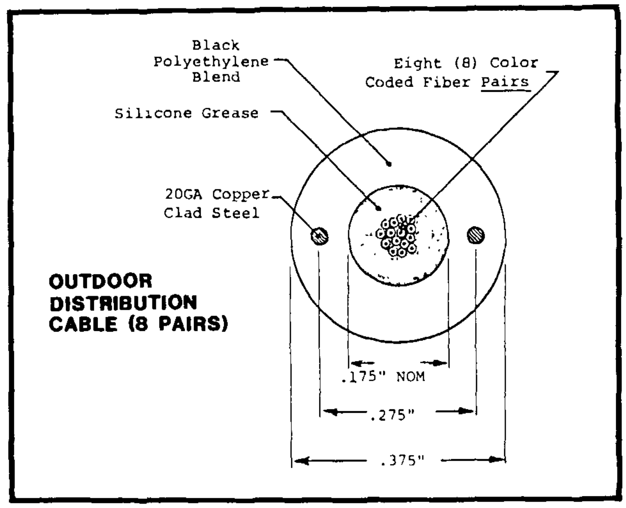


Figure 3



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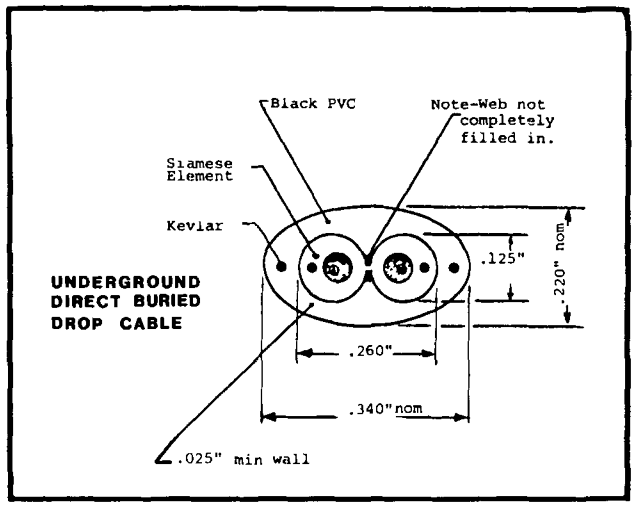

Figure 5

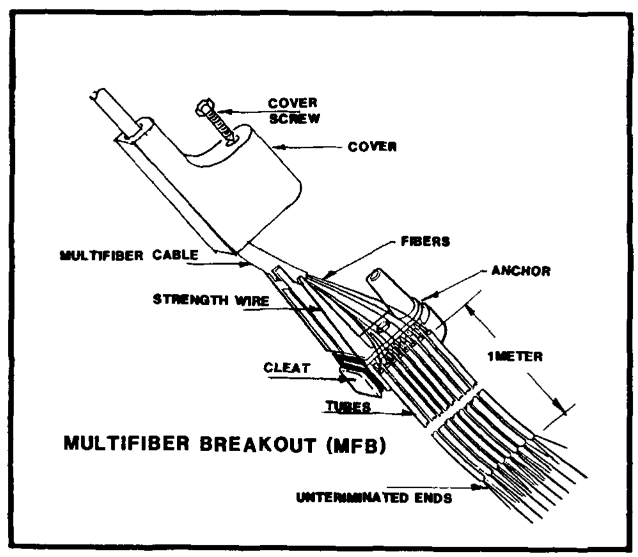

Figure 6

FIBER CABLES

Two different types of fiber cable were used in Alameda. The cable used in the preinstalled drop sections from the hub to a junction point near the subscriber's residence were of a loose tube multifiber construction. Two-, four-, six-, and eight-pairs of fibers were enclosed in a silicone grease-filled, steel-reinforced polyvinylchloride jacket (Figure 4). This type of cable was designed for pulling ease in both the aerial and underground plant situations. The cable's small diameters of 0.250 and 0.375 inches, resulted in clean, neatly lashed strands. Efficient scaling of junction box and tap sizes to the various neighborhood densities was permitted because several multifiber cable designs were used.

The second type of cable was a "zip cord" (Figure 5) duplex-fiber design. It was used for the "installed drop" from the junction box to the subscriber's home. This was a second generation cable developed by TFC which replaced an older oval duplex type of cable which required a fiber breakout assembly on both ends.

MULTIFIBER BREAKOUT

Mini-Hub I installations prior to Alameda had used a fiber cable jumper to connect a converter card to a junction box cable termination in the hub. An extra connector pair that had a higher link loss and cost more was the result. The duplex breakout idea was developed into the Multifiber Breakout (MFB) (Figure 6). The key to the success of the MFB was the novel idea of plowing the fiber into pre-slit tubing and then terminating the fiber in a connector. This allowed for a multifiber connection cable to be made to the converter output with an unbroken fiber. Tubing was color coded in pairs to match the fiber colors and to facilitate easy tracing of the fiber from the junction box to the hub.

SUBSCRIBER JUNCTION BOXES

A new aerial subscriber junction box (SJB) (Figure 7) was designed to terminate multifiber cables in a subscriber tap configuration. Molded of UV resistant polypropylene in two compartments (one for weatherproof looping of the fiber and the second for weatherproofing the installed drop fiber connection), the SJB was made football-shaped to provide pulling a preterminated cable easy. In practice, 20 feet of cable was dropped from the strand to ground level where the junction box was assembled. This extra cable caused greater power loss and cost more.

