MILLIMETER RESOLUTION OTDR SYSTEM

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OPTO-ELECTRONICS INC.

RESEARCH IN ELECTRO-OPTICS

OPTO-ELECTRONICS INC.

MILLIMETER RESOLUTION

OTDR SYSTEM

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ABSTRACT

The Opto-Electronics MILLIMETER RESOLUTION OTDR SYSTEM is a unique new instrument with special capabilities not found in standard OTDR's. Using less than 100 ps wide light pulses, the instrument measures Fresnel reflections along the fiber with a time resolution less than 10 ps and a corresponding distance resolution less than one millimeter. Multimode or singlemode operation at wavelengths from 820 to 1550 nanometers are provided by a variety of Transmitter/Receiver modules as plugin units. The Mainframe can accommodate two of these modules. The dynamic range of the MM RES OTDR for short and long wavelengths, respectively, are over 44 and over 36 decibels. The system is ideal for measuring absolute and relative distances in SM or MM fibers from one millimeter to 30 kilometers without lead-ins or masking; for locating the precise position of connectors, couplers, reflective splices and reflective breaks or other reflective faults in fibers and cables; for testing, mapping and monitoring LANS in buildings, ships or airplanes; for measuring the performance of sensors, connectors, couplers, attenuators, switches and integrated optics; for measuring the precise strain, time delay changes, and loss changes of fibers in cable pull testing, cable installations, fiber spooling and fiber payouts; for measuring precise fiber group index, group index variations, strain and temperature coefficients of fiber group index, and many other applications where picosecond or submillimeter resolution and accuracy is required.

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1 INTRODUCTION

Standard OTDR instruments for both multimode and singlemode operations utilize the Rayleigh back scattered signal from a length of fiber to measure fiber distances and losses, as well as connector, splice and break locations and losses. In order to detect the Rayleigh backscattered signal the laser transmitter pulses have to be wide, in the range of 5-500 nanoseconds. The spatial resolution of these instruments is thus limited to 5-500 cm. This resolution range is suitable for most long and medium haul measurements but is insufficient for short and very short haul measurements.
The Opto-Electronics MILLIMETER RESOLUTION OTDR SYSTEM utilizes the Fresnel reflection signals from reflective features along a length of fiber to measure distances and losses with a spatial resolution of less than 1 mm. This resolution is achieved by using Laser Transmitter pulsewidths in the range of 50-100 ps. These short pulses are positioned in time within ± 2 ps by a sophisticated Time Delay Generator having an ultralow time jitter and are detected by an ultrafast and very sensitive Receiver. The pulses are repeated at a rate of 30 kHz and the waveform from the Receiver is sampled at the same rate to provide the output signal. A signal averager, with a maximum capability of 65,536 averages improves the signal to noise ratio of the output signal by up to 24 dB, and a signal processor calculates the time position of the pulse with a precision down to ± 1 ps. The signal processor also resolves double pulses with separations down to one millimeter. The MM RES OTDR is a modular instrument and is housed in two 19" rack mountable main frames. They may be mounted in a case as shown in Figure 1, in an instrument rack, or placed on the bench. The MF20 PICOSECOND FIBEROPTIC SYSTEM mainframe houses the Laser Transmitter, the Receiver, the fiber Coupler, the Time Delay Generator and the Sampler. The other mainframe houses the TDR10 OTDR PROCESSING SYSTEM. The modules are optically connectorized with either the standard ST type or customer specified connectors. The MF20 can accommodate one or two sets of plugins for single or double wavelength operation.
The system, as illustrated in Figure 1, is without the Sampler module. In this form the OTDR is used with an auxiliary sampling oscilloscope, such as the Tektronix 7904 with 7S11, 7T11 and S4 plugins. When the Sampler module is used, signals are displayed on a low frequency single channel laboratory oscilloscope.

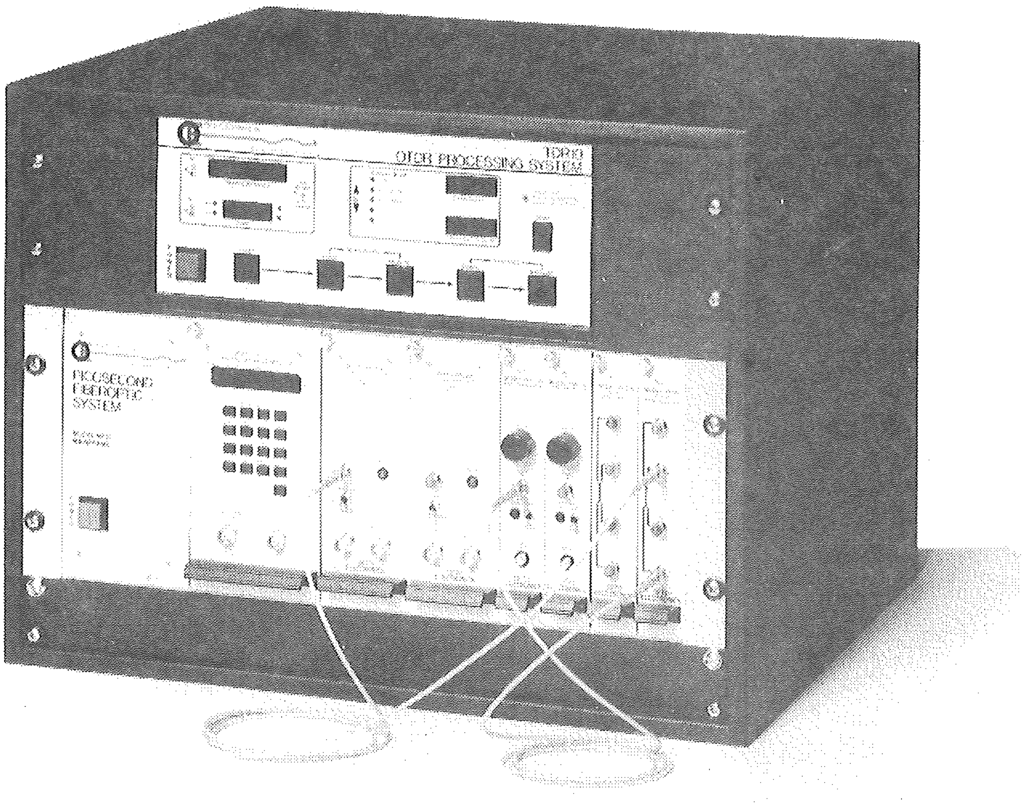


Figure 1 The Opto-Electronics MILLIMETER RESOLUTION OTDR System. Two 19" mainframes mounted in a single case, ready to use. The mainframes may also be mounted in a standard instrument rack or be stacked on the bench.

