

# Automation of Optical Time-Domain Reflectometry Measurements

The HP 81700 Series 100 remote fiber test system is a first-generation system consisting of a personal computer controlling one or more OTDRs and optical switches. It is well-suited for automated testing of small fiber networks such as company networks.

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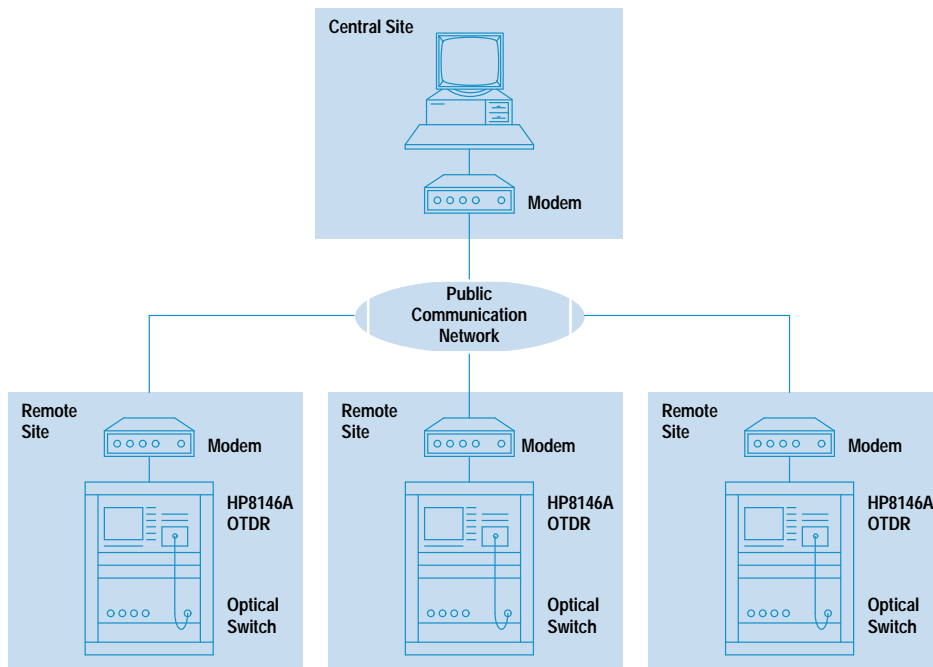
The world of telecommunications is changing very rapidly from a voice-based, nationwide network to one that is service-oriented and international. The network has to be capable of transporting voice, data, and video. New technologies like SONET, SDH, ATM, and SS#7 help meet the increasing demand for new services. However, the resulting complexity of the network calls for a higher degree of surveillance and management than the traditional network.

One of the driving forces of this multimedia age is the capability of optical fiber to support high transmission rates. Telecom operators already have large installed bases of fiber cables and are continuing to deploy fiber to meet the growing demands of their customers for new services. It is becoming increasingly important to have a more cost-effective maintenance strategy for the fiber-optic network than is in place today. The traditional method of using field-portable optical time-domain reflectometers (OTDRs) needs to be complemented with an automated testing solution. The HP 81700 Series 100 remote fiber test system (RFTS) is designed to meet this need. The RFTS helps improve overall network

