



PMD440

Polarization Mode Dispersion Test System

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1.0 HARDWARE CONFIGURATION

1.1 Introduction To The PMD440

The PMD440 is designed to measure polarization mode dispersion in optical fibers and cables. It consists of a separate polarized LED light source and a interferometric receive unit controlled by a laptop computer. There is no requirement for communication between the two units; measurements are easily made on installed cables as well as in the factory.

CAUTION

The PMD440 is designed for field use, but it must not be directly exposed to water.

1.2 Inspection

Newly received equipment should be inspected for shipping damage. If any is noted, immediately notify GN Nettest and file a claim with the carrier. Save the shipping container for possible inspection by the carrier.

The complete PMD440 system consists of the following:

- PMD440-1 receive interferometer
- PMD440-2, PMD440-3, or PMD440-4 polarized LED light sources
- Laptop controller
- Three power leads plus parallel interface cable to connect the computer to the PMD440-1
- Documentation
- Shipping/transportation packing

WARNING

Protective grounding may be rendered ineffective in damaged equipment. Damaged equipment should not be operated until its safety has been verified.

1.3 Safety

As defined in IEC Publication 348, Safety Requirements for Electronic Measuring Apparatus, the PMD440 is a Class 1 apparatus (that is, apparatus that depends on connection to a protective conductor to earth ground for equipment and operator safety). Before any other connection is made to the apparatus, the protective earth terminal shall be connected to a protective conductor. The protective connection is made via the earth ground prong of the power cord plug. This plug shall be inserted only into a socket outlet provided with the required earth ground contact.

A suitable power cord plug is provided. The power cord plug provided for the U.K., European, and the U.S. is of the type illustrated in Figure 1-1. Should it be necessary to change the power cord plug an approved type should be used. In every case the wiring color code is as follows:

- Brown Live (L)
- Blue Neutral (N)
- Green/yellow Earth (E)

WARNING

If it is necessary to replace the power cord or the power plug, the replacement cord or plug must have the same polarity as the original. Otherwise, use may pose a hazard from potential fatal electrical shock.

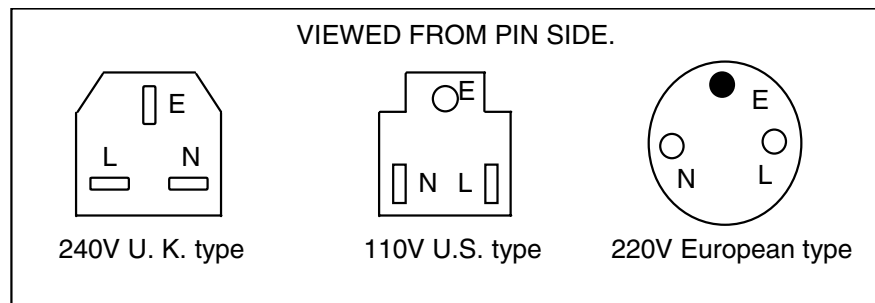


Figure 1-1: Power Cord Plugs With Polarity Indication (pin-side view).

Whenever it is likely that the protection provided by the connection to earth ground has been impaired, the equipment shall be made inoperative and secured against any unintended operation. The protection is likely to be impaired if, for example, the equipment:

- Shows visible damage
- Fails to perform the intended measurement
- Has been subjected to prolonged storage or operation under unfavorable conditions
- Has been subjected to severe transport stresses

Damaged equipment should not be used until its safety has been verified by qualified service personnel

1.4 Power Voltage Selection And Line Fuses

WARNING

The equipment described in this manual may be operated with mains power sources from 85-264 volts, 50/60hz without adjustment. Changing the line fuse should be done only by a qualified service technician, and then only with the instrument disconnected from all sources of power.

Check the fuse rating. Both the receive unit and the light sources require 20mm T1.0A anti-surge fuses. Ensure that the correct fuses are used for safe operation.

1.5 Equipment Servicing

WARNING

Potentially lethal voltages are present inside this apparatus. Service should be performed by qualified personnel only.

1.6 Ventilation

The PMD440 receive unit and light source are both cooled by convection. Ensure that a free airflow is possible around the units and that they are not covered up during use. The ambient operating temperature is restricted to the range of 0°C to 35°C.

1.7 Hardware Installation and Control

NOTE

Installation requires a trained technician who has read and understood this manual. The PMD440 is controlled from an IBM-compatible personal computer. Control is via the parallel port.

1.8 Specification

Table 1-1: PMD440 Specifications

Operating Wavelength Range	
1300 nm light source	1250 nm to 1350 nm
1550 nm light source	1500 nm to 1600 nm
PMD Scan Range	250 ps
Time Resolution	7 fs
Measurement Time	15-30 seconds (typical) for full 250 ps scan
Input Power	0 dBm ¹
Operating Temperature	0° to 35°C
Storage Temperature	-20° to +65°C
Weight (Max.)	
Receiver Unit	4.0 kg (8.0 lbs.)
Light Source	0.7 kg (1.5 lbs.)
Dimensions	
Receiver Unit	36 x 32 x 11 cm
Light Source	24 x 15 x 6 cm
Power Consumption (Max.)	
Receiver PMD440-1	30 W (100/240 V, 50/60 Hz)
Light Source PMD440-2, PMD440-3	10 W (100/240 V, 50/60 Hz)

Specifications are subject to change without notice.

1. The detector may be damaged if input level exceeds 0 dBm. Recommended maximum measurement input power is -18 dBm.



2.0 SYSTEM SOFTWARE OPERATION

2.1 Introduction

The PMD440 instrument is entirely software controlled using a personal computer. The program is controlled by the use of on-screen menus and Softkeys, which correspond with keyboard function keys. These functions may be selected by the user to perform measurements, store data, print results, etc.

NOTE

Refer to “Typical Measurement Sequence” on page 35 for instructions on making PMD measurements.

2.2 Modes of Operation

The system has two modes of operation: Test Mode and Service Mode.

2.2.1 Test Mode

Test mode is used for the normal measurements of fibers. It allows the operator to select and edit test files, to store fiber details and test parameters, and to take measurements of PMD. Results may displayed on screen or printed and imported as ASCII text files by external programs. A Power Bar allows the instantaneous power level in the fibers to be monitored on the screen. Access to test level functions is restricted through use of user-defined passwords.

2.2.2 Service Mode

Service mode requires a service password and is designed for use by service engineers. It allows reference power levels to be established and calibration information to be recorded. Password access may be set up under the service menu.

2.2.3 Software Installation and Parallel Port Configuration

PMD440 program is supplied factory installed, and the computer's parallel port is configured for standard bi-directional operation. No further actions are required.

2.2.4 Supplied Files

- PMD440 installation program for Windows 95
- PMD440 application: PMD440.EXE, PMD440.HLP, and PMD440INF.INI (created when the program is first executed)
- National Instruments NIDAQ software CDROM (A number of programs and files are installed by the NIDAQ software including NIDAQ32.DLL and configuration utilities.)

A full installation requires both the PMD440 application and the National Instruments NIDAQ software. Once installed, the NIDAQ software must be set for operation with a National Instruments DAQPAD 1200 data acquisition card (built into the PMD440 instrument) and a parallel port must be allocated to it and set for standard bi-directional operation.

The PMD440 installation disk should be used to install the Windows95 PMD440 program. When initially installed, the PMD440 programs acquisition menus and buttons are disabled. These menus and buttons are enabled when the National Instruments NIDAQ software is installed and configured. The program will then allow acquisition to proceed.

If measurements will not be taken, a Stand Alone installation may be performed by installing only the Windows95 PMD440 application. This mode of operation allows use of all functions with the exception of those concerned with data acquisition. Menu functions and keys associated with data acquisition are shaded and inactive.

2.2.5 Installing PMD440 for Stand-Alone Operation

Place the installation disk in drive A and using Control Panel>Add/Remove programs, install the PMD440 program. A PMD440.exe shortcut is installed on the desktop.

2.2.6 Installing PMD440 for Data Acquisition

The PMD440 receiver is designed to operate with a standard bi-directional parallel port or with an EPP parallel port.

PMD440 version is designed for parallel port communications. Set the computer's CMOS settings to configure the parallel port mode to this standard bi-directional mode of operation. The PMD440 receiver will not operate with a parallel port ECP mode, which is frequently the CMOS default setting.

Refer to your computer manual for instructions on modifying the CMOS settings, and use the software utilities provided by the computer manufacturer to edit the parallel port configuration.

To install the NIDAQ drivers and test the PMD440 receiver, proceed as follows:

1. Place the installation disk in drive A. Use Control Panel>Add/Remove Programs to install the PMD440 program.
2. Install the NIDAQ software.
Use Control Panel>Add/Remove Programs to install the NIDAQ drivers (from the NIDAQ CD-ROM).