2 DESCRIPTION

2.1 OPERATING PRINCIPLES

The Opto-Electronics MM RES OTDR measures the time of flight of an optical pulse launched into the near end of the fiber and returned to the same end from the far end or from a feature along the fiber, having Fresnel reflection. The distance (d) from the near end to the reflective point is calculated from the two way time of flight (t) and the effective group index of the core (n) by

$$d = \frac{ct}{2n} \qquad (1)$$

where $c = 3.10^{8}$ m/s is the velocity of light in vacuum.

2.1.1. TIME OF FLIGHT MEASUREMENTS

A typical pulse reflected from around the near end of the test fiber and displayed on the CRT screen has a fullwidth at half maximum (FWHM) of approximately 150 ps. The width of the screen may be adjusted from 100 ps to 100 ns and the pulse may be moved in the time direction by stepping the pulse delay generator. These adjustments enable the operator to find and place a pulse on the screen which is reflected from anywhere along the test fiber, from the near end at the bulkhead of the instrument, to the far end. The far end can range from 1 mm to 30 km. It also enables the operator to zoom out for search (wide field) and zoom in for accurate measurement (narrow field). The TDR10 Processor determines the time position of the pulse peak on the screen with a precision of ± 1 ps or within ± 0.1% of the time width of the screen, whichever is greater.
If the width of the pulse does not change appreciably with distance (low dispersion fiber) then the accuracy of time measurement depends on the time width of the screen and the signal to noise ratio (SNR) of the pulse. Using a 1 ns wide screen and a return pulse with FWHM=150 ps and SNR 50, the accuracy of time measurement is ± 1 ps. The accuracy of time interval measurement between two such pulses is ± 2 ps.
If the test fiber is dispersive and/or the SNR is reduced, the time measurement accuracy decreases. See 2.2.5. for details.

2.1.2. DISTANCE MEASUREMENTS

For a given value of (n) the distance (d) may be calculated from the measured value of (t), according to Eq (1). If the value of (n) is known with sufficient precision the time accuracy of ± 2 ps translates to a distance accuracy of ± 0.2 mm.
The value of (n) may be entered on the front panel of the PDG20 module and the distance is displayed directly in centimeters.

2.1.3. EFFECTIVE GROUP INDEX MEASUREMENTS

The value of the index is usually given by the fiber manufacturer to ± 1 part in 10^4. If greater accuracy is desired, measurements of (d) and (t) are made on a length of fiber and (n) is calculated. If a 100m long fiber is measured to be within d ± 1 mm and t ± 2 ps then its average (n) value is calculated to be within ± 1.2 parts in 10^5.

2.1.4. LOSS MEASUREMENTS

The loss in a length of fiber or a component, such as a connector, a splice, a coupler, a switch, a star, an attenuator, a sensor or integrated optics, can be measured by the ratio of two known Fresnel reflections, one at the input end, the other at the output end, of the test piece. If the two reflectors are identical and the reflected pulse areas are I_1 and I_2, then the loss (L) in decibels is calculated from

$$L = \frac{1}{2}\, 10 \log \frac{I_2}{I_1} \tag{2}$$

One advantage of this method of loss measurement over the Rayleigh method is that if the test piece itself is reflective, then the total loss may be resolved into its reflective and scattered (or absorbed) components. This way one may "look inside" fiber optic components and devices. Another advantage is that the full dynamic range of the instrument can be used in the measurements of I_1 and I_2, which increases the accuracy of (L). The disadvantage is that the exact location of non-reflecting losses can not be determined.

The value of L in decibels is displayed automatically in the <u>VERTICAL SCALING</u> window of the TDR10 in <u>SHIFT</u> mode.

2.2 THE MILLIMETER RESOLUTION OTDR SYSTEM

In the following, the optical circuit, the electrical circuit, the modes of operation, the loss budget, the time and distance resolution and the various data outputs of the instrument are outlined.

2.2.1. THE OPTICAL CIRCUIT

The MF20 Mainframe houses three optical plugin modules. The Laser Transmitter, the four port Coupler and the Receiver. These are optically connectorized and are interconnected by jumpers. The optical outputs to the Test Fiber and the optional Reference Fiber are connectorized pigtails supplied with temporary quick splices. The schematic diagram is shown in Figure 2 below.

