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Atlanta Fiber System Experiment:

The Chicago Lightwave Communications Project

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The Bell System installed and is evaluating an exploratory lightwave communications system in downtown Chicago. In addition to regular interoffice trunk service, the system provides a range of telecommunications services to customers in Chicago's Brunswick Building, including voice, analog data, digital data, and PICTUREPHONE® *Meeting Service, a 4-MHz video service. This paper describes the transmission medium, its installation, and the system configuration, and includes some preliminary performance data.*

I. INTRODUCTION

The Atlanta Fiber System Experiment[1,2] utilizes cable ducts similar to those currently being installed in the telephone plant, but atypical of active Bell System ducts in that they were dry and uncrowded.

In 1976, new cable-placing methods and equipment were developed and tested at Bell Laboratories' Chester, New Jersey location. With these methods and equipment, optical fiber cables like those used in Atlanta[3] but containing only two ribbons (24 fibers) were installed in downtown Chicago in February 1977. The location was selected for the range of services that could be provided on fibers, as well as for the demanding cable route, representative of those found in busy, long-established metropolitan areas.

During the winter months, much of the Atlanta Experiment equipment was modified, replaced, or repackaged, and shipped to Chicago. On April 1, 1977 the first commercial traffic was carried on the new system, and on May 11 the Chicago Lightwave Communication System was fully cut over. Video encoders and other terminal equipment had been added so that the system could provide customer voice and data service, and *PICTUREPHONE®* Meeting Service (PMS) as well as regular interoffice trunk service.

II. SYSTEM CONFIGURATION

Figure 1 is an overview of the Chicago Lightwave System. Standard video signals from a PMS customer in the Brunswick Building are digitally encoded and transmitted at the DS3 rate (44.7 Mb/s) using a pair of fibers (one for the return signal) in a 1-km long optical cable extending from the Brunswick Building to the Franklin Central Office (CO). There the fibers are connected directly to a pair of fibers in a second cable, 1.6 km long, between the Franklin CO and the Wabash CO. Thus, the length of this optical link is 2.6 km. The video is decoded and carried by standard means to the Television Operating Center (TOC) adjacent to the Wabash CO where it can be connected to standard intercity video circuits. Another pair of fibers in the second cable provides a two-way link between the TOC and a public PMS room at Illinois Bell Telephone (IBT) Headquarters, which is adjacent to the Franklin CO.

The Brunswick-to-Franklin cable also carries customer voice and data signals. Using three of its full capacity of 28 DS1 (1.54 Mb/s) channel inputs, an M13 multiplex combines 78 voice circuits and one 2.4-kb/s analog data signal from two *SLC**-40 (subscriber loop carrier) terminals, and two 4.8 kb/s digital data signals onto a single pair of optical fibers. The digital data signals are connected by a T1 (DS1 rate) circuit to the Canal St. Digital Data Service Office.

A third pair of fibers in the Franklin-Wabash cable carries 576 interoffice trunk circuits (24 DS1 channels). Here, again, M13 multiplexes combine signals from standard T1 systems to produce 44.7 Mb/s streams that pass through the fibers. Voice and data links are backed up by an operating spare fiber pair in each cable. All fiber links operate at 44.7 Mb/s, just as they did in Atlanta. The Franklin CO installation is shown in Fig. 2.

III. OPTICAL CABLE

The optical cable design used in Chicago is identical to the one used in Atlanta except that two ribbons (each containing 12 fibers produced by Western Electric—Atlanta) rather than 12 ribbons were used (Fig. 3). Three long cables, each approximately 1 km in length, and four short cables ranging from 160 to 460 m were made by Bell Laboratories for the project. Two fiber breaks occurred in one of the long cables and two breaks occurred in a 180-m cable; all breaks occurred in cable manufacture. The remaining four cables had no broken fibers. Two of the long cables and the three unbroken short cables were cut into ten cable segments of specified lengths. Half-connectors of the type reported pre-

* Trademark of Western Electric.