NOTE

The installation program provides a number of selection check boxes. Install only the NIDAQ drivers to minimize disk requirements. The drivers option installs drivers and the configuration utilities required to setup the PMD440 receiver card.

3. Inform the PC of the PMD440 receiver hardware.
 - a. Click the Control panel Add New Hardware.
 - b. Click Next to begin the installation.
 - c. Click the NO check box to prevent Windows95 from searching for new hardware. Windows will not automatically find the PMD440 receiver.

- d. Click NEXT to see a list of hardware types.
 - e. Click Data Acquisition devices, and select the PMD440 receiver.
 - f. Click next and proceed with the installation.
4. Plug the PMD440 receiver into the parallel port and switch it on.

A NIDAQ configuration utility program may be used to allocate a parallel port to the PMD440 receiver and check its operation. This utility is automatically installed when the drivers are installed.

1. To use the configuration utility, start NIDAQ for Windows.
2. Select a device number for the PMD440 receiver.
3. Select Configure and allocate a parallel port to the device. (e.g., LPT1)
4. Run the Test Panels to check operation of the board.
5. Run the PMD440 program and ensure that acquisition can proceed by performing a measurement.

2.3 Start Up

1. Connect the PMD440 instrument to the computer.
2. Switch on instrument power.
3. Switch on the computer. "Microsoft Windows 95" loads.
4. Launch the PMD440 control software.

See "Typical Measurement Sequence" on page 35 for instructions on making measurements.

2.4 The Windows 95 Environment

The PMD440 program runs in the Microsoft Windows 95 environment.

The system can be controlled with a mouse or from the keyboard. "Click" refers to moving the cursor over the item and pressing the left mouse button once. "Double click" refers to moving the cursor over the item and pressing the left mouse button twice in rapid succession.

In the PMD440 software, the main pull-down menu functions are duplicated on Softkeys F1 to F10 shown at the bottom of the screen.

2.4.1 Function keys

A function can be selected by pressing a function key on the keyboard or by clicking the corresponding Softkey.

2.4.2 Pull-down Menus

The main menu provides access to all of the functions needed to control data acquisition, display, and storage. Select a menu by clicking on the menu title with the mouse or by pressing the Alt followed by the underlined letter in the menu title. Once the menu is open, select a sub-menu with the mouse or by pressing the key that corresponds to the underlined letter. Functions that are shown in grey are inaccessible; such functions may require a password to be used or a processing task to be performed before permitting access to the function.

For descriptions of menus and submenu items, see “Menu Commands and Functions” on page 16.

2.4.3 Toolbar

Clicking on the toolbar buttons may access certain frequently used menus. Position the mouse cursor over the buttons to show context help. The PMD440 contains the following toolbar buttons: [File-New], [FileOpen], [File Save], [Print], and [Help].

2.4.4 Dialog boxes

Certain selections open a dialog boxes that contain one or more controls. These allow various items to be chosen using either the keyboard or a mouse. The item selected in the dialog is shown highlighted by a dotted line box. Such an item is termed as having the input focus and further key strokes are aimed at that object. To move the input focus to another object use the TAB key or TAB + SHIFT to retrace the movement.

To exit a dialog, click OK to accept settings, or click CANCEL to ignore new selections and revert to the old settings. In most cases, the keyboard RETURN will choose OK, and ESCAPE will choose CANCEL.

2.4.5 Tab Dialog boxes

Tab dialogs are used to group entries that may be related onto several pages or “tabs.” Click the tab at the top of the dialog to display entries.

2.4.6 Buttons

Most dialog boxes contain a CANCEL and OK button and sometimes further buttons.

The OK button can be selected by clicking it with the mouse, pressing ALT and “O” or often by just pressing RETURN. OK signifies that you will use the selected item(s) or set ups, and it closes the dialog.

The Cancel button can be selected by either clicking it with the mouse, pressing ALT and 'C' or by pressing the Escape button. Cancel closes the dialog box without changing anything.

The Apply button in tab dialog boxes can be used to accept the selected item(s) or set ups as if the OK button had been pressed. The Apply button does not close the dialog box and allows further modifications to be made. In instances where this facility is inappropriate or not required, the button remains shaded and inaccessible.

2.4.7 List box

A list box offers a list of items from which one or more can be selected. For example, the file select dialog box lists available test files. One file can be selected either by clicking over the file name with the mouse or moving the up/down cursor and pressing return. The selected file is highlighted.

2.4.8 Option buttons.

Option or radio buttons signify a series of options, only one of which can be selected. Selecting one automatically deselects the others. They can be selected by either being clicked with the mouse, or pressing the TAB key to move forward to the group of buttons (or SHIFT + TAB to move backwards), then using the cursor keys to select the button.

2.4.9 Check boxes

These are square boxes which may have a check mark in the center. The box is used to signify the item or function shown along side, being selected or

not. A check mark signifies selection; an empty box signifies no selection. Selection is achieved by either clicking with the mouse or moving to the item with the TAB / SHIFT + TAB key and then pressing the SPACE bar to toggle the selection.

2.4.10 Edit boxes

These are boxes, which allows the user to enter a number or characters from the keyboard. Select a box by using the TAB/SHIFT + TAB key or clicking with the mouse. When the item is initially selected and displayed in inverse video entering a new character will remove all the existing data. To prevent this, first press a cursor key, then edit the existing entry. For example, in the Fiber dialog box, the Fiber length, ID, and message are entered via edit boxes. Backspace and delete are also allowed.

2.4.11 Drop-down list boxes

A drop-down list box appears initially as a small rectangular box with the current choice (default) highlighted in the box. The arrow in a square box at the right of the rectangular box opens into a list of available choices when you select it. If there are more choices than can fit in the drop-down list box, scroll bars are provided at the right hand side of the box.

To open a drop-down list box and select an item using the Mouse:

1. Click the arrow in the square at the right of the box to open the drop-down list box.
2. Click the Up or Down scroll arrow or 'drag' the scroll bar to move to the item you want.
3. Click the item.

To open a drop-down list box and select an item using the keyboard:

1. Press ALT+DOWN ARROW to open the drop-down list box.
2. Use the UP or DOWN ARROW key to reach the item you want, and press ALT+UP ARROW or ALT+DOWN ARROW to select the items

2.5 Main Display

The Main Display Page displays a plot of PMD data and a summary report of the PMD. A number of controls are available to manipulate the plot display and display additional information.

2.5.1 Changing the plot display window.

The default plot display window is set in the test file. The mouse may be used to expand or contract the display window by creating an expansion rectangle over the plot as follows:

TO EXPAND THE PLOT

1. Position the mouse over the plot at the imaginary corner of an expansion rectangle.
2. Hold down the left mouse button, and drag the mouse to the opposite corner of the expansion rectangle.
3. Release the mouse button. The plot within the expansion rectangle is redrawn full size.

An expanded plot shows a number of indicators:

- Grey Fill
Area designated as an auto correlation peak, not contributing to PMD
- Blue Fill
Area contributing to PMD
- Red Plot
Signal designated as noise and rejected from the PMD processing

TO CONTRACT THE PLOT

Click the mouse right button. The plot is redisplayed at its previous expansion or over the full psec range (-50 psec to +250 psec).

2.5.2 Displaying a position cursor

A movable psec position cursor may be displayed over the screen:

1. Click over the Cursor F4 soft key. A cursor is displayed on the left hand side of the plot with the psec delay indicated in a display rectangle.

2. To move the cursor, position the mouse over the display rectangle below the psec axis, and hold down the mouse left button. Drag the cursor to the desired position, and release the left button.
3. Click over the Cursor F4 soft key again to remove the cursor from the display.

2.5.3 Report Display List box

The report display indicates the PMD from the last measurement with summary information about the acquisition. Horizontal and vertical scroll bars may be used to view information off screen.

Information displayed includes a goodness-of-fit parameter when random PMD is being measured. Fit values range from 0, which indicates a poor fit, to 1, which indicates an optimum gaussian PMD.

Table 2-1: Acquisition Status Indicators

Display	
Total PMD	Displays the average of all of the PMDs within the current repeat sequence.
Pass/Fail	Displays “Pass” if the total PMD falls within the test file warning limits, otherwise displays “Failed”.
Run Number	Displays the current run number.
Repeat Number	Displays the current repeat number.
Time to Next Run	Counts down to the next run in a run-repeat sequence.