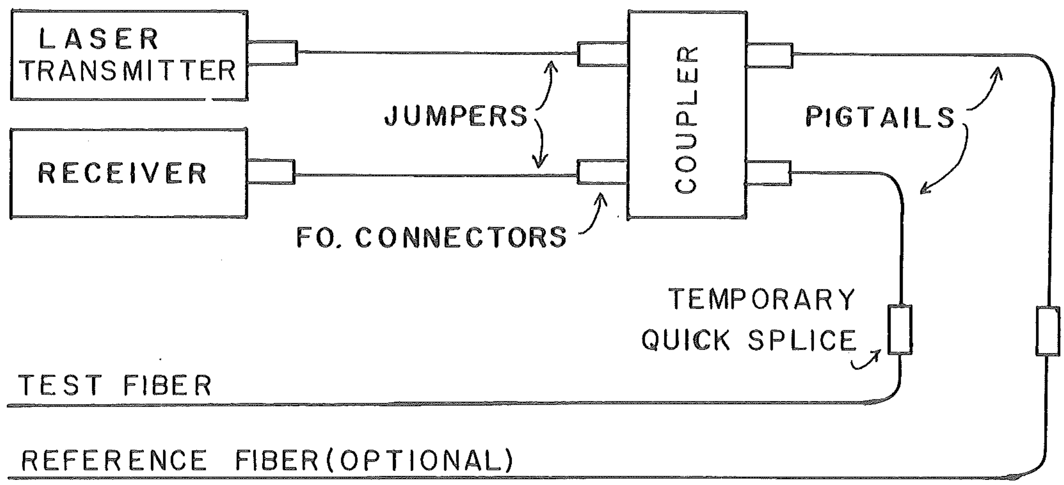


Figure 2 Schematic diagram of the optical circuit

2.2.2. THE ELECTRICAL CIRCUIT

In addition to the Laser Transmitter and Receiver, the MF20 mainframe houses the Time Delay Generator and the Sampler (if an external sampling oscilloscope is used, the Sampler plugin module is not required). The other mainframe houses the TDR10 Processor. The signal is displayed on a low frequency single channel lab oscilloscope. The interconnection of the modules is shown in Figure 3 below. The Time Delay Generator triggers the Laser Transmitter, waits for a predetermined length of time, then triggers the Sampler. The Sampler detects the pulse from the Receiver and passes it on to the Processor. The Processor performs the necessary signal averaging, scaling and calculations according to the settings selected by the operator and displays the detected signals as well as the end results. The end results may also be printed out on an auxiliary dot matrix printer, or transferred to an external computer by an RS232 port. A GPIB interface is available as an option.

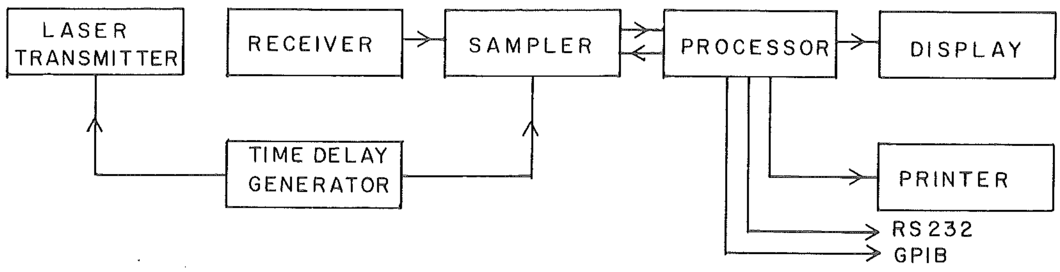


Figure 3 The schematic diagram of the electrical circuit

2.2.3. MODES OF OPERATION

The feature to be measured is first found using the search mode without averaging. Once the desired feature is found on the screen, measurement follows using the TDR10 Processor.

A. SEARCH MODE The first step in operating the Opto-Electronics MM RES OTDR is to find the bulkhead pulse. This is done by opening the CRT screen to a width of 50-100 ns and by stepping the bulkhead pulse to the LHS of the screen. Additional pulses, reflected from 5 to 10 meters away from the bulkhead may now be visible. Now estimate the distance to the feature to be found and dial the time on the Time Delay Generator, see Figure 4. Leave the screen wide, adjust the detection sensitivity to a high value, see Section 2.2.4. for details. Once the desired pulse is found, narrow the screen to 1-2 ns for time position measurement. Adjust detection sensitivity so that the pulse nearly fills the screen. Adjust the time position to provide 1-2 division lead-in baseline at LHS of screen. Proceed to MEASUREMENT MODE.

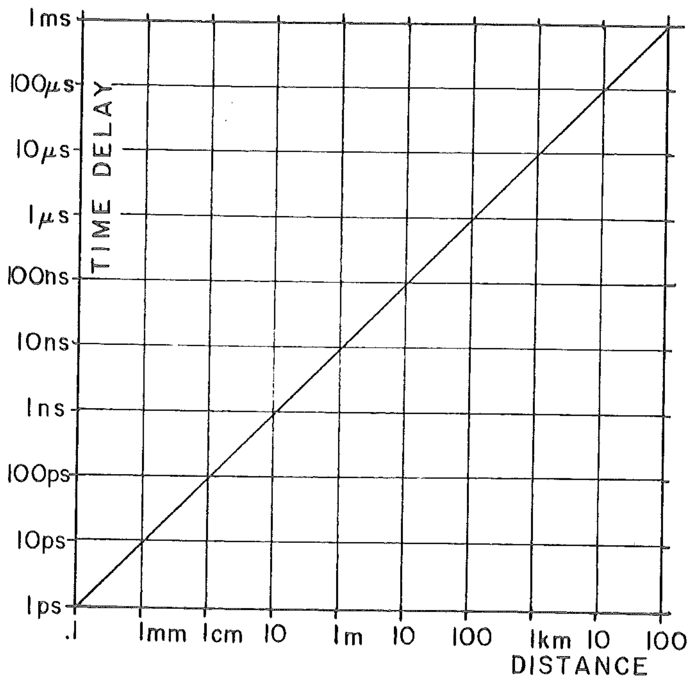


Figure 4 Approximate time delay in fibers with effective group index n=1.5 as a function of one way distance.

B. MEASUREMENT MODE. Select the number of averages desired, according to the SNR of the signal. Improvements in the SNR and averaging times are listed in Table I below.

NO. AVG		32	128	512	2,048	8,192	32,768	65,536
SNR IMPR.	X	5.2	10	20	42	84	168	240
	dB	7.2	10.0	13.1	16.3	19.2	22.2	23.8
AVG. TIME		0.3 Sec	1. Sec	5. Sec	20 Sec	80 Sec	5 Min	9 Min

Table I. SNR improvements and averaging times for number of averages of the TDR10.

Proceed with measurements using SHIFT, RESOLVE or SUBTRACT settings. The averaged result will be displayed on the screen. The TDR10 processor will auto scale the output attempting to fill the screen with it. The scaling ranges from 1x to 64x. The TDR10 processor will also display the FWHM of the pulse, or the separation of pulse peak values.