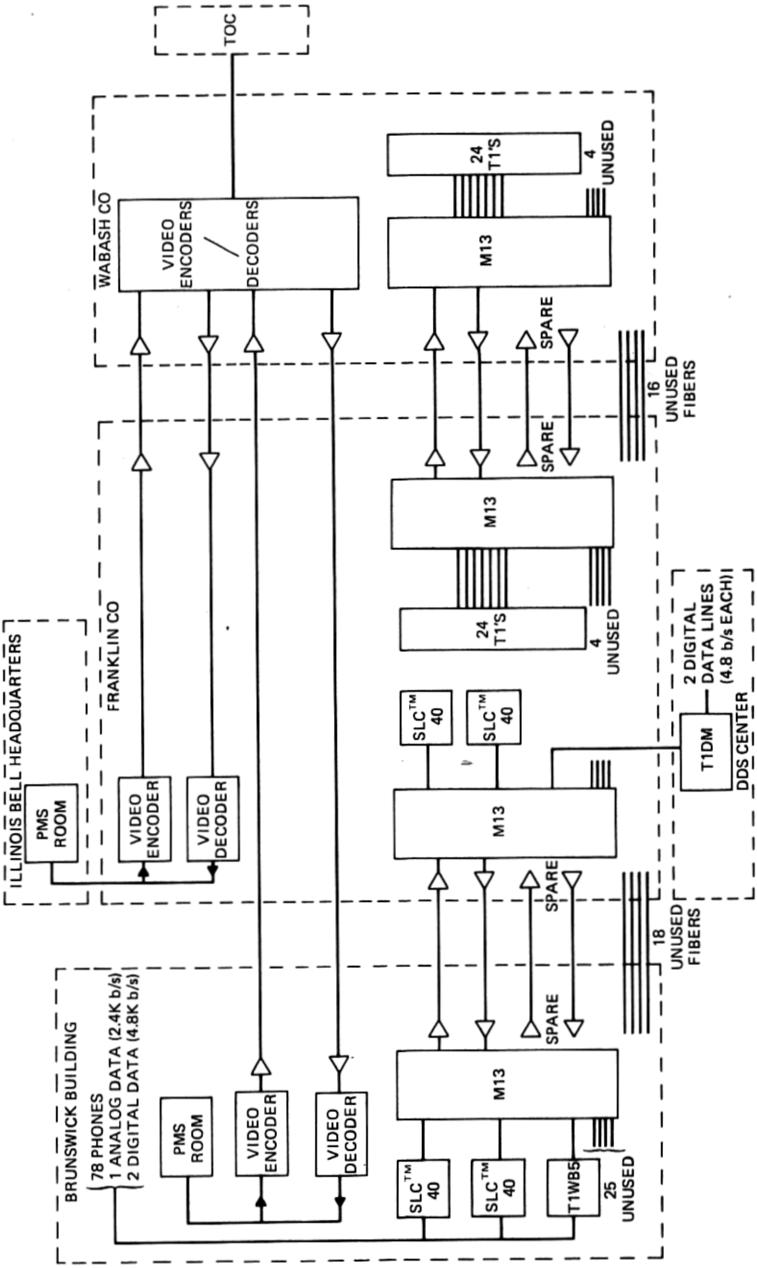

Fig. 1—Chicago lightwave system.

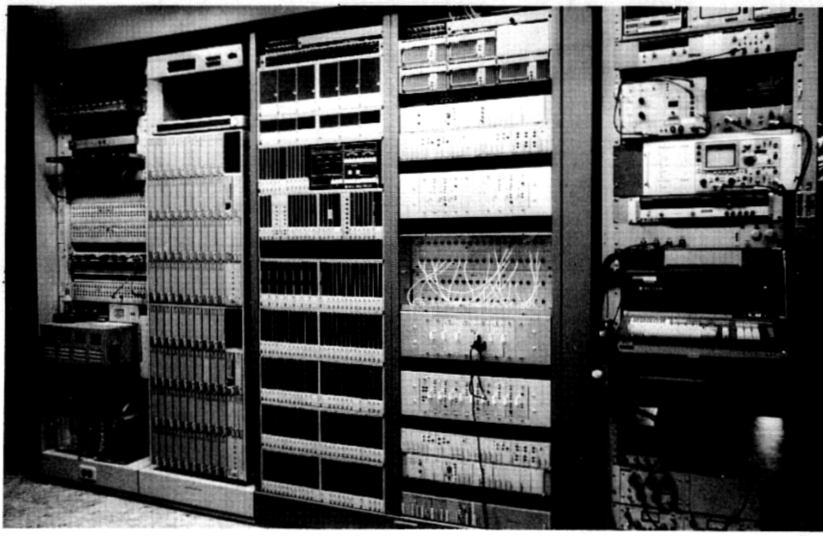

Fig. 2—Franklin Central Office installation.

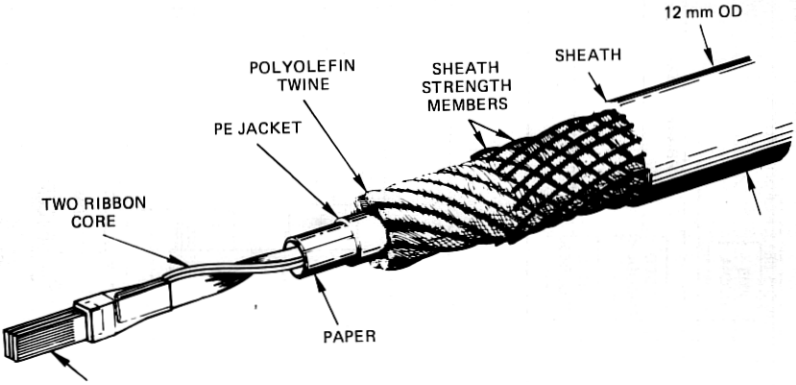

Fig. 3—Two-ribbon lightguide cable.

viously[4,5] were fabricated on all 10 cables. As a result, when the cables were installed in the field, splicing was a straightforward job that did not involve handling individual fibers. Figure 4 is a photograph of a half-connector formed on one end of a two-ribbon cable.