2.6 Menu Commands and Functions

Table 2-2: File Menu Functions

Sub-Menu	Function
New	Clears current data from memory, clears the display, and creates a new data file ready for a new measurement. The current test file establishes data-acquisition and display parameters.
Open	Opens a previously stored *.PMD data file.
Save	Saves the current data in two formats: filename.PMD, which contains all graphic data, and filename.TXT, which contains a summary of results in text form. (The current filename is displayed in the window's title bar.)
Save As	Saves the current data file in .PMD and .TXT formats with a new filename.
Save Report as Text	Saves the results in .TXT format only. Comma and quote formatting information is removed from the report during the save.
Export Raw Data as Text	A special Save As command that saves plot data in a fixed comma- and quote-delimited text file. The file consists of a fixed number of header strings (quote delimited) followed by a list comprising index number, pico second, and percent intensity, for each data point in the file. Each data field is separated by a comma. The export dialog requires setting the quantity of data points to be exported. Enter the number of points to be ignored. For example, entering 0 exports all data, entering 1 exports every other point, entering 4 exports every fifth point.
Print	Prints a graph or summary report to the active printer.
Print Preview	Displays a graph or summary report. Often used to check a file prior to printing a hard copy.
Page Setup	Sets up the printed page format (e.g., page margins).
Exit	Terminates data acquisition and closes the PMD440 program.

Table 2-3: Edit Menu

Sub-Menu	Function
Setup PMD	<p>Establishes run sequencing, data storage, and printing information. The function of each dialog or check box is detailed below:</p> <p>Fiber Data Entry—Enter company name for display in reports. Toggles the Fiber Data dialog display at the start of a run.</p> <p>Logo—Set a Logo as the first line in the report.</p> <p>On/Off—Selects Fiber Data dialog display at the start of a run.</p> <p>Data Acquisition—Run sequencing.</p> <p>Runs To Average Per Repeat—The number of measurements to be made. A running average PMD is reported for these measurements.</p> <p>Number Of Repeats—The number of times to repeat the running average sequence. The total number of measurements is Runs To Average Per Repeat x Number Of Repeats. The average value reported is reset at the start of each repeat.</p> <p>Delay between runs—Minutes between runs.</p> <p>Delay between repeats—Minutes between repeats.</p> <p>Storage—Storage parameters.</p> <p>Autosave—Check to automatically save measurement data.</p> <p>Base Filenames—Filename selection dialog. An autosave number and a file extension are appended to the selected filename. For example, when autosave is activated, a base filename “Untitled” is saved as Untitled_1.pmd and Untitled_1.txt. Existing files are overwritten when storage occurs.</p> <p>Autosave Number—the numeral appended to the next autosave.</p> <p>Save as ID—Assigns the fiber I.D. as the Base Filename.</p> <p>Print Results—Printout options.</p> <p>Graph Results—Check to print a plot report after each measurement.</p> <p>Final Summary Report—Check to print the final summary report at the end of a run-repeat sequence.</p>

Table 2-3: Edit Menu

Sub-Menu	Function
Test File	<p>The Test File menu allows test files that contain all of the parameters governing data acquisition and initial display to be created and maintained. Test files are stored in groups of ten in a disk file with a “.ptf” file extension. Clicking Test File presents a Select Test Files dialog. The dialog allows an existing group of test files to be selected from a drop down list box, or it allows a new group to be created by the user clicking on a New Group button.</p> <p>Default test files are generated whenever a new group file is created. The dialog displays a list of the test files numbered 1 through 10 together with their individual names. A group file description may be entered into the description field.</p> <p>To edit a test file, first select the test number-description from the list box and click the edit test files button. A Test File Options Tab dialog is presented containing a number of tab selections with controls to set up operating parameters.</p>
Test Type tab	<p>Test File—The file name used for reports and in the test number description list of the Select Test Files dialog.</p> <p>Description—Narrative description of the test file.</p>

Table 2-3: Edit Menu

Sub-Menu	Function
PMD Process Options tab	<p>Source—Source type and its coherence time. Default coherence times are as follows:</p> <ul style="list-style-type: none"> 1310nm0.056psec 1550nm0.064psec White light0.020 psec A.S.E0.400 psec <p>Process—Processing to be performed:</p> <p>Deterministic—Records every PMD value greater than an intensity threshold.</p> <p>Report%—Establishes a percentage intensity threshold above which PMD values are recorded. Available only for deterministic reports.</p> <p>Random—Report of the average PMD determined from the second moment of the measured data.</p> <p>Warning limit psec—Sets a PMD threshold above which a warning message is recorded for random reports.</p> <p>Standards—Allows a PMD warning limit to be selected.</p> <p>Warning limit psec/km^{-1/2}—Enters a PMD/km^{-1/2} threshold above which a warning message is recorded for random reports. Warning messages are annotated with an "(R)" in the Acquisition field of the summary report.</p> <p>Display range—Sets the initial window for the PMD plot at 4, 10, 30, 140 or 250 psec.</p>

Table 2-3: Edit Menu

Sub-Menu	Function
Results	<p>Displays a plot scale dialog that allows the x and y axes' upper and lower limits to be entered and selected for use with all files. It also allows fiber length, I.D., and message to be modified. When the dialog is displayed, the last selected zoom values are presented. Values may be modified by entering new values into edit boxes or by selecting the current plot's axis limits.</p> <p>Minimum psec—Enters the minimum psec plot axis value.</p> <p>Maximum psec—Enters the maximum psec plot axis value.</p> <p>Minimum intensity—Enters the minimum intensity plot axis value.</p> <p>Maximum intensity—Enters the maximum intensity plot axis value.</p> <p>Current expansion—Press to select the current plots axes values.</p> <p>Apply to All—Check to apply the zoom values to all files.</p> <p>Fiber data—Click to present the Fiber data dialog box to allow the fiber length, I.D. and message to be entered. When new values are entered and accepted by clicking on the OK buttons, PMD results are recalculated using the new values.</p>

Table 2-4: Measure Menu

Sub-Menu	Function
PMD F2	<p>PMD F2 starts a measurement. A fiber data entry dialog opens if the Edit-Setup PMD fiber data entry was selected followed by a Power Bar.</p> <p>Fiber length (km)—Enter Fiber length (km).</p> <p>Fiber ID—Enter fiber identifier description.</p> <p>Message—Enter free form message.</p> <p>Click OK on the dialog to continue with a PMD measurement and display the power bar, or Cancel to abort the option.</p> <p>Click OK on the Power bar to continue with the measurement or Cancel to abort the option.</p> <p>A PMD measurement scan takes about 20 seconds. During acquisition, a progress indicator on the status bar will indicate that acquisition is in progress. At the end of acquisition and processing, the PMD plot is displayed and results displayed. The PMD plot data and summary files are stored and printed according to the Edit-Setup PMD settings.</p> <p>A temporary report file PMDREPORT.TXT is updated at the end of a run with the latest summary results. This file is overwritten each time a new run repeat sequence is started.</p>

Table 2-4: Measure Menu

Sub-Menu	Function
Power Bars F7	<p>Displays the power bars. The Power Bar F7 menu displays a power bar dialog and starts monitoring the power at a rate of 1 sample per second.</p> <p>A power readout relative to reference power values set by the Service Get Reference Powers menu is calculated and displayed in the power bars. The reference level is shown by a red line on the power bar and represents the maximum power level (no loss).</p> <p>Caution: The maximum input power is 0 dBm (1 mW). Exceeding this level can damage the instrument. The power of the optical source provided is approximately -21 dBm.</p> <p>Power (db)–100+ optical power dBm.</p> <p>Loss (db)–reference optical power – Instantaneous optical power.</p> <p>When the Service password is used, the amplifier range and gain may be set manually and additional readouts are available on the power bar.</p> <p>Voltage/(Range x Gain)–voltage divided by the range x gain.</p> <p>ADC–instantaneous ADC counts.</p> <p>Autorange–Check to automatically setup the amplifier range and gain. Uncheck to use the existing range and gain settings that were set using the Measure Gain F3 menu. When auto range is checked, clicking on OK on the power bar will cause the new range and gain settings to be recorded and subsequently used. This function is operational in service mode for diagnostic purposes only. In other operational modes the amplifier range and gain is always set up automatically and cannot be set manually.</p>
Gain F3	<p>Displays a service mode gain selection dialog. The Gain F3 menu allows the amplifier range and gain to be set manually when the Service password is in use. The option is not available in other operational modes.</p> <p>Range–Selects range 1, 10.</p> <p>Gain–Selects gain of 1, 10, 100, 1000.</p> <p>Click OK to accept the setting or Cancel to exit the dialog.</p>
Stop F10	<p>Aborts a run or sequence of runs. (Available as F10 key only.) The Stop F10 key stops data acquisition, terminating the current run and any sequence of runs and repeats.</p>