SHIFT. This is used with REF RETAIN to measure absolute and relative distances and losses by taking MEASUREMENT and REFERENCE of the near end pulse, by stepping the far end pulse on the screen and then by taking MEASUREMENT of the far end pulse. The TDR10 will calculate the interval between the near and far end pulses and display the results. The time delay is the sum of this figure and the one displayed on the Time Delay Generator. The distance is calculated by Eq (1). The loss between the near end and far end pulses is displayed in decibels. This mode is also used for fiber stress-strain measurements, cable pull testing, fiber elongation threshold measurements, spooling and payout strain measurements, and the measurements of stress and temperature coefficients of the core index. The measurements are made using REF RETAIN, and by taking MEASUREMENT and REFERENCE with the unstressed fiber and then at each stress level (or at each temperature) taking a MEASUREMENT. The TDR10 will display the time shift and loss. If the shift advances the pulse off screen on the RHS, step it back by the Time Delay Generator. Add the two delay times displayed to obtain the total time shift. Calculate the distance using Eq (1).
If simultaneous time shift and physical length measurements are made, the change in the effective group index may be calculated with very good accuracy. This method may be used to measure strain or temperature coefficients of (n).
From Eq (1) we get

$$\frac{\Delta d}{d} = \frac{\Delta t}{t} - \frac{\Delta n}{n} \qquad (3)$$

A plot of Eq (3) is shown in Figure 5. A plot of the experimental t and d values gives $\Delta n/\Delta d$.

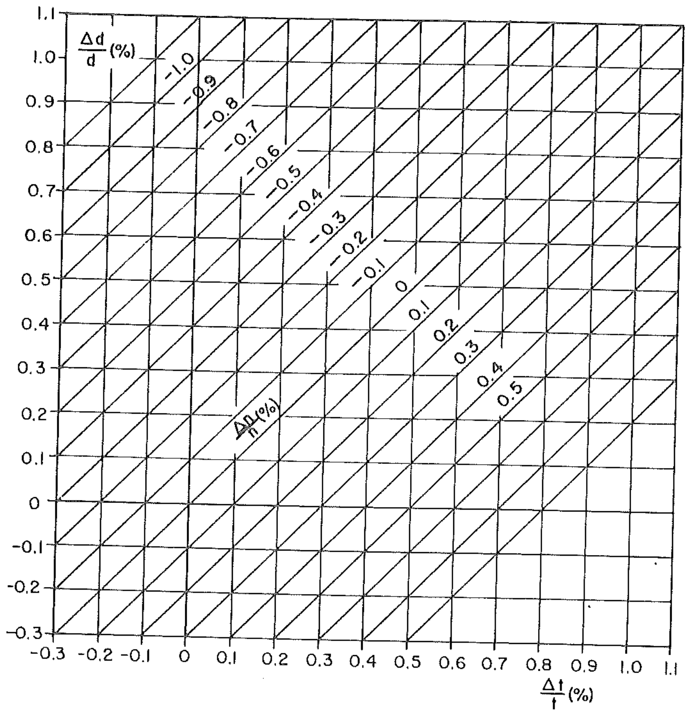


Figure 5 Plot of Eq (3) used to determine strain or temperature coefficients of group index.

RESOLVE. This setting is ued with REF ERASE when there are two reflections close together, both appearing on the display screen simulateneously, either as separate pulses or as a composite one. The relative heights of the pulses may range from 1:1 to 10:1. This situation is encountered when reflective breaks occur next to connectors, reflective cracks form next to splices, connectors fail to mate properly, or when one wishes to look inside fiber optical components such as connectors, sensors, switches, attenuators, couplers or integrated optics. The measurement is made by taking MEASUREMENT followed by REFERENCE of any other single pulse in the vicinity of the double pulse. The Processor resolves the double pulse into its two constituent pulses, giving relative peak positions in time and intensity. The pulses appear on the display screen with the relevant numerical data. Distance and loss values are calculated from the time and intensity readings according to Eq (1) and Eq (2) respectively.

SUBTRACT. This setting is ued with REF ERASE when there are two reflections close together, as in RESOLVE above, but one of the two may be removed by the operator. This is typical in experimental situations when measuring fiberoptic components or assemblies. In this case the measurement is made by taking MEASUREMENT of the double pulse, removing one of the two pulses at the source (eg disassembling the connector under test) and then taking REFERENCE. The Processor subtracts the reference pulse from the double pulse and presents the end results as in RESOLVE above. Calculations of distance and loss proceed as in RESOLVE above.

2.2.4. THE LOSS BUDGET

The loss budget of the Opto-Electronics MM RES OTDR is determined by tracing the Laser Transmitter pulse in Figure 2 through the Coupler to the bulkhead connector with 4% reflectivity and back through the Coupler to the Receiver. The Coupler and connector losses are 1 dB each and the Coupler has a 1:1 splitting ratio, i.e. a 3 dB splitting loss. The detected signal DB in terms of the Transmitter output T at the bulkhead is DB = T - 1 - 1 - 4 - 14 - 4 - 1 - 1 or DB = T - 26. If we denote detector sensitivity at SNR = 1 as D and two way loss budget as LB then

$$D = T - 26 + LB, \text{ or } LB = D - T + 26 \qquad (4)$$

The values of T and D for standard modules, used in most applications, are listed in Table II below.

MODULE	OUTPUT OR SENSITIVITY IN dBm	
	SHORT WAVELENGTH 820-900 nm	LONG WAVELENGTH 1300 nm
Laser Transmitter Multimode	23 (200 mW)	17 (50 mW)
Laser Transmitter Singlemode	20 (100 mW)	14 (25 mW)
APD Receiver	-27	-17
Amplified APD Receiver	-43	-33

Table II The outputs of standard Laser Transmitters and sensitivities of standard Receivers at SNR=1.

Substitution of the tabulated values into Eq (4) yields the values of maximum allowable two way losses, starting at the bulkhead connector. These values are tabulated in Table III below.

RECEIVER TYPE	LOSS BUDGET (dB)			
	Short Wavelength Multimode 820-900 nm	Long Wavelength Multimode 1300 nm	Short Wavelength Singlemode 820-900 nm	Long Wavelength Singlemode 1300 nm
APD	-24	-8	-21	-5
Amplified APD	-40	-24	-37	-21

Table III Maximum values of two way losses, starting at the bulkhead connector, to obtain a signal output with SNR=1.

The values in Table III are important in the Search Mode, see Section 2.2.3.A. With losses greater than these, the pulse cannot be found without averaging.
Once the pulse is found and measurement can proceed, averaging is possible. With averaging, the SNR can be improved by a factor up to 240 times, or the loss may be increased by -24 dB. The loss budget for the general case and for various SNR values is summarized in Figure 6 for multimode and Figure 7 for singlemode operation.