Figure 5 is a comparison of the loss histograms of the three long Chicago cables with the Atlanta Experiment cable.[3,4]

At the system wavelength of 0.82 microns, the mean loss of the Chicago cables was 5.1 dB/km, whereas the mean loss of the Atlanta Experiment cable was 6.0 dB/km. Most loss reduction is due to the smaller added loss (micro-bending loss) of 0.5 dB/km as opposed to 1.3 dB/km in the Atlanta Experiment.

Fig. 4—Half-connector on two-ribbon cable.

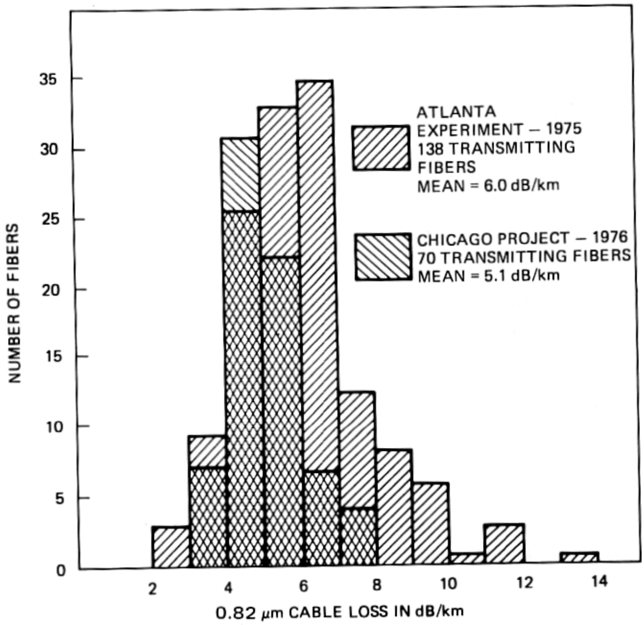

Fig. 5—Cabled fiber losses.

IV. CABLE INSTALLATION

Figure 6 shows the optical cable route connecting the Brunswick Building to the Franklin CO to the Wabash CO. Two short connectorized optical cables were installed from the cable vault to the equipment bay in the Franklin CO by WE and IBT personnel, and a similar intra-building cable was installed in the Wabash CO. The remaining seven connectorized cables were installed in underground ducts along the route with five outside plant manhole splices located as indicated in Fig. 6. Since there was no cable vault in the Brunswick Building, the cable entering the building ran directly to the equipment bay.

Before the installation of 12-mm O.D. optical cable, a polyethylene inner duct with an I.D. of 24 mm was installed inside the existing old tile

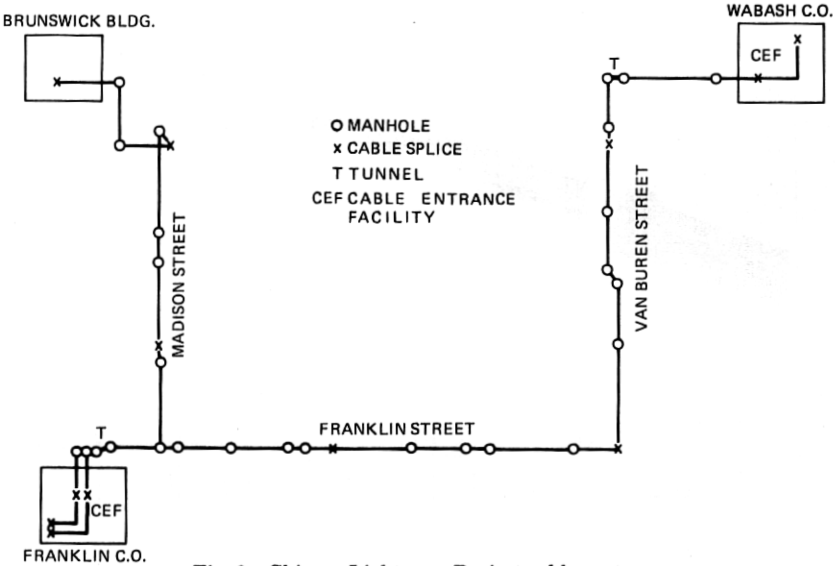

Fig. 6—Chicago Lightwave Project cable route.