Table 2-5: System Menu

Sub-Menu	Function
Enter Password	The Password menu displays a password entry dialog. Only those functions designated for use with the password (System Menu Configure Menus and Passwords) are enabled.
Configure Function Keys	<p>The Configure function keys menu allows the text descriptions of the function keys to be customized. The menu presents a dialog which will allow text for function keys F1 through F10 to be entered. The text strings are displayed on the function keys together with a label "F number" (e.g. F1) when the OK button is used to accept the entries</p> <p>The following controls may be used to setup the text labels:</p> <p>Function key text edit boxes—Enters up to 20 characters of text.</p> <p>Defaults—Restores the function label keys to supplied defaults.</p>
Configure Menus and Passwords	<p>The Configure menus and passwords menu is used to set up password access to PMD440 functions. Three passwords are permitted. Two passwords may be set to restrict access.</p> <p>Password 1—Enters a password with restricted access.</p> <p>Password 2—Enters a password with restricted access.</p> <p>Service/All Functions Password—Enters a password with full access.</p> <p>Double click the check boxes, or use the spacebar on a highlighted entry, to indicate functions that may be accessed. The Up and Down arrow keys may be used to scroll through a list.</p> <p>Click OK to accept the selections or Cancel to exit the dialog.</p>

Table 2-5: System Menu

Sub-Menu	Function
Configure Remote Control	<p>The Configure remote control menu may be used to set up the RS232 communications protocol to allow remote control by a host computer. To make a connection, it is important that the same protocol is use on the PMD440 series computer and host computer. A number of options may be selected for use. These are accepted when the OK button is pressed to exit from the dialog:</p> <p>Enable remote control by RS232Check to connect to the host computer when the OK button is used to exit from the dialog. Uncheck to disconnect the host computer.</p> <p>Baud Rate—Sets the bit rate.</p> <p>Data bits—Sets the number of data bits.</p> <p>Stop bits—Sets the number of stop bits.</p> <p>Parity—Sets the parity test protocol.</p> <p>I/P Terminator—Sets the input terminators. (Characters used to identify a command received from the host computer).</p> <p>O/P Terminator—Sets the output terminators (Characters appended to data transmitted to the host computer).</p> <p>Flow Control—Sets the flow control protocol.</p> <p>Start End Characters—Check to start a transmission with ASCII 0x2 (STX) and terminate with ASCII 0x3 (ETX) characters.</p> <p>Defaults—Sets up a default protocol.</p>

Table 2-6: View Menu

Sub-Menu	Function
Toolbar	Check the menu to display the tool bar. Click again to hide the bar. When visible, the tool bar may be relocated by clicking on it and dragging to its new location before releasing the left mouse button.
Status Bar	Check the menu to display a status bar at the bottom of the PMD440 display. Click again to hide the bar. The status bar indicates data-acquisition progress; the red-green indicator blinks during data transfer. Context-sensitive help is displayed on the status bar following acquisition.

Table 2-6: View Menu

Sub-Menu	Function
Button Bar	The button bar contains buttons that emulate the function keys. Check the menu to display the tool bar. Click again to hide the bar. When visible, the tool bar may be relocated by clicking on it and dragging to its new location before releasing the left mouse button.
Results Summary	<p>The Results summary menu displays a dialog that shows the summary report data.</p> <p>The Summary dialog shows the contains a number of buttons:</p> <p>Next–Displays the next page.</p> <p>Prev–Displays the previous page.</p> <p>Open File–Opens a highlighted file. Double clicking on the results of interest in the summary dialog list box, or clicking on the Open File button will display a file open dialog containing the filename of the data file. Clicking on OK will open the open the .PMD file and display the plot and results.</p> <p>To print the summary data, close the report dialog, and use the File Print or File Print Preview menus.</p>

Table 2-7: Service Menu

Sub-Menu	Function
Instrument ID	<p>The Instrument I.D. menu presents a dialog allows an instrument identifier string to be entered. This information is stored in each data file and displayed in the report header.</p> <p>Instrument I.D.–Enter the identified string.</p>
Remote Control Diagnostics	<p>The Remote Control Diagnostics menu dialog shows a history of RS232 Read and Write transactions. This may be used as a diagnostic tool when setting up remote control programs.</p> <p>The dialog will display 5000 characters in any one transaction up to a total of 64000 characters maximum. The screen clears automatically if more than 64000 characters are present before being updated with new data. If raw data or reports containing more than 5000 characters are transmitted, the display is truncated. Under these circumstances, points of ellipsis (...) appended to the partial raw data or report display indicate that further information was transferred.</p>

Table 2-7: Service Menu

Sub-Menu	Function
Get Reference Powers	<p>Get Reference Powers menus are designed for use by service engineers and set up calibration values. Calibration values are factory set and, under normal operating conditions, need no adjustment.</p> <p>Four sub-menus allow the reference power level to be setup according to the wavelength of the source in use. Reference power shows as a red line in the power bar display. Loss displayed on the power bar dialog is calculated relative to reference power levels.</p> <p>1310nm—Measures 1310 nm source reference.</p> <p>1550nm—Measures 1550 nm source reference.</p> <p>White Light—Measures White light source reference.</p> <p>A.S.E.—Measures A.S.E source reference.</p> <p>AD Value—Displays the ADC count.</p> <p>Voltage/(range x gain)—Displays the voltage/(range * gain).</p> <p>Power (dB)—Displays 100+ reference power.</p> <p>Get Reference Power—Measures the power using the current range and gain settings. Click Get Reference Power to monitor the power; click OK to accept and record the value.</p>

Table 2-7: Service Menu

Sub-Menu	Function
Acquisition Mode	<p>The Acquisition Mode menu is designed for use by service engineers to set up diagnostic and calibration values. These values are normally factory set and should not be adjusted. Acquisition Mode also sets up system data acquisition parameters. Default values should be applied as follows:</p> <p>Software Start—Uncheck to select hardware triggered start (default = unchecked).</p> <p>Demo—Check to simulate the presence of PMD440 series hardware. Measurement start and stop functions become enabled and data from the Demo.Dat file is used for demonstrations (default=unchecked).</p> <p>Ignore leading points—Enter the number of leading points to ignore (default=0).</p> <p>Ignore trailing points—Enter the number of trailing points to ignore (default=0).</p> <p>Filter order—Enter a binomial filter order to be applied (default=0).</p> <p>Noise threshold—Enter the noise threshold (default 4).</p> <p>Hardware—Select Parallel for use with the PMD440 series instrument rather than PCMCIA or PC ATMIO16XE110 cards (default=parallel).</p> <p>Switch Source—Check to cause the white light source switch to be switched if present (PMD440 only) when the test file indicates white light. IO line CONFIG_0 is set high for white light or low otherwise (default = unchecked).</p> <p>Range—Switches between original scan range of +/- 140ps and the current range of -50 to +250ps. The second mode is selected when the box is checked. The two following boxes, Center psec minimum and maximum are used to locate the central auto correlation peak as part of the factory calibration process.</p> <p>Click OK to accept new parameters or Cancel to exit the dialog.</p>
Range Calibration	<p>The Range Calibration menu is designed for use by service engineers to set up range calibration values. These values are normally factory set and should not be adjusted.</p> <p>Voltage—Enter the voltage for the range calibration.</p> <p>Distance (mm)—Enter the distance for the calibration voltage.</p> <p>Click OK to accept the new calibration or Cancel to exit the dialog.</p>

Table 2-7: Service Menu

Sub-Menu	Function
Gain Calibration	<p>The Gain Calibration Menu is designed for use by service engineers to set up gain calibration values. These values are normally factory set using a laser source and should not be adjusted.</p> <p>Gain calibration compensates the detector response for mirror position and fits a quadratic response curve. The menu presents a dialog that allows the response curve to be set up automatically using a laser calibration or allows the quadratic coefficients to be entered manually. Setting all coefficients to zero prevents the gain calibration from being applied.</p> <p>X² Coefficient—Enters the coefficient.</p> <p>X Coefficient—Enters the coefficient.</p> <p>Intercept—Enters the coefficient.</p> <p>Max signal—Indicates the maximum signal level.</p> <p>Std Err Estimate—Indicates the curve fit.</p> <p>Laser Calibration—Starts an automatic calibration using an external 1550nm DFB –20dBm laser source. Pressing the Laser Calibration button will present the power bar. Clicking OK on the Power bar causes a measurement to be performed and a calibration curve to be plotted.</p>

Table 2-7: Service Menu

Sub-Menu	Function
Warning Limits	<p>The Warning Limits Menu is designed for use by Service Engineers to set up warning calibration values. These values refer to the maximum operating range of the PMD440 series instrument under normal operating conditions and should not be adjusted.</p> <p>Upper Limit (psec)—Enters the maximum PMD above which a warning is reported.</p> <p>Lower Limit (psec)—Enters the minimum PMD below which a warning is reported.</p> <p>Upper Limit (volts)—Enters the maximum voltage above which a warning is reported.</p> <p>Lower Limit (volts)—Enters the minimum voltage below which warning is reported.</p> <p>Show Warning Limits—Check to cause a warning dialog to be displayed if any PMD data falls outside of the warning limits after each run. (NB. The dialog will only be displayed when one run and one repeat is specified in the Edit Setup PMD dialog).</p> <p>Warnings are always annotated in the PMD summary report as an “(E)” displayed in the Acquisition time field. Additional warnings specified in the Test File result in “(R)” annotations in the acquisition field of a random report.</p>

Table 2-8: Help Menu

Sub-Menu	Function
Contents	Shows the online help.
About	Shows the PMD440 series version number.