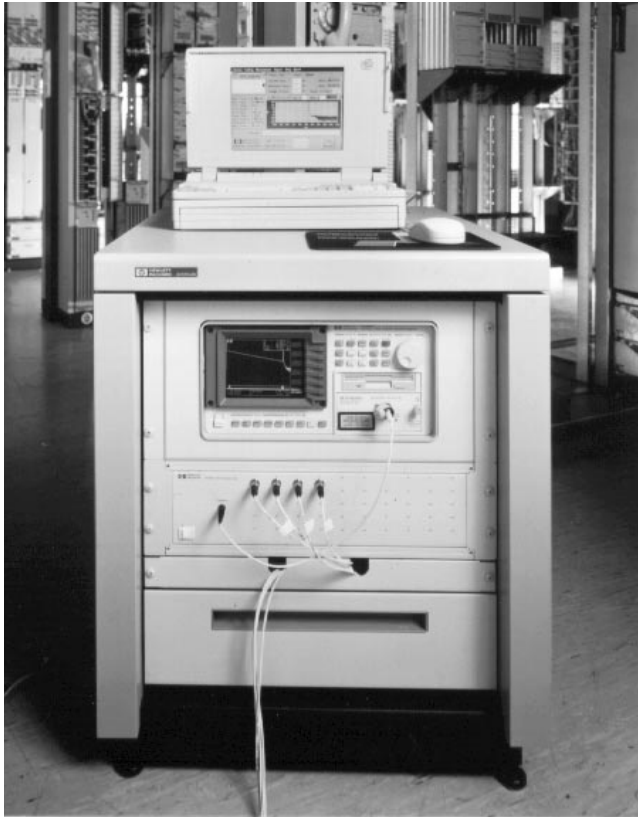
reliability and maintainability and reduces operating and maintenance costs.

The HP 81700 Series 100 RFTS is a first-generation system consisting of one or more OTDRs, an optical switch to share each OTDR between many fibers, and a personal computer to control these devices. The controller is capable of accessing several OTDRs through the normal telephone network by using modems.<sup>1</sup> The system is shown schematically in Fig. 1. It is based on the HP 8146A OTDR,<sup>2</sup> and the optical switch is supplied by an OEM partner. Fig. 2 shows an example of this system.

Systems of this kind provide fast, accurate fault location in case of an error and serve as a tool for preventive maintenance, allowing the analysis of long-term degradations through automatic periodic measurements. They are very effective if only a small system is required, for example for a small network of a private network operator or for a company private network. However, these systems are proprietary and do not provide full integration into the operations



**Fig. 1.** The HP 81700 Series 100 remote fiber test system (RFTS) is based on the HP 8146A optical time-domain reflectometer (OTDR).



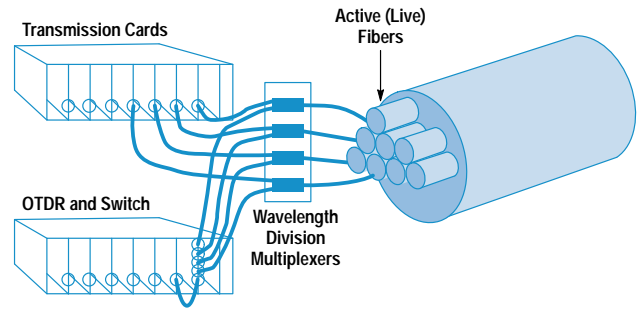
**Fig. 2.** A typical HP 81700 Series 100 remote fiber test system.

system of a telephone operating company. For this reason, a system of this kind can only be an intermediate step towards a solution of much higher complexity.<sup>3</sup>

### Using the RFTS

There are three main methods of carrying out automated testing of a fiber link using the RFTS. The first is testing of a dark fiber, that is, a spare fiber within a cable that is never used for transmitting traffic. Bellcore states that 80% of all errors occur on the whole cable and not on an individual fiber, so with this method there is a high but not 100% certainty of catching the error.<sup>4</sup> With dark fiber testing there is no interference between the transmission signal and the test signal.

