THE BELL SYSTEM
TECHNICAL JOURNAL

DEVOTED TO THE SCIENTIFIC AND ENGINEERING
ASPECTS OF ELECTRICAL COMMUNICATION

Volume 57 July–August 1978 Number 6, Part 1

Atlanta Fiber System Experiment:

Overview

By IRA JACOBS

(Manuscript received December 29, 1977)

A complete 44.7-Mb/s lightwave digital transmission system was evaluated at the joint Western Electric and Bell Laboratories facility in Atlanta in 1976. An overview is provided to the papers describing the technology employed and some of the principal results of the experimental evaluation. Two interrelated themes are emphasized: (i) the importance of careful measurement and characterization, and (ii) the need for parameter control. Both the Atlanta Experiment and the follow-on Chicago installation have given confidence in the feasibility of lightwave technology to meet Bell System transmission needs.

On January 13, 1976 the Atlanta Fiber System Experiment was turned up, and 44.7 Mb/s signals were successfully transmitted over the entire system. The following papers in this issue describe the technology employed and some of the principal results of this experiment. Although there have been a number of conferences[1–6] and prior publications[7–10] in which some aspects of this experiment have been discussed, the present papers provide the first comprehensive report.

The purposes of the Atlanta Fiber System Experiment were:

(*i*) To evaluate lightwave technology in an environment approximating field conditions.

(*ii*) To provide a focus for the exploratory development efforts on fiber, cable, splicing and connectors, optical sources and detectors, and system electronics.

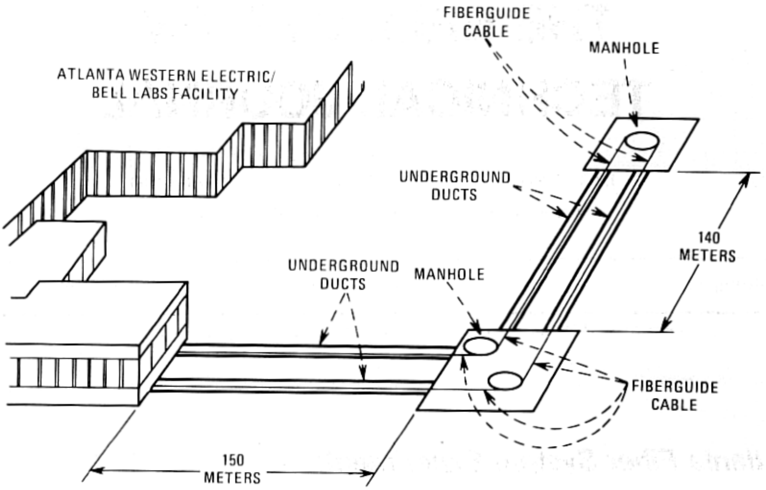

Fig. 1—Atlanta Fiber System Experiment ducts.

(*iii*) To address interface problems that arise when a complete system is being implemented (a system is more than the sum of its component parts).

In short, the purpose was to assess the technical feasibility of lightwave communications for Bell System application.

The locale of the experiment was the joint Western Electric and Bell Laboratories facility in Atlanta, Georgia where the fiber and cable were made, and where ducts, typical of those in metropolitan areas, were available. These ducts, including two in which temperature and humidity may be controlled, were installed when the Atlanta facility was constructed, and were intended as a test bed for new cables. The ducts terminate in a Bell Laboratories basement room and extend 150 meters to a manhole and then another 140 meters to a second manhole (Fig. 1). The fiberguide cables* are looped in the second manhole so that both ends terminate in the basement room. This room provides the office envi-

Table I—Atlanta System Experiment parameters and results

Transmission rate	44.7 Mb/s (672 voice channels)
Cable	144 graded-index fibers (12 × 12 ribbon array)
Average loss	6.0 dB/km (0.82 micron wavelength)
Average transmitter power	−3 dBm (0.5 mW)
Receiver sensitivity	−54 dBm (4 nW)
Calculated repeater spacing	7 km
Maximum repeater spacing	10.9 km

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* Two cables, both made by Bell Laboratories, were installed. The first, containing fibers made solely by Western Electric, formed the principal cable for the experiments. The second cable was made with Western Electric, Bell Laboratories, and Corning Glass Works fibers.

ronment for the lightwave system; indeed, it simulates both end offices and intermediate offices in an interoffice trunk system.

The principal parameters and results of the experiment are summarized in Table I. The transmission was digital at a rate of 44.7 Mb/s corresponding to the third level (DS3) of the North American digital hierarchy. Lightwave systems tend to be power- rather than bandwidth-limited, and digital transmission is particularly desirable in such cases.[8] The transmission speed of 44.7 Mb/s was chosen as that hierarchical level at which lightwave systems might initially be most economic and practical.[11]

A ribbon-structured cable was chosen to facilitate splicing. The large number of fibers in the cable (144) was to gain experience in the making of large fiber-count cables. Also, since the total length of the installed cable was only 650 meters, many fibers were required so that long paths could be obtained by looping through the cable many times. The objective was to achieve at least 100 good fibers in the cable with an average loss of no more than 8 dB/km. The results achieved were 138 good fibers with an average loss of 6 dB/km.