2.7 Remote control commands

All of the following remote control commands return BUSY if the system is currently performing an operation and is unable to execute them.

Table 2-9: Remote Control Commands and Responses

Command	Response
Dialogs	
GET DATA message	The function allows the user to be prompted by a dialog box. The message is displayed at the top of the box. If OK is selected, the entered character string is returned. If Cancel is selected, CANCEL is returned. The message can be any string up to 70 characters.
GET FIBER DATA	The function allows the user to be prompted by a dialog box normally used at the start of a measurement. The fiber length, ID and a message can be entered. When OK is selected, OK is returned. When Cancel is selected, CANCEL is returned. To read back the entered data, use the READ ID, READ LENGTH, and READ MESSAGE commands.
PROMPT nn	The function allows the user to be prompted by a dialog box. nn should contain a character string that is shown when the dialog box is displayed. When OK is selected, OK is returned. When Cancel is selected, CANCEL is returned.
Test Information	
READ ID	Fiber ID
READ LENGTH	Fiber Length in km
READ MESSAGE	Fiber Message
SET ID nn	Sets the fiber identification message. The ID string length should be less than 256 characters.
SET LENGTH nn	Sets the fiber length used during a measurement. nn is the length (0.00001 to 250 km).
SET MESSAGE nn	Sets the fiber message associated with a measurement. nn is the message string. Length of nn must be less than 256 characters.
Test groups and files	
READ FILE	Returns the Test File number used for the measurement (1-10).
READ GROUP	Returns the Group File name used for the measurement (1-10).
SET FILE nn	Sets the test file number used for the measurement. nn is the file number (1-10).

Table 2-9: Remote Control Commands and Responses

Command	Response
SET GROUP nn	Sets the Group file used for the measurement. nn is the group name. Length of the group name should be less than 256 characters.
READ DESCRIPTION	Returns the Test file description used for the measurement
READ SOURCE	Returns the source wavelength used for the measurement: 1310 nm, 1550 nm, White Light, A.S.E.
READ COHERENCE	Returns the coherence of the source used for the measurement (e.g., 0.06)
READ PROCESS	Returns the process type use for results calculations: Deterministic, Random.
READ PSEC WARNING	Returns the random process psec limit. If the test file is set to deterministic process type, ERROR is returned.
READ PSECKM WARNING	Returns the random process psec/km ^{-1/2} limit. If the test file is set to deterministic process type, ERROR is returned.
READ RANGE	Returns the initial display range used for the measurement.
READ THRESHOLD	Deterministic process report threshold Returns the deterministic process report threshold. If the test file is set to random process type ERROR is returned.
Setup information	
READ RUNS	Returns the number of runs in a run repeat sequence (1-999).
READ REPEATS	Returns the number of repeats within a run repeat sequence (1-99).
READ DELAY RUNS	Returns the delay between runs in minutes (0-59).
READ DELAY REPEATS	Returns the delay between repeats in minutes (0-59).
READ BASE FILENAME	Returns the base filename (255 characters maximum).
READ AUTOSAVENO	Returns the autosave flag (0=No, 1=Yes).
READ LOGO	Returns the logo used in the first line of a report (255 characters max.).
READ FINAL SUMMARY	Returns the printout final summary flag (0=No, 1=Yes).
READ GRAPH REPORT	Returns the printout graph summary flag (0-No, 1=Yes).
READ AUTOSAVE	Returns the autosave reports flag (0=No, 1=Yes).
READ MEASUREPOWER	Returns the flag which dictates whether the power bar should be displayed during a measurement (0=No, 1=Yes).
SET RUNS nn	Sets the number of runs use for a run - repeat averaging sequence. nn is the number of runs (1-999).

Table 2-9: Remote Control Commands and Responses

Command	Response
SET REPEATS nn	Sets the number of repeats used for a run - repeat averaging sequence. nn is the number of repeats (1-99).
SET DELAY RUNS nn	Sets the delay between runs in minutes. nn is the delay (0-59).
SET DELAY REPEATS nn	Sets the delay between repeats in minutes. nn is the delay (0-59).
SET BASE FILENAME nn	Sets the base filename for results storage. Nn is the base filename (255 characters maximum).
SET AUTOSAVENO nn	Sets the postfix number, which is appended to the base filename to construct the filename for data storage. nn is the number (1=50000).
SET LOGO nn	Sets the logo that is displayed as the first line of a report. nn is the logo (255 characters maximum).
SET FINAL SUMMARY nn	Sets a flag to indicate whether to print a final summary report at the end of a run repeat sequence. nn is the flag (0 = No, 1=Yes).
SET GRAPH REPORT nn	Sets a flag to indicate whether to print a graph report after each run. nn is the flag (0=No, 1=Yes).
SET AUTOSAVE	Sets a flag to indicate whether to automatically save report after each run. nn is the flag (0=No, 1=Yes).
SET MEASUREPOWER	Sets a flag to indicate whether to display the power bar before taking a measurement (0=No, 1=Yes).
Measurements	
STATUS	The STATUS command indicates current run information: 0 = Instrument is ready but no results not available e.g. File New menu was used 1 = Measurement started 2 = Measurement finished without error 3 = Results loaded from disk e.g. File Open menu was used. 4 = Run Aborted or some error occurred
MEASURE	The Measure command initiates a sequence of runs and repeats according to the current test file and setup conditions. OK is returned when the command is accepted. FINISHED is returned when the sequence of runs and repeats has finished. ABORTED is returned if the sequence of runs and repeats is terminated early by the user pressing the F10 button, or if an error occurs during PMD calculations.
MEASURE POWER	Power measured in dB

Table 2-9: Remote Control Commands and Responses

Command	Response
READ PLOTDATA	Returns Psec vs. intensity data or ERROR The command creates a temporary file "RS232DATA.TXT" in the PMD installation directory which contains the data as a large number of comma delimited strings with carriage return line feed terminators e.g. -140.00000, 0.000000 crlf. Up to 40000 of these strings are present, which takes several minutes to transfer via RS232. Abort stops transfer.
READ CALCDATA	Returns noise corrected psec vs. intensity data or ERROR. The command creates a temporary file "RS232DATA.TXT" in the PMD installation director which contains the data as a large number of comma delimited strings with carriage return line feed terminators e.g. -140.00000, 0.000000 crlf. All intensity values falling below the noise level are set to zero. Up to 40000 of these strings are present, which takes several minutes to transfer via RS232. Abort stops transfer.
READ GAUSDATA	Returns the random process Gaussian fit psec vs. intensity data or ERROR. The command creates a temporary file "RS232DATA.TXT" in the PMD installation director which contains the data as a large number of comma delimited strings with carriage return line feed terminators e.g. -140.00000, 0.000000 crlf. Up to 40000 of these strings are present, which takes several minutes to transfer via RS232. Abort stops transfer.
Other Commands	
RUN nnn	This command runs an external program called nn.

2.8 Typical Measurement Sequence

1. Switch on the system. (See “Start Up” on page 10.) The following is displayed on the computer screen.

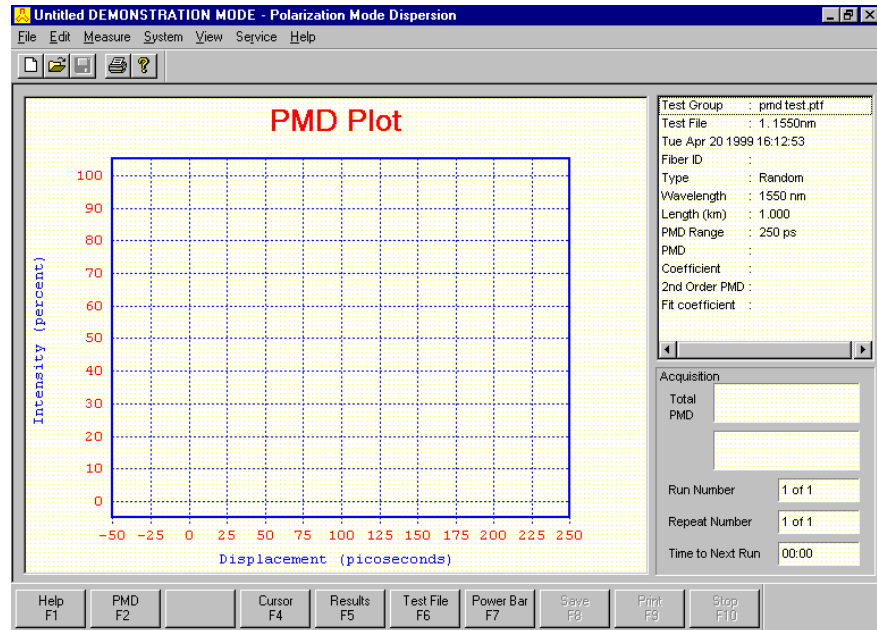


Figure 2-1: PMD440 Main Screen

- From the Edit menu, select Test Files.