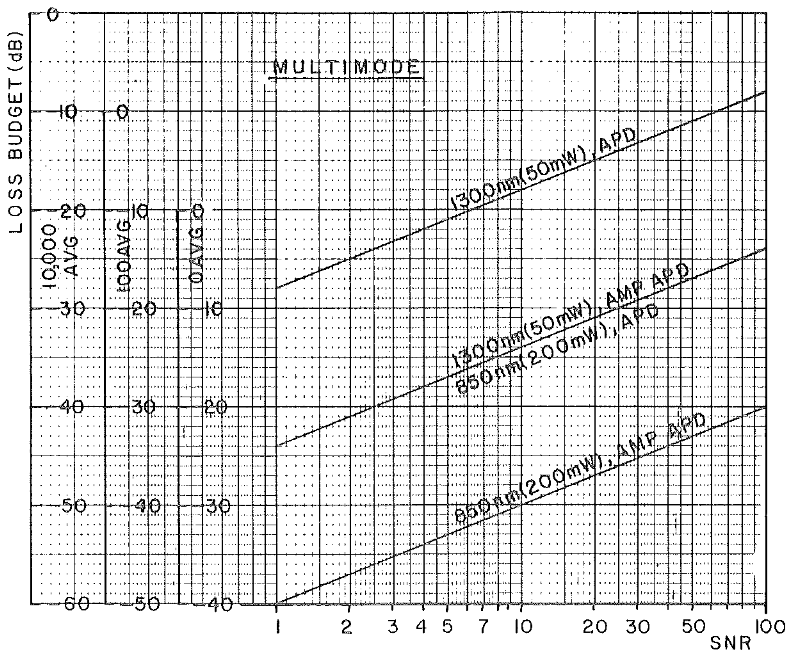


Figure 6 Loss budget for multimode short and long wavelengths and for two types of receivers as function of signal SNR. (N=2 mV)

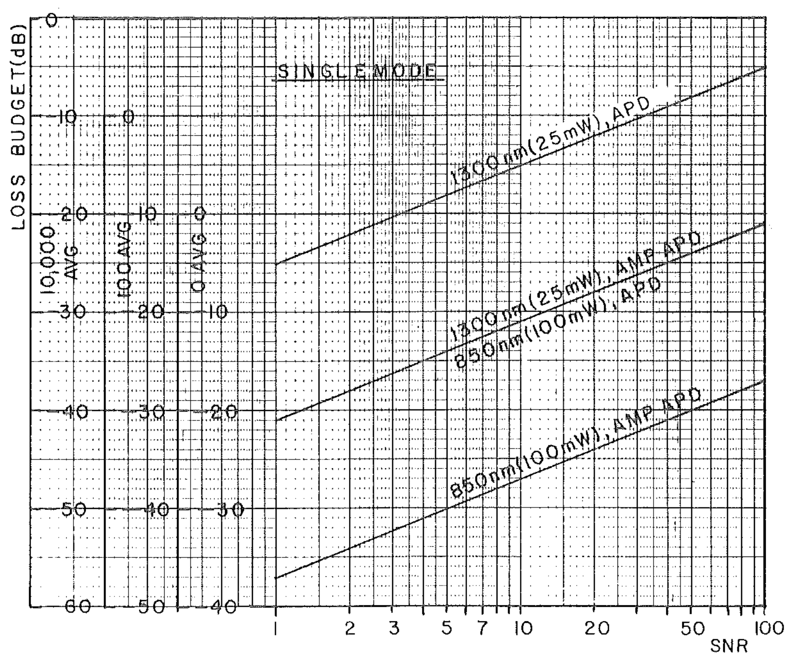


Figure 7 Loss budget for singlemode short and long wavelengths and for two types of receivers as function of signal SNR. (N=2 mV)

2.2.5. TIME AND DISTANCE RESOLUTION

In section 2.1.1. the time resolution on the MM RES OTDR was stated to be ± 0.1% of the time width of the screen or ± 1 ps which ever was greater. This applies to a pulse displayed on the screen with FWHM ≤ 150 ps and with SNR ≥ 50. In general, the displayed pulsewidth varies with the type of receiver used from 150 ps (APD) to 350 ps (AMPL. APD) and with fiber dispersion, while the SNR varies with the link loss, see charts in Figure 6 and Figure 7. The time resolution depends on both the FWHM and the SNR of the received pulse. The relationship is shown in Figure 8 for the case of the smallest time width of the screen for a given pulse.

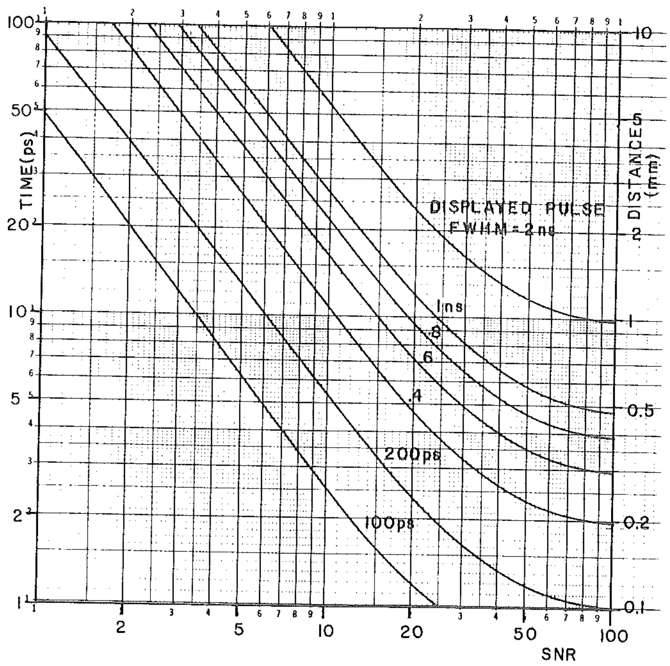


Figure 8 Time and distance (for n=1.5) resolution of the MM RES OTDR as function of SNR for various FWHM values of the displayed pulse.