duct by IBT personnel. The inner duct provided a controlled environment for the optical cable as well as a simple method of pressurizing around the optical cable. No problems were encountered in installing and splicing the inner duct. The optical cables were pulled into the inner duct and spliced by Bell Laboratories with the assistance of IBT personnel. Special optical cable installation equipment was designed and built by Bell Laboratories, including sheaves and a special reel and reel-handling assembly, that allowed cable to be payed out in opposite directions from an intermediate point. The two-way cable pull reduced the cable pulling tension when the cables were placed. All 10 cables were pulled in without any breakage in the installation process. The five cable manhole splices and seven inside building cable splices were made in a manner similar to that described previously.[4] The optical splices were enclosed and well protected by a special case inside a modified splice case. The splice cases also permitted pressurization continuity of the inner duct.

V. PERFORMANCE OF THE INSTALLED MEDIUM

After cable installation and splicing was completed, loss measurements were made on the two cable routes, Franklin-Brunswick and Wabash-Franklin. Loss histograms for the 24 fibers in each cable route are shown in Fig. 7. Based on these data and cable loss measurements alone, it is estimated that cable splice losses average about 0.5 dB per splice. Since the transmission distances are short in the Chicago route, the longest

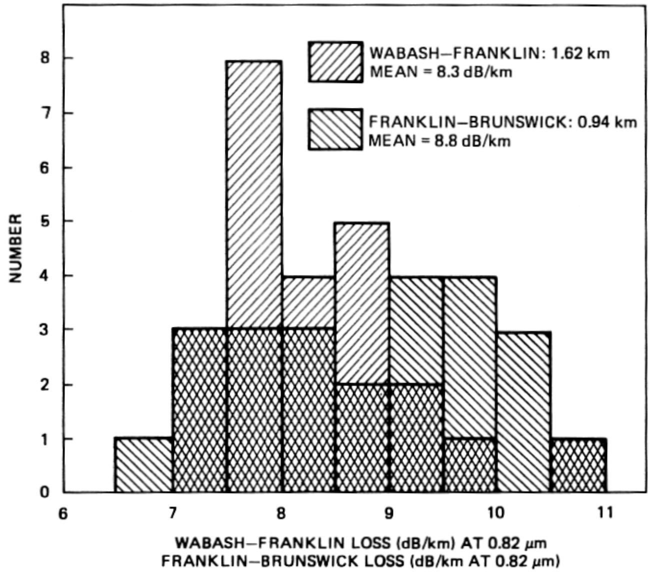

Fig. 7—Installed, spliced Chicago lightguide loss.

being about 2.6 km, neither the loss nor the bandwidth limit of the system is approached.

It is of interest to roughly estimate what the maximum regenerator spacing could be at the DS3 rate for a system using the Chicago technology. In doing this, we assume the following average values:

Allowable loss at DS3	= 46.0 dB
Single fiber connector loss*	= 0.5 dB
Cable splice loss	= 0.5 dB
Average connectorized unspliced cable length	= 350 m
Cabled fiber loss	= 5.1 dB/km

With these values, an average loss budget can be constructed (Table I). The results indicate that a spacing of about 6.5 km, including building cable, is achievable with this technology.†

VI. SYSTEM PERFORMANCE

The Chicago Lightwave Communication System was fully cut over on May 11, 1977 and has been carrying voice, data, and PMS to commercial customers on a trial basis since that time. A repeat of loss mea-

* In Chicago, an improved version of the single-fiber connector reported previously (Refs. 7–9) was used.

† This is intended to provide a rough estimate of regenerator spacing. An actual system design must account more carefully for loss distributions as well as for mean losses.

Table I — Estimating regenerator spacing at the 44.7 Mb/s rate, based on Chicago technology

Average loss budget

Item	No.	Loss (dB)
Single fiber connectors	4	2.0
Terminal cable splices	4	2.0
Building cables (2 × 130 m)	2	1.3
Outside cables (6.3 km)	18	32.2
Outside cable splices	17	8.5
		46.0

surements on the installed spliced medium, made two weeks after the initial measurements, showed no changes.

All spans except those used for video are continuously monitored. As of mid-December, 1977, the system had no outage; 75 percent of the days of operation had been error-free, 99.999 percent of seconds had been error-free, and one laser failure had occurred in 75,000 cumulative device hours, a record consistent with the expected mean time to failure of those devices in excess of 100,000 hours.

VII. ACKNOWLEDGMENTS

The work reported here, carried out under the auspices of AT&T, was accomplished through the extensive efforts and many individual contributions of WE, IBT, AT&T, and Bell Laboratories personnel. Its success stands as a tribute to the work and cooperation of everyone involved.

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