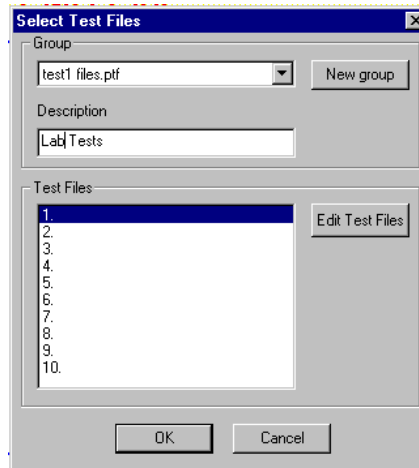


Figure 2-2: Test Files Dialog Box

- Select a prepared test file *or* click “EDIT TEST FILE” to define new test parameters.
- To change the measurement parameters, click “PMD method.”
- Select the correct light source to be used with the PMD system to automatically select the correct source coherence time:
 - Select “Random” for fiber measurements
 - Select “Deterministic” for hibi fibers or for some calibration artifacts.
- Choose the PMD range to be displayed.

NOTE

The PMD440 always measures over the whole scan range to ensure a true result. PMD range affects only the screen display—measurement is made over the full range. Selecting a smaller display range is particularly useful when measuring low PMDs. Warning limits enable the software to flash a PASS/FAIL message if the measurement exceeds these limits (e.g., 40 ps for an OC48 system). To disable the function, set to 1000.

- Click “OK” when finished.

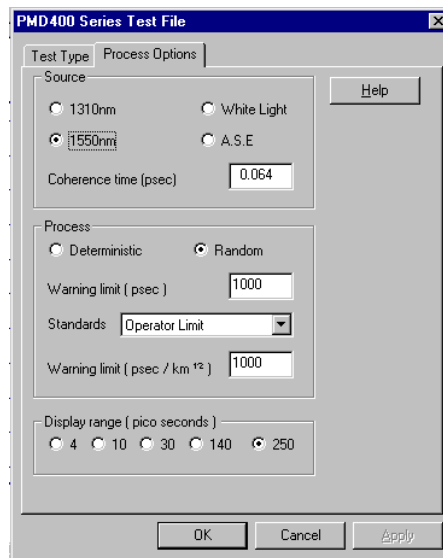


Figure 2-3: Test File Parameters

- Click “EDIT, Setup PMD.” Fiber Data entry allows you to manually enter fiber details before each entry. The Setup PMD box displays. (See Figure 2-4: PMD Setup Details.)

Multiple measurements—up to 99 repeats of 999 measurement runs—may be made. To make a single measurement, set both “Runs to average per repeat” and “Number of Repeats” to 1.

Set “Autosave” to ensure that the computer saves measured data. The base filename can be set by the associated button on the right as well as the start number, which is incremented by one for each measurement. The “Print results” button allows for automatic printing after a measurement, but must be enabled only if a printer is connected.

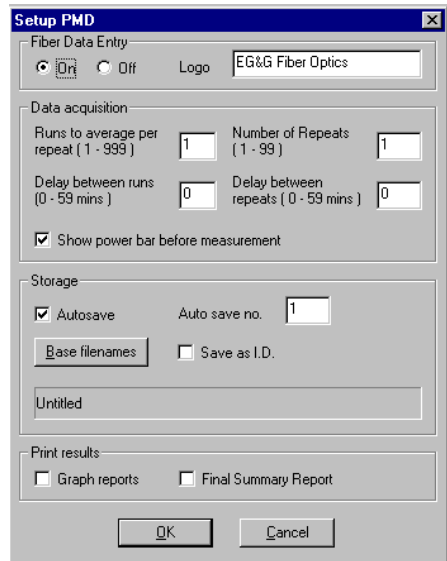


Figure 2-4: PMD Setup Details

9. Perform measurement.
 - a. Select the PMD key. A fiber details box appears. The next box shows a power bar to check that the fiber has been correctly connected.
 - b. Click “OK” when the fiber has been correctly connected. A measurement is made, and the result displayed.

Measurement progress is indicated by a moving bar graph display at the bottom of the screen. As part of the auto ranging function, more than one measurement scan can be made.

The example shown in Figure 2-5: Test Display shows a measurement of a fiber with a total PMD of 9.287 ps. Also shown is the value per root km. A red curve superimposed over the measurement data is a Gaussian curve with the same PMD value as the measured data. It can be used *subjectively to see how “random” the measured data is. The “fit” value can be used similarly: the closer to a unity value, the more random the data.*

10. If “Runs” and “Repeats” have been set up, the multiple measurements are made but only the last measurement is displayed. Use the “View” menu at the top of the screen to display a summary of all the measurements.

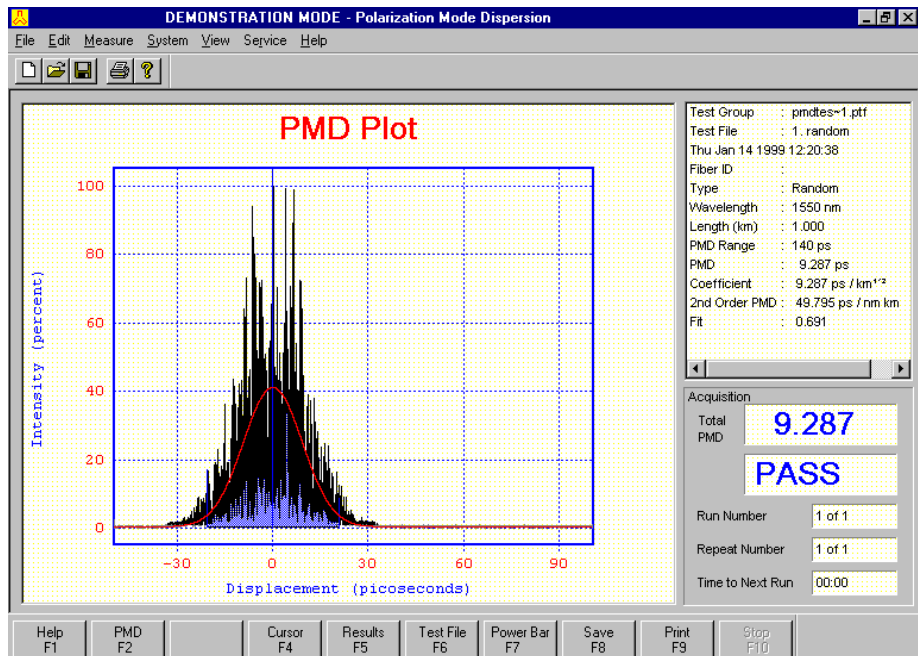


Figure 2-5: Test Display

2.9 PMD File Format

Test results are normally stored in a delimited text file for import into a spreadsheet. It is possible on the "File" menu to select storage as a normal text file if the data is to be imported into a word processor. A typical file is as follows:

```
" GN Nettekst Fiber Optics"
" Polarization Mode Dispersion"
" TestTime   : Thu Jul 09 1998 10:04:13"
" Test File  : 2. 1300nm 50 ps"
" Test Group : 1.ptf"
" System ID  : GN Nettekst Fiber Optics PMD440 #1"
" Fiber Length : 2.700 (km)"
" Fiber ID   : a5"
" Message    : 1300nm"
" Report File : A:\a5.txt"
" Process    : Random"
" Wavelength : 1310 nm"
" PMD Range  : 4 ps"
" Auto Save  : Off - Data not saved"
" Run ", " Repeat ", " PMD ", " PMD per ", " PMD 2nd ", " Fit ", " Average ", "
Avg PMD ", " Avg. 2nd ", " Acquisition "
" No ", " No ", " ", " root km ", " Order ", " ", " PMD ", " /root km
", " Order PMD ", "
1, 1, 1.148, 0.698, 0.282, 0.820, 1.148, 0.698, 0.282, "
Thu Jul 09 1998 10:04:13 "
```

Imported into a spreadsheet as comma-delimited data with a “qualifier, the result is:

GN Nettest Fiber Optics								
Polarization Mode Dispersion								
TestTime : Thu Jul 09 1998 10:04:13								
Test File : 2. 1300nm 50 ps								
Test Group : 1.ptf								
System ID : GN Nettest Fiber Optics PMD440 #1								
Fiber Length : 2.700 (km)								
Fiber ID : a5								
Message : 1300nm								
Report File : A:\a5.txt								
Process : Random								
Wavelength : 1310 nm								
PMD Range : 4 ps								
Auto Save : Off - Data not saved								
Run	Repeat	PMD	PMD per	PMD 2nd	Fit	Average	Avg PMD	Avg. 2nd
No	No		root km	Order		PMD	/root km	Order PMD
1	1	1.148	0.698	0.282	0.82	1.148	0.698	0.282

Acquisition
Thu Jul 09 1998 10:04:13

If repeated measurements have been selected there are multiple rows of results.