SHIFT. In this setting the absolute and relative distance measurement accuracies are those shown in Figure 8.

RESOLVE. In this setting the pulse peaks must be separated by at least one half of the FWHM value, and the relative peak heights must be in the range of 1:1 to 10:1. The resolution now depends also on the relative peak heights. The values are plotted in Figure 9 below for a 150 ps wide pulse.

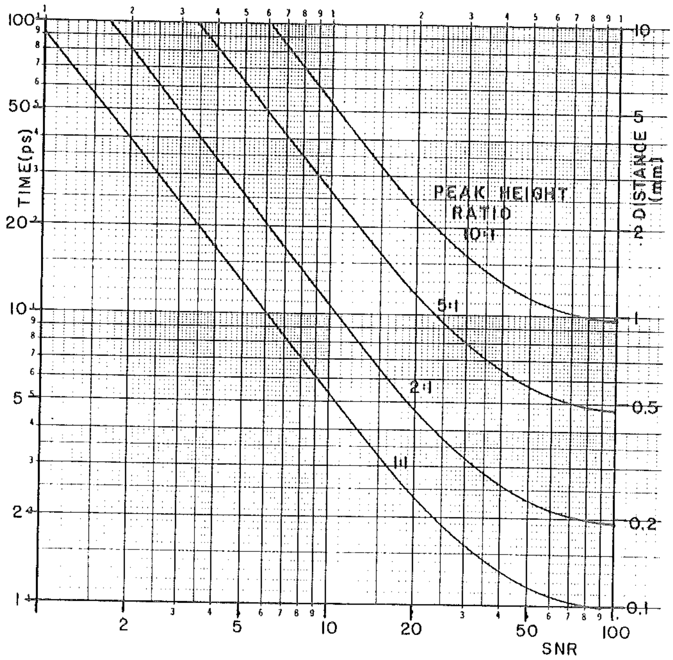


Figure 9 Time and distance resolution of the MM RES OTDR in the RESOLVE setting as function of SNR and relative peak heights for a 150 ps wide pulse.

SUBTRACT. In this setting the pulse peak separation is not important. The relative peak heights must be in the same 1:1 to 10:1 range as in RESOLVE. The resolution is the same as in RESOLVE, see Figure 9.

2.2.6. DATA OUTPUTS

The 256 points of each of the MEASUREMENT, REFERENCE and OTDR (calculated) data are stored in the TDR10 as 24 bit numbers. These data may be outputed to the screen of the oscilloscope, to a dot matrix printer, to an external computer via an RS232 port, or via an optional GPIB (IEEE 488) interface.

A. SCREEN DISPLAY. The TDR10 has output connections for a realtime oscilloscope dispaly (second channel of the sampling oscilloscope or a standalone realtime oscilloscope). It sends the stored MEASUREMENT, REFERENCE or OTDR data from memory, via a D/A converter, to be displayed on the screen. The selection of data is by a front panel switch on the TDR10.

B. PRINTING. Connections to the printer are made by a standard printer cable from the back of the TDR10. The data selected to appear on the screen maybe printed on a dot matrix printer (with graphics capabilities) by pushing the PRINT button on the front p of the TDR10. A typical hard copy is shown in Figure 10 for a two point measurement with reflective features separated by 144 ps or 14.4 mm. In another example, shown in Figure 11, the reflective features are separated 39 ps or 3.9 mm.

C. RS232 INTERFACE. An RS232 connection maybe made between the back panel of the TDR10 and any desktop PC equipped with this interface. Code letters sent from the keyboard to the TDR10 will activate data transfer to the PC from the memory location addressed. These data (MEASUREMENT, REFERENCE, OTDR) can be stored in the PC, or disk, or be further processed.

D. GPIB INTERFACE. An optional GPIB (IEEE 488) port is provided on the back panel of the TDR10 to transfer data to a desktop PC or other computer. Under development is the model TDR20 whose operation will be local/remote and will be completely controlled by GPIB for fully automatic operation. The TDR20 will be available by the first half of 1988.