The second automated test method is testing of an active fiber in-service by using wavelength division multiplexing (WDM), as shown in Fig. 3. For traditional systems in which only a wavelength of 1310 nm is used for transmission, the measurement can be performed at 1550 nm. This is obviously not possible if either the transmission wavelength is 1550 nm or an upgrade to a 1550-nm system is being contemplated. In this case an out-of-transmission-band wavelength higher than 1550 nm must be used. Currently there is a trend towards monitoring at a center wavelength of 1625 nm. This wavelength is a good compromise: it is not too close to the transmission band, which reduces the requirements for the WDM wavelength separation, and it is not too high, which allows acceptable OTDR performance. (Increasing the wavelength decreases the dynamic range of an OTDR.) This method of testing the active fiber leads to 100% surveillance of the network. However, the need for WDM equipment means higher link losses and higher cost. Because the WDM



**Fig. 3.** Active (in-service) fiber testing using wavelength division multiplexing.

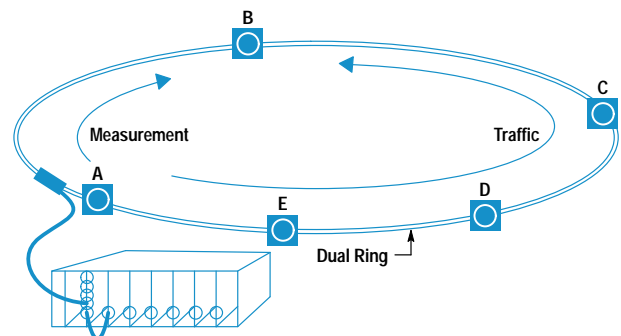
equipment is nonideal, there is interference between the OTDR signal and the system signal, which must be analyzed carefully. In many applications no significant system degradation should occur. However, it may be necessary to incorporate additional filters into the link.

The third automated test method is testing of an active fiber out-of-service. This technique can be used if there is enough backup capacity so the signal traffic can be rerouted during the measurement. This method can be performed with the same wavelength as the transmission signal. It does not need WDM equipment or additional filters but only a device to combine the system signal and the measurement signal. This can be either a wavelength independent coupler, which is a low-cost device but adds a 3-dB loss to the link, or a 1-by-2 optical switch, which has less insertion loss but is extremely expensive. This method may be very suitable for a dual-ring structure because traffic can always be rerouted through the other ring. As shown in Fig. 4, the traffic that is normally routed directly from A to B can be rerouted via E, D, and C while the measurement is performed.

### Overview Window

The RFTS tests the fibers of a network and informs the user if changes in the total link loss, or at specified points along the fiber, exceed the thresholds the user sets for acceptable performance. There are two levels of alarm. The first is the warning level, and the second is the failure level.

A summary of the status of the fibers under test is given in the overview window (see Fig. 5). If there are any fibers with failures these are listed at the top of the window and are marked with a red light. (When printed, the red light on the PC screen is shown as a box containing the word FAIL,



**Fig. 4.** In a dual-ring network, fibers can be taken out of service for testing while traffic is rerouted to the other ring (opposite direction).