3.0 Warranty and Repair

3.1 Warranty Information

GN Nettetst products, including all mechanical, electronic, and optical parts and assemblies, are unconditionally warranted to be free of defects for one year from the date of delivery.

This warranty does not apply to any instrument or component that has been subjected to misuse or alteration. It is the customer's responsibility to understand all instructions and specifications prior to operating this instrument. The warranty does not extend to any collateral damage consequent to failure of the warranted product.

3.2 Service and Repair

GN Nettetst engineers, inspects, and tests the products it manufactures to ensure reliable performance. Direct telephone technical assistance and factory service are available.

If your problem cannot be successfully addressed through phone assistance, Customer Service will provide a Return Material Authorization (RMA) for you to use when returning a device to GN Nettetst.

All products must be returned to GN Nettetst by prepaid freight. Products under warranty will be returned prepaid upon repair. GN Nettetst is not responsible for returned products that do not reference the GN Nettetst RMA number on the customer's shipping paperwork.

3.2.1 In-Warranty Repair

Often technical support staff can help you to correct a problem, and repairs can be made on-site without violating your warranty.

Call us! USA 1-800-443-6154

 International 1-315-797-4449

Always call GN Nettetst before returning any equipment or if you have a question regarding warranty or return policies or status.

3.2.2 Out-of-Warranty Repair

Repairs are available for out-of-warranty units. Such service is billable for time and material.



Appendix A: PMD Overview

What is PMD?

Polarization Mode Dispersion (PMD) is an effect caused by a single mode optical fiber supporting two forms of light, each having a separate polarization state. Silica, the major constituent of optical fibers, exhibits a property called *birefringence*. Birefringence causes these two polarization states described above to travel at slightly different velocities.

Imagine a pulse of light travelling in the fiber. This will be split into two pulses, each of a different polarization state. As they move down the fiber they travel at slightly different velocities, as determined by the fiber birefringence. At the far end of the fiber, this velocity difference will cause the two pulses to arrive at slightly different times. A sharp pulse at one end of the fiber will therefore be gradually spread out by the time it reaches the far end. This pulse broadening is known as *dispersion*.

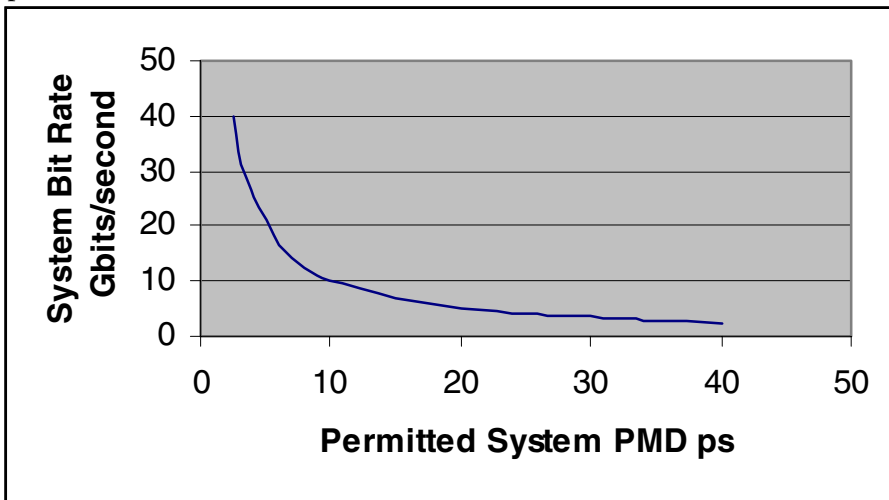
A digital signal consists of a rapid stream of pulses. If excessive dispersion causes one pulse to run into the next (intersymbol interference), system electronics has difficulty separating them, and bit error rate increases. This increase in bit error rate is the major effect of PMD.

One thing separates out PMD from other fiber characteristics. The fiber birefringence is affected by stresses on the fiber caused by the cabling process, the installation environment and temperature fluctuations. *PMD therefore changes with time, cable design and location*. Measurements are only repeatable to within 10 to 15 percent and are given as average values in picoseconds per square root of the length (normally in km).

PMD Limits For Digital Systems

The usual guide for PMD is for the dispersion to be less than one tenth (10 percent) of the time between adjacent pulses in the digital system (the bit period). Theoretically, PMD in excess of 10 percent of the bit period may cause the transmission system to exceed its designed error rate. Some systems work with PMD levels considerably higher than this limit. The overall system error rate will depend on system noise, chromatic dispersion,

and the actual performance of electronics rather than the target specification for PMD.



PMD Limits for Common Systems

System Type	Bit Rate (Gbits/sec.)	PMD Limit (ps)
OC-48 SDH16	2.5	40
OC-192 SDH64	10	10
OC-768 SDH256	40	2.5

Practically speaking, you need to be aware of PMD, and you *may* have problems, when installing OC-48. For OC-192, PMD limits the fibers that can be used. Studies on PMD and OC-768 systems are ongoing.



Who Needs To Measure PMD?

Anyone who is installing or using digital systems of 2.5Gbits/second (OC-48) or above should measure PMD. At present, this tends to be for links between towns and cities, but metropolitan routes will operate at these rates as the demand for bandwidth increases.

Recently manufactured cables have PMD levels of 0.5 ps/ $\sqrt{\text{km}}$ or less. (0.2 ps is becoming an accepted limit.) At the lower limit of 0.2 ps an amplified cable can be 2500 km long before the 10ps OC-192 limit is reached ($0.2 \times \sqrt{2500} = 0.2 \times 50 = 10\text{ps}$ total). As long as cables meet these limits, PMD should not be a problem. Older, installed cables often contains fiber with very high PMD that pose an obstacle to expanding the use of the installed network.

Fibers have been found, in all parts of the world, with PMD values in the range of 6 to 40ps over 100KM or less of cable. Many of these fibers will not support OC-48 or OC-192 systems or will give high error rates under certain circumstances. Suspect fibers may be discovered by measurement using the PMD440 or by system failure.

System providers must specify a PMD operating limit for their systems, and it is in their interest to be able to make field measurements in case of disputes with customers. If a system is not performing correctly, the source of the problem has to be located.

What Can You Do About PMD?

It is important to check out your network for cable loss, reflections, chromatic dispersion, and PMD. Measuring these factors enables you to estimate the maximum bit rates that may be used. If maximum bit rates are too low to accommodate traffic forecasts, there are three options:

- Use regenerators to re-time the signal and eliminate problems resulting from PMD and Chromatic Dispersion. This option is expensive and works at one bit rate only.

Appendix A: PMD Overview

- Use wavelength division multiplexing. Instead of one OC-192 system, operate four channels at OC-48 to get 10Gbits/sec. Again, this is costly but your system can be upgraded to more channels in the future.
- Install a new cable. This will ensure you have the right transmission medium for your system. This may be the most costly option of all.

Appendix B: First and Second Order PMD

First Order PMD

In standard telecommunications single mode fiber, two orthogonally polarized modes are supported by the waveguide structure. The two polarized modes travel with different *phase* velocities (giving rise to birefringence) and also different *group* velocities (giving rise to mode dispersion, often called “polarization mode dispersion” or “PMD”).

The intrinsic birefringence is often as a result of core ovality or ellipticity, or from asymmetric thermal stresses frozen-in to the fiber. In standard single-mode telecommunications fiber, the intrinsic birefringence is generally quite low. Thus the two modes are so closely matched in their respective phase and group velocities that external effects, acting on the refractive indices of the glass which makes up the waveguide structure strongly couple the modes together. It is the random mode coupling connected with the intrinsic birefringence that gives PMD in fibers its unique properties.

Conversely, in high-birefringence or Polarization-Maintaining fibers (PMF), birefringence is deliberately made high in order that the external effects are swamped, so that a polarization-maintenance function is achieved. In this case, the intrinsic birefringence leads to two distinct output pulses of light – one corresponding to the “slow” mode and the other to the “fast” mode. This kind of fiber can be used to produce calibration artefacts to check the repeatability of PMD measurement systems. The total birefringence is proportional to the length of fiber measured and has a single value. If measured on the PMD440 the deterministic option should be selected in the “PMD Method” screen.