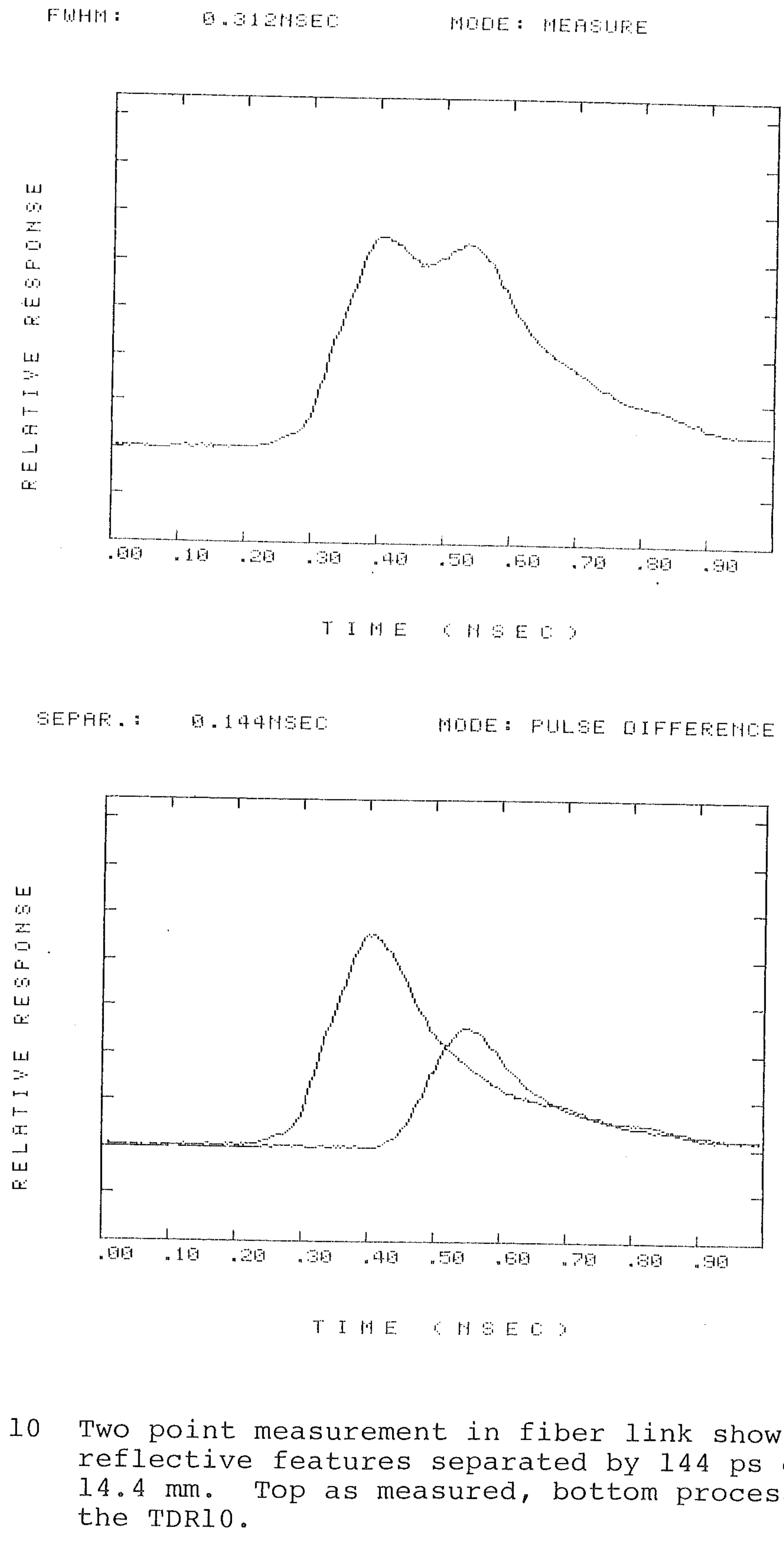
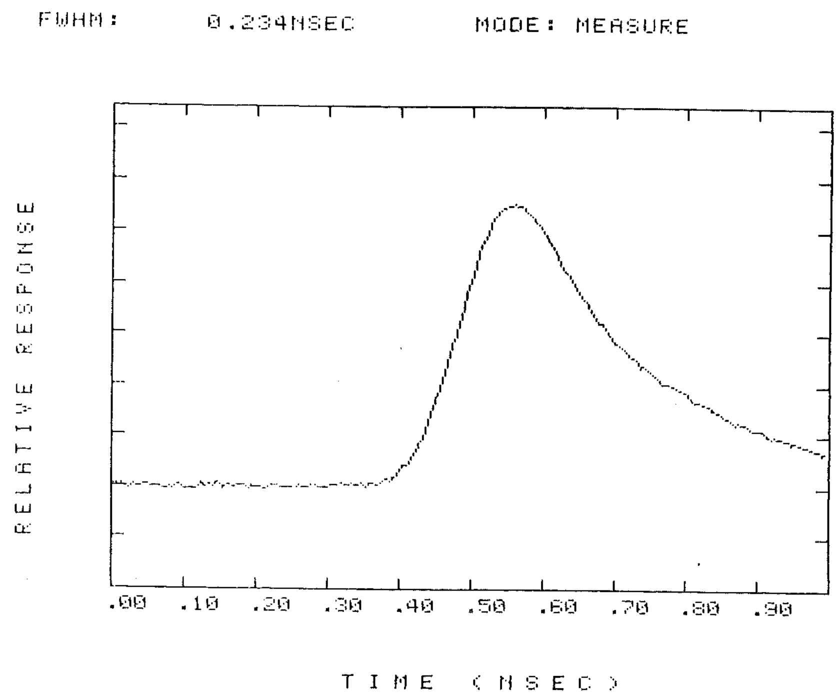


Figure 10 Two point measurement in fiber link showing two reflective features separated by 144 ps or 14.4 mm. Top as measured, bottom processed by the TDR10.



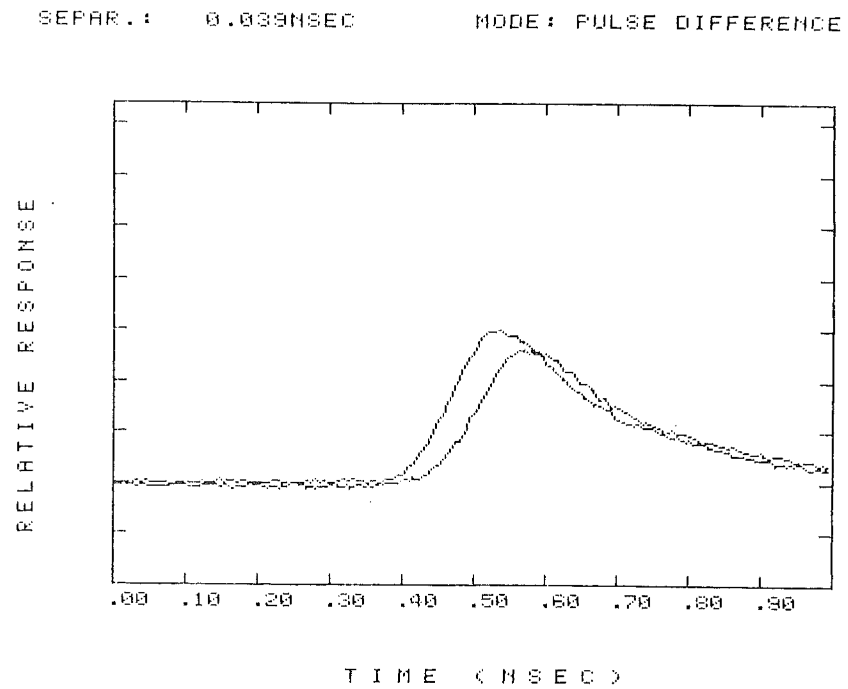


Figure 11 Two point measurement in fiber link showing single pulse (top), which is resolved by the TDR10 into two pulses (bottom). The reflections are from features separated by 39 ps or 3.9 mm.