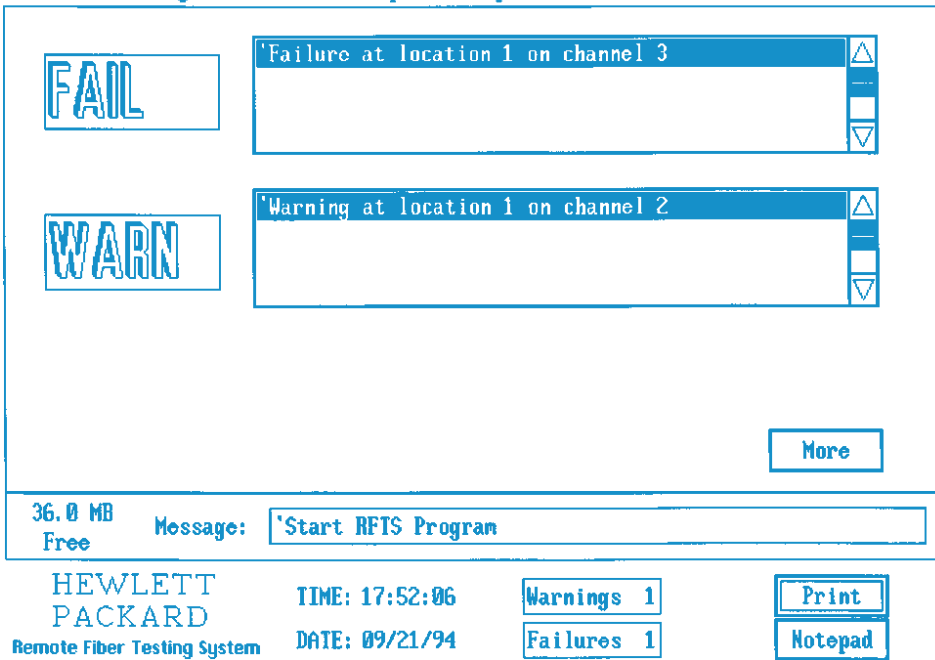


Fig. 5. RFTS overview window.

as shown in Fig. 5.) Fibers with warnings are listed in the middle of the overview window and are marked with a yellow light (printed as a box containing the word WARN). The red or yellow light starts flashing when the RFTS detects any new failure or warning. As long as no measurement result triggers any of the warning or failure criteria, a green light is displayed. Thus, the operator gets a quick picture of the overall status of the fiber network.

**Report Window**

Selecting More in the overview window shows the report window (Fig. 6), which lists all fibers of one specific location. The report window uses the same color scheme as the overview window: a red background for fibers with failures, a

yellow background for fibers with warnings, and a green background for fibers without significant changes. The user can select any of 30 supported locations.

**Trace Window**

The user can examine fibers in greater detail by double-clicking on the list entry in the report window. The resulting trace window (Fig. 7) shows the current and reference measurements of the selected fiber, the fiber identification information, the overall loss of the fiber, and the measurement parameters that were used to take the OTDR measurements.

The user can set a movable marker and zoom the trace around this marker.

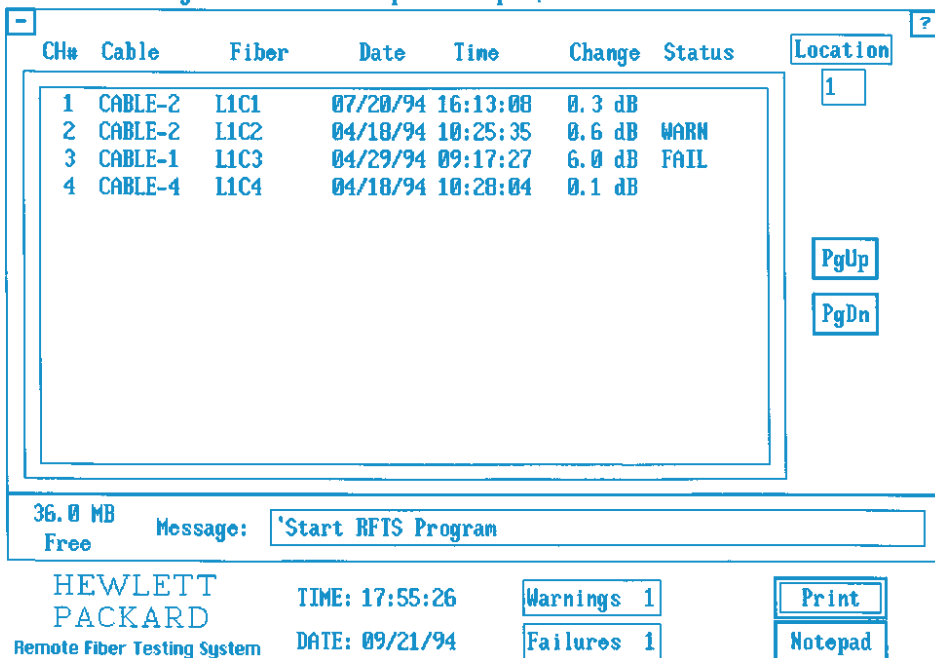


Fig. 6. RFTS report window.