The underground junction box (UJB) (Figure 8) differed from the aerial design only in that the top polypropylene shell was replaced with a cast polyester concrete air bell. Used in the underground plant in two- and four-pair versions, UJBs were placed in hand vaults that were subjected to water runoff from lawn sprinklers and rain. The underground duplex jacket of the fiber cable must be stripped away to remove an escape route for the air from the bell. Otherwise, air leakage caused by the soda straw action of the cable can force out all the air in the bell and cause water flooding. Also, the lack of stable mounting of a UJB in a vault would cause flooding.

TOOLING

Performance testing the preinstalled fiber drop links was accomplished by using a standardized light source that contained 16 output LEDs. The multiport light sources were enclosed in a portable case and battery powered. After each day's use, the light sources were charged overnight. Factory LED selection enabled all 16 LEDs to have the same dynamic tuning range, aging rate, and stay at a stablized tuned setting for each day's use.

The light sources were connected to the multifiber breakouts at the hub and power readings were made at the junction box connectors. A Wilcom model T319 meter was used to calibrate the light source and make the light measurements.

The performance readings taken provide an interesting statistical review of the installation quality, the connectors, the fiber, and the accepted links. Figure 9 shows a graph of 492 readings in which the bulk of the links has only a 2 to 3 dB loss that results in an average of 100 microwatts delivered to the RIU. The second peak at 3.0 dB corresponds to a predominance of 250 to 450 ft links in the plotted data.

SUMMARY

The lessons of the Alameda installation involve all phases of the project.

The review of insertion loss test results for the connector matings and installed subscriber links indicate that a theoretical approach of

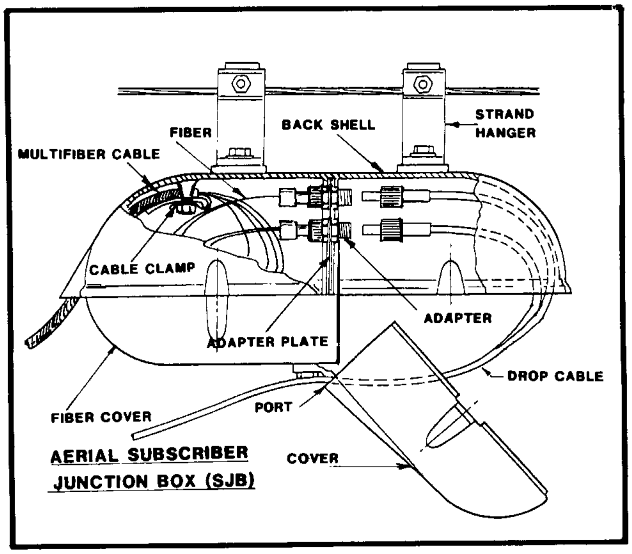

Figure 7

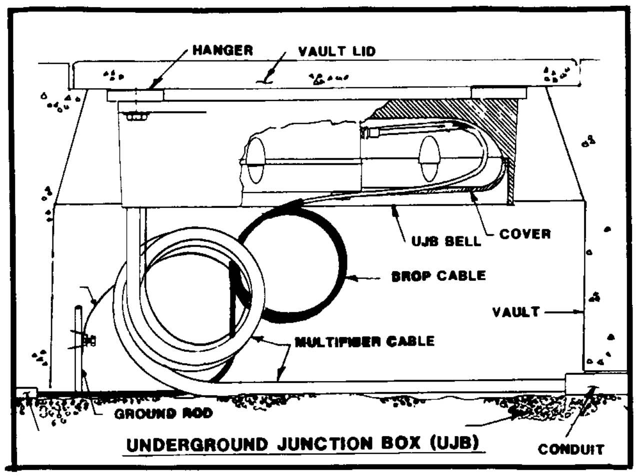

Figure 8

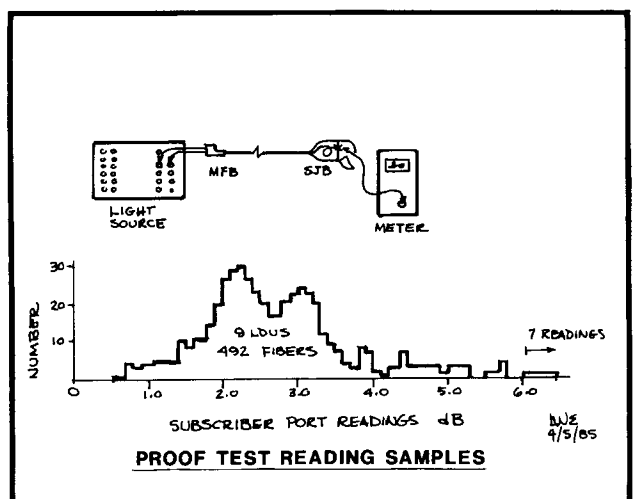

Figure 9

worst case design may not be necessary in the future. The statistical evidence indicates that designing to a less conservative statistical limit may be more in order.

The future generation design efforts will concentrate on improvements in the connector cleaver operation and the multifiber breakout. Desirable enhancements of the light source include improved diurnal stability and ease of recharge.

Another lesson of Alameda is that manuals, training materials and media presentations must reflect the detail "do's and don't's." Procedural steps and equipment positioning and orientation have to be explained in detail.

Last but not least, a recognition of one or two new crafts is necessary. The connector installation craft requires a training phase prior to and during the early on-site employment in order to quickly develop skills and weed out those not suited. Cross craft training between lineman, F.O. connector installers, and hub technicians is necessary to assure smooth working relations and to reduce reworking.

TFC has successfully installed the first large scale two-way addressable off-premises cable television converter system in the world and used fiber optic drops throughout. The project has definitely shown the technical efficacy of fiber optic subscriber distribution links in cable television systems. Newer second and third generation designs have brought the cost of fiber optics more in line with future needs.