3 SPECIFICATIONS

3.1 MECHANICAL

MF20 Mainframe	SIZE :	19"W x 14 1/4"L x 7" H
	WEIGHT :	6 1/2 kg (14 lbs)
	CAPACITY:	Time Delay Generator, Sampler and one or two Transmitter/ Receiver modules
	MOUNTING:	Standard 19" instrument rack or bench top
TDR10 Processor	SIZE :	12"W x 13"L x 5 1/2" H
	WEIGHT :	4 kg (9 lbs)

3.2 ENVIRONMENTAL

TEMPERATURE :	10C to 40C operating -15C to 60C storage
LASER SAFETY:	Meets Class I laser product safety

3.3 ELECTRICAL

POWER :	110/220V, 50/60 Hz line

3.4 OPTICAL

CONNECTORS :	Standard ST bulkhead connectors Custom biconic, FC, D4, SMA
TRANSMITTER/ RECEIVER :	Single or multimode pigtailed and connectorized
COUPLER :	Single or multimode connectorized
FIBERS :	Compatible with multimode 50/125, 100/140 or singlemode 125 OD fibers

3.5 INTERFACES

EXTERNAL MODEL :	Requires external sampling oscilloscope such as the Tektron 7904 with 7S11, 7T11, and S4 plugin units
SAMPLING MODEL :	With Sampler module, requires single channel low frequency oscilloscope for display only
PRINTER :	Auxiliary dot matrix with graphics capability
RS232 :	Data port to dump stored data from TDR10 Processor
GPIB (OPTIONAL) :	Data port to dump stored data from TDR10 Processor
GPIB (FUTURE OPTIONAL) :	Enables fully automatic remote operation of OTDR

3.6 PERFORMANCE

DISTANCE RANGE. Singlemode, 1 mm to 30 km; Multimode, 1 mm to 3-5 km (dispersion limited).

DYNAMIC RANGE. Defined as the maximum one way loss (dB) for a 4% Fresnel reflection at a SNR=1

SEARCH MODE, NO AVERAGING (dB)

FIBER & DETECTOR / WAVELENGTH	MULTIMODE		SINGLEMODE	
	APD	AMP.APD	APD	AMP.APD
850	-12	-20	-10	-18
1300	- 4	-12	- 3	-10

MEASUREMENT MODE, 65,536 AVERAGES (dB)

FIBER & DETECTOR / WAVELENGTH	MULTIMODE		SINGLEMODE	
	APD	AMP.APD	APD	AMP.APD
850	-36	-44	-34	-42
1300	-28	-36	-27	-34

RESOLUTION. Single point measurement is defined as that of a single pulse from a single reflection. Two point measurement is defined as that of two pulses, or one composite pulse, from two reflections. Values are for negligible pulse dispersion.

SINGLE POINT MEASUREMENT (ps/mm)

SNR / DETECTOR	50	20	10	5
APD	1/0.1	2/0.2	4/0.4	10/1.0
AMP.APD	3/0.3	5/0.5	10/1.0	25/2.5

TWO POINT MEASUREMENT (ps/mm)

SNR / PULSE RATIO	50	20	10	5
APD 1:1	2/0.2	3/0.3	5/0.5	12/1.2
APD 2:1	3/0.3	5/0.5	11/1.1	25/2.5
APD 5:1	5/0.5	10/1.0	22/2.2	50/5.0

4 ORDERING INFORMATION

The Opto-Electronics Millimeter Resolution OTDR is made in the company's Oakville, Ontario, plant. For sales information call Louise Maher and for technical information call John Marton at the Oakville office of Opto-Electronics, Tel 416/827-6214.

EXTERNAL MODEL This model operates with an auxiliary sampling oscilloscope. Specify the short or long wavelength model as follows.

Short wavelength model for 820, 850 or 905 nm operation, insert λ value for transmitter.

	Multimode Model No.	Singlemode Model No.
Mainframe	MF20	MF20
Time Delay Generator	PDG20	PDG20
OTDR Processor	TDR10	TDR10
Transmitter	PPL30K-λMM	PPL30K-λSM
Receiver APD	PPD30	PPD30
or Amplified APD	PAD230	PAD230
Coupler, 4 port	PFC50	PFC6

Long wavelength model for 1300 or 1550 nm operation, insert λ value for transmitter.

	Multimode Model No.	Singlemode Model No.
Mainframe	MF20	MF20
Time Delay Generator	PDG20	PDG20
OTDR Processor	TDR10	TDR10
Transmitter	PPL30K-λMM	PPL30K-λSM
Receiver APD	PPD40	PPD40
or Amplified APD	PAD240	PAD240
Coupler, 4 port	PFC50	PFC10

SAMPLING MODEL This model operates with an auxiliary low frequency single channel realtime oscilloscope as a monitor. Specify the short or long wavelength model as follows.

Short wavelength model for 820, 850 or 905 nm operation. Insert λ value for transmitter.

	Multimode Model No.	Singlemode Model No.
Mainframe	MF20	MF20
Time Delay Generator	PDG20	PDG20
Sampler	PSU10	PSU10
Sampling Head, Tektronix	S4	S4
OTDR Processor	TDR10	TDR10
Transmitter	PPL30K-λMM	PPL30K-λSM
Receiver APD	PPD30	PPD30
or Amplified APD	PAD230	PAD230
Coupler, 4 port	PFC50	PFC6

Long wavelength model for 1300 or 1550 nm operation, insert λ value for transmitter

	Multimode Model No.	Singlemode Model No.
Mainframe	MF20	MF20
Time Delay Generator	PDG20	PDG20
Sampler	PSU10	PSU10
Sampling Head, Tektronix	S4	S4
OTDR Processor	TDR10	TDR10
Transmitter	PPL30K-λMM	PPL30K-λSM
Receiver APD	PPD40	PPD40
or Amplified APD	PAD240	PAD240
Coupler, 4 port	PFC50	PFC10

FUTURE MODELS AND MODIFICATIONS

Under development is the TDR20 fully automatic processor, controlled by a GPIB bus for remote operation. This model will be available in the first half of 1988.

Custom modifications are available upon request.

WARRANTIES

Opto-Electronics warrants all its OTDR models for parts and labour in normal operation for a period of 12 months from the time of shipment. The cost of shipment to Opto-Electronics and back to the customer, is to be borne by the customer.

CHANGES

All specifications and prices are subject to change without notice.