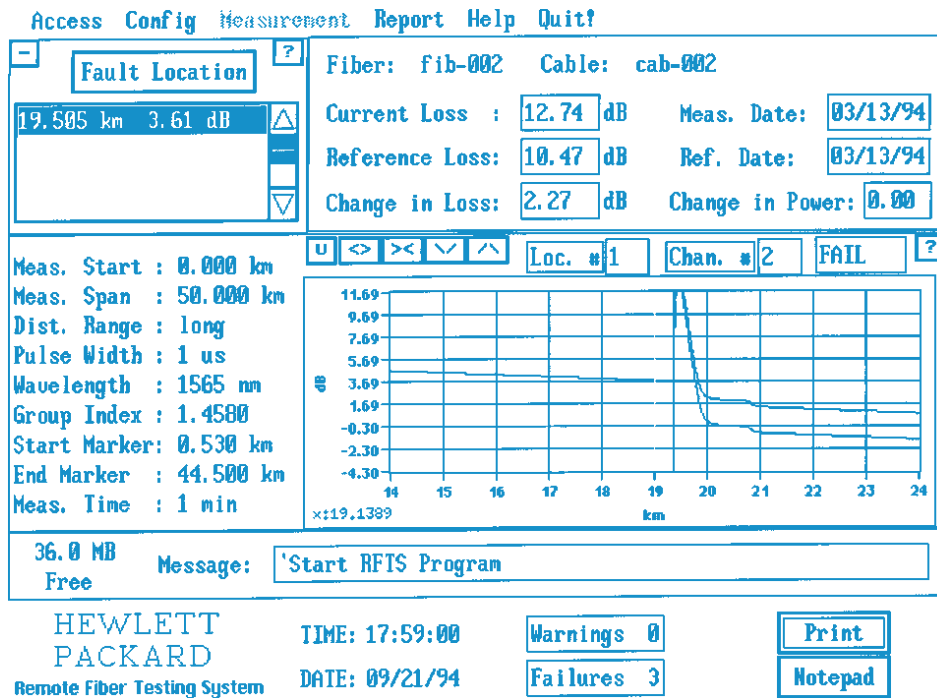


Fig. 7. RFTS trace window.

The current loss result, the reference loss result, and the change in the total link loss are shown above the traces. The loss is calculated as the difference between the power levels at two user-definable markers.

This screen also shows changes in launch power for the purpose of preventively maintaining the OTDR. This information can indicate when the laser power of the OTDR is degrading and repair is required. Without this information, the system might signal a warning or failure on a good fiber because of a problem in the OTDR.

### Configuring a Fiber

The RFTS offers two user access levels: one standard user level and one password protected level. The standard user access level allows the user to monitor the system configuration and measurement results. The password protected user level allows an authorized user to configure and operate the system.

During configuration the user provides the information to link a fiber to the corresponding optical switch port at a specific location. The information for a fiber consists of the location number and the channel number of the switch, the ID of the cable to which the fiber belongs, the ID of the fiber, text fields to store names and addresses of responsible persons for installation and maintenance, text fields to store emergency procedures, the date when the channel was configured, the date when the reference measurement was taken, thresholds for warning and failure detection, OTDR parameters used to take measurements on this fiber, and information about cable access points that provides a map of the geographic positions of fiber locations or events. The user can deactivate a fiber, which means the fiber will not be measured in the future if the user starts a continuously cycling measurement or if the system starts a periodic measurement. This is helpful while a broken fiber is under repair.

### Measuring Fibers

The RFTS makes two types of measurements: reference and actual. Reference measurements are those against which others are compared to determine the condition of the fiber. Typically, the user takes a reference measurement when the fiber is newly installed and is known to be in good condition. Actual measurements give the current condition of the fiber. The user must take a reference measurement before the fiber can be tested automatically.

The RFTS offers several ways to group measurements of fibers: measure a specific cable, measure all fibers at a specific location, measure all fibers at all locations, measure all fibers at all locations continuously, or measure all fibers at all locations periodically at a specific time.