The operating wavelength of 0.82 microns was chosen to be below the water absorption peak. Average transmitter power into the fiber from the GaAlAs laser was 0.5 mW, and the sensitivity of the APD receiver was 4 nW. A laser and an APD were used to maximize repeater spacing. With allowances for connector loss and system margin, a system repeater spacing of 7 km was calculated. Utilizing some of the lower loss fibers in the cable, error-free transmission was obtained with a repeater distance of 10.9 km.

The system in Atlanta contained all elements of an operational digital transmission system, including the three major subsystems (Fig. 2):

(*i*) Cable.
(*ii*) Distribution system.
(*iii*) Terminal electronics.

The first four papers in this issue relate to the cable, starting with the characteristics and reproducibility of the graded-index germania borosilicate fibers (DiMarcello and Williams), then treating the preform fabrication and fiber drawing (Myers and Partus), and the cable manufacture and performance characterization (Santana, Buckler, and Saunders), and concluding with optical crosstalk evaluations (Buckler and Miller).

The key element in the interconnection system is the molded plug single-fiber connector used both on the distributing frame and on the optical regenerators. The structure and performance of these connectors is described in the paper by Runge and Cheng.

The next sequence of four papers covers the system electronics. There are two papers on the detector, one (Hartman, Melchior, Schinke and

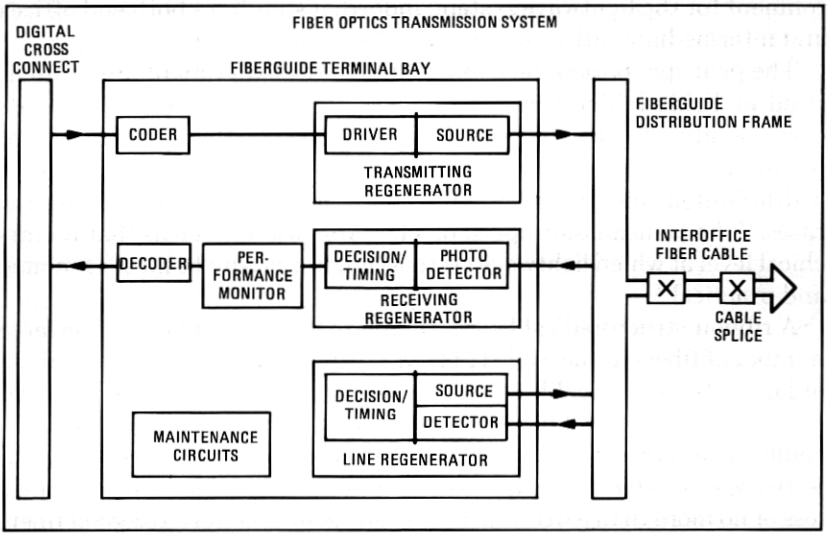

Fig. 2—Atlanta Fiber System Experiment transmission system.

Seidel) on the avalanche photodiode and one (Smith, Brackett, and Reinbold) on the detector package including the transimpedance preamplifier. The transmitter package, including the GaAlAs laser, is covered in the paper by Shumate, Chen, and Dorman. The design and performance of the optical regenerator, including timing recovery and decision functions in addition to the transmitter and receiver, is covered in the fourth paper (Maione, Sell, and Wolaver) of this sequence.

Following the papers on the technology and subsystems, Kerdock and Wolaver describe the experiments performed and the results obtained. In all cases, the system met or exceeded expectations.

Two themes run through all these papers. First is the importance of careful measurement and characterization. The loss of a multimode fiber or of a single fiber connector is critically dependent on how they are measured, and particular attention is paid in these papers not only to the results obtained, but to how they are obtained. Most of these results are of a statistical nature, and the second recurrent theme is the "tail of the distribution." From a research standpoint, one is often interested in the best result achieved. But from an exploratory development standpoint, the other end of the distribution is of importance, and technical feasibility means achieving the knowledge and understanding to control the low-performance tail of the distribution. The Atlanta Experiment has provided important inputs of this nature, but it is only one of many steps in the exploratory development phase prior to specific design and development.

The system in Atlanta accepted standard DS3 (44.736 Mb/s) signals, and the system was interfaced with an M13 multiplex and a D3 channel bank, and voice, data, and television were transmitted over the system. But it is one thing to set up an experimental link on premises, and it is another to incorporate a system into the telephone network carrying actual customers' signals. The results achieved in Atlanta gave us confidence that we were ready for this next step. A trial system was installed in Chicago early in 1977, and has been carrying a wide range of services on a trial basis since May 11, 1977. Although the evaluation of this trial system is still in progress,[12,13] a brief article (Schwartz, Reenstra, Mullins, and Cook) is included in this issue describing the Chicago installation and the results to date. Both the Atlanta experiment and the Chicago installation have given confidence in the feasibility of lightwave technology to meet Bell System transmission needs.

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