### Detecting Failures on Fibers

After a reference measurement has been taken, the OTDR scans the trace for anomalies. The algorithm builds an event table that lists all reflective events (connectors, mechanical splices), nonreflective events (splices), through loss and return loss values of the events, and the attenuation between two successive events. After each actual measurement, the data is compared with the reference measurement event table. Any problems identified are classified as warnings or failures.

The RFTS first calculates the total link loss of a measured fiber from the actual measurement data. The change in total link loss is tested against the channel-specific warning and failure thresholds. If the change exceeds a threshold, there are two possible reasons: degeneration of an existing event or one or more new events.

In this case the RFTS starts a new scan trace to find any new event, perhaps a new fiber end if the fiber is broken. These new events are merged into the actual measurement event

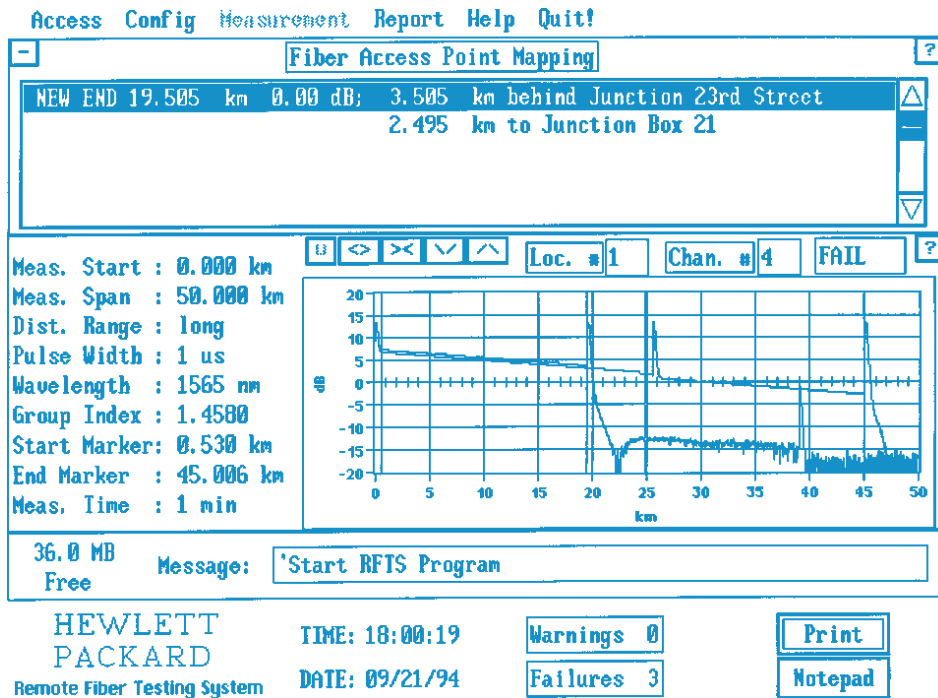


Fig. 8. Trace window with fault location box.

table. The actual event table is compared with the reference event table event by event. The loss values of all events are checked against the event loss thresholds. The user can define absolute thresholds for the through loss of nonreflective events, change thresholds for the through loss of nonreflective events, absolute thresholds for the through loss and return loss of reflective events, change thresholds for the through loss and return loss of reflective events, and change thresholds for attenuation between successive events. If any of these thresholds is exceeded, a warning or failure is signaled on this fiber.

### Locating Failures on Fibers

After the RFTS has set any warning or failure on a fiber, the trace window shows a red or yellow line at the location of any event that failed one of the tests. The location and the type of a failure or warning is listed in a fault location box at the top of the trace window (Fig. 8). If the user sets up landmarks, the cable access points list box shows the fiber distance to the previous and the next landmark, if existing. The RFTS automatically prints out this information if the system is configured to do it.

### History of Trace Results

Old measurement results are backed up to a separate directory before any new measurement is taken. To prevent the hard disk from being filled up with old data, the user can specify a time period after which the backup data will be deleted from the hard disk.

After a new reference measurement has been taken, the RFTS creates summary files for any measured fiber. A summary file is an ASCII file containing measurement parameters, date and time, total link loss, and event table results of the reference measurement. The total link loss and event table results of any ongoing actual measurements are appended to this summary file. Thus, the RFTS gathers historical information on the fiber network. Since the summary file

is an ASCII file the user can load this information into charting programs or spreadsheets or store the information into databases.

### Printing Reports

The user can print reports of the fiber status (Fig. 9). The report consists of a list of all active channels, showing for each channel the channel number, the fiber identification,

#### HP 81700 Series 100 Hewlett-Packard Remote Fiber Testing System

##### Location 1: Stuttgart

CH#	Cable ID	Fiber ID	Date	Time	Change	Status
1	CABLE-2	L1C1	07/20/94	16:13:08	0.0 dB	
2	CABLE-2	L1C2	04/18/94	10:25:35	0.7 dB	WARN
3	CABLE-1	L1C3	04/29/94	09:17:27	0.5 dB	WARN
4	CABLE-4	L1C4	04/18/94	10:28:04	0.1 dB	

##### Location 2: Freiburg

CH#	Cable ID	Fiber ID	Date	Time	Change	Status
1	CABLE-1	L2C1	04/18/94	10:29:32	0.8 dB	WARN
2	CABLE-2	L2C2	04/18/94	10:31:00	4.8 dB	FAIL
3	CABLE-1	L2C3	04/18/94	10:31:41	0.0 dB	
4	CABLE-1	L2C4	04/18/94	10:33:08	0.1 dB	

##### Location 3: Tuebingen

CH#	Cable ID	Fiber ID	Date	Time	Change	Status
1	CAB001	FIBER-1	07/20/94	18:53:36	0.0 dB	
2	CAB001	FIBER-2	07/20/94	18:55:47	0.1 dB	
3	CAB001	FIBER-3	07/20/94	18:47:52	0.0 dB	
4	CAB002	FIBER-1	07/20/94	18:50:11	0.0 dB	

##### Location 6: Heidelberg

CH#	Cable ID	Fiber ID	Date	Time	Change	Status
1	CABLE-1	L6F1	04/18/94	11:21:53	0.2 dB	
2	CABLE-2	L6F2	04/18/94	11:23:20	1.4 dB	WARN
3	CABLE-2	L6F3	04/18/94	11:24:49	0.4 dB	
4	CABLE-1	L6F4	04/18/94	11:26:16	0.1 dB	

##### Location 9: Munich

CH#	Cable ID	Fiber ID	Date	Time	Change	Status
1	CABLE-1	L9C1	04/18/94	17:52:47	0.4 dB	
2	CABLE-1	L9C2	04/18/94	17:54:15	0.0 dB	

Fig. 9. Fiber status report.

the cable identification, date and time of the last measurement, and the change in total link loss since the last reference was taken. If the measurement has crossed a warning or failure limit, the report also shows this information.

Reports can be manually printed for a single location or for all configured and activated locations. Reports can also be printed automatically once per day, once per week, or once per month. The user can configure the system to print out an alarmed trace automatically when the alarm occurs.

## References

1. *HP 81700 Series 100 Remote Fiber Test System*, Hewlett-Packard publication no. 5091-8003E.
2. J. Beller and W. Pless, "A Modular All-Haul Optical Time-Domain Reflectometer for Characterizing Fiber Links," *Hewlett-Packard Journal*, Vol. 44, no. 1, February 1993, pp. 60-62.
3. F.A. Maier, "The Evolution of Fiber Analysis," *Proceedings of NFOEC 1993*.
4. J.W. Peters, "Integrated Approach to Remote Fiber Test Systems," *Proceedings of NFOEC 1992*.