In a normal fiber, where birefringence is low, intrinsic effects are of a similar magnitude to the external effects (extrinsic effects), which act as a random set of disturbances to the fiber, each of which is capable of causing significant mode-coupling between the orthogonal modes of the fiber. The mode coupling will depend on the strength and spatial position/orientation of the external effect(s) relative to the intrinsic birefringence of the fiber.

These effects are temperature, bending, twist, side pressure, etc., which occur naturally in most installed fiber cables, in an uncontrolled and generally random manner.

Since mode coupling is an almost random phenomenon, the apparent group velocity differences between the modes are 'smeared' resulting in a random distribution of light pulse arrival times. Alternatively the light can be considered as packets that have travelled in random proportions of total travel time in each of the two modes (coupling across from one to the other at a random set of disturbances). Packets will spend time more time, or less time, in each mode, but with some variation in proportions. Individual packets will arrive sooner or later than the mean arrival time of all the packets. PMD is a measure of this mean value but it will vary instantaneously in value.

The strength of the mode coupling has a significant effect on the width of any pulses sent down the fiber and hence the bandwidth of the transmission medium. Weak coupling would act only slightly upon the intrinsic birefringence of the fiber, so the output pulse width could be quite wide- almost equal to the intrinsic PMD. Conversely, strong mode coupling can act strongly upon the intrinsic birefringence, mix the fast and slow modes and so reduce the pulse width. That is, strong mode coupling gives low PMD. In this case there is almost the same propagation delay for all input polarizations and no “memory” of what that input polarization state was in the output light. Mode coupling is an extremely important component in the development and understanding of PMD in fibers.

The random mode coupling in a fiber has the effect of creating new orthogonal states (referred to as Principal States of Polarization [“PSPs”]) or “Eigenmodes”), which no longer bear any relation to the original (intrinsic) modes of the fiber waveguide. The differential group delay (DGD) between these two states is the instantaneous PMD. Polarization dispersion is defined as the RMS DGD between orthogonally polarized light paths in the fiber over a given averaging regime.

Since the modes are continually randomly coupled together, the PMD builds up along the fiber with a square-root length dependence. Thus

PMD is measured in units of ps/ $\sqrt{\text{km}}$. Generally, the effect of PMD is small compared to chromatic dispersion (CD), except when operating near the dispersion zero. The network systems which operate near this dispersion zero include high bit-rate submarine or long haul systems, especially those using optical amplifiers. It is in these systems and also analogue (CATV) transmission that PMD plays a significant role. PMD can be related from fiber to cable, but only in cases where production and design are stable, well-controlled and where a large sample of measurements has been taken to build up a “mapping function” from fiber to cable. Even then, statistical uncertainty limits must be given.

To summarize:

- PMD stands for Polarization Mode Dispersion
- PMD limits fiber bandwidth
- PMD can be affected strongly by external “mode coupling” influences such as bending or twisting.
- PMD is a randomly varying quantity in fibers
- PMD is quantified on a statistical basis; therefore actual PMD at a given moment in time can vary above or below the nominal value determined from a measurement.

Second Order PMD

First order PMD represents a primary bandwidth limitation in fiber transmission. This is now part and parcel of link power/bandwidth budgeting. However, the variation of the DGD between PSPs as wavelength varies can also cause bandwidth limitation, in the form of “second order PMD”, called PMD2 for short. Here’s how:

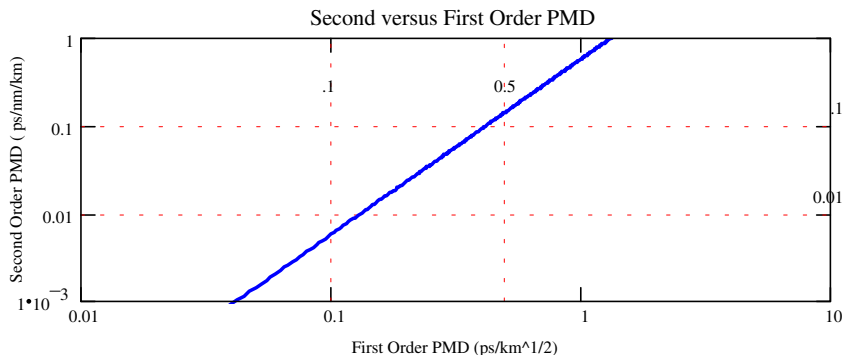
If a laser that has variable frequencies (or is modulated and/or has chirp) is used, DGD, which varies rapidly with wavelength, will similarly be modulated and will create the appearance of a form of chromatic dispersion. Hence, the variation of DGD with wavelength (as well as the DGD level itself) is important. It is possible to show that the PMD2 builds

up linearly with length in a long strongly coupled fiber. Thus PMD2 has units of ps/nm/km, just like CD. PMD2 has a mean value of zero, but remember again that this is a statistical parameter, with again no memory of the input state of polarization. The instantaneous value of PMD2 may be positive or negative. Therefore for system CD budgeting, the maximum *numerical* total CD plus PMD2 must be taken as the design parameter.

It is possible to relate PMD2 directly to first order PMD. *For a long-length fiber with strong mode coupling*, a very simple relationship pertains between the RMS PMD2 and RMS PMD:

$$\text{Second Order PMD (in ps/nm/km)} = \frac{\{\text{First Order PMD (in ps}/\sqrt{\text{km}}\})}{\sqrt{3}}$$

RMS PMD2 and RMS PMD relationship in a log-log format



The current fiber specification level (0.5 ps/ $\sqrt{\text{km}}$) is marked and such a fiber has ~0.1 ps/nm/km additional chromatic dispersion. While for state-of-the-art fibers of 0.1 ps/ $\sqrt{\text{km}}$, the additional chromatic dispersion is less than 0.01 ps/nm/km.

Thus a fiber with 1 ps/ $\sqrt{\text{km}}$ PMD (RMS) will have 0.7 ps/nm/km PMD2 (RMS). This PMD2 adds directly to the fiber’s normal chromatic dispersion.

Second Order PMD (PMD2) is a natural consequence of PMD in a fiber. The value of PMD2 is statistically variant, like PMD, and is governed by a

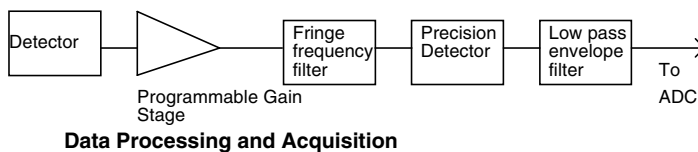
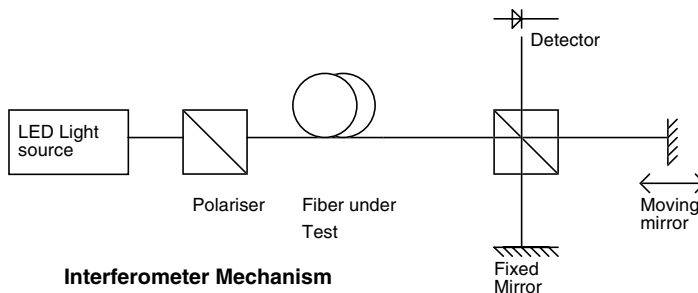


distribution. There is a simple relationship between PMD and PMD2, which may be used for strongly mode-coupled fibers. The working “safety factor” for PMD2 is typically five. PMD2 is only likely to be a problem in high-PMD fibers.

Interferometric Technique

The interferometric technique, which uses a polarized light source and an interferometer as the receiver, has been accepted for PMD measurement by the TIA and ITU. This method is described in TIA FOTP 124.

The test fiber is excited by a linearly polarized light source typically comprising a 1310nm or 1550nm LED plus a polarizer effective over the operating wavelength region. The polarizer has a typical extinction ratio of over 30dB to meet the TIA recommendations of >20dB. In addition the source spectral shapes are approximately Gaussian to ensure a smooth auto correlation function that can be subtracted from the measured fiber result. The spectral width of these sources directly affects the minimum PMD measurable. Typically values of 0.065ps are achievable at 1550nm and slightly less at 1310nm. This will result in a minimum accurate PMD measurement of 0.1 to 0.15ps. The maximum PMD range is defined by the FOTP as one third of the maximum delay measured. For the 250ps range of the PMD440 this would give a maximum PMD of 83ps. In practice, measurements up to 100ps can be made with only small errors.



The receiver consists of a Michelson interferometer. This is implemented mainly in fiber but the variable optical path is accomplished in air by moving a mirror over a range of approximately 55mm. As the mirror is moved fringes of varying amplitude will be seen by the detector diode. The envelope of these detected fringes is utilized to provide PMD information. When the two arms of the interferometer are of equal length the amplitude of the interference fringes will reach a maximum. This central autocorrelation peak is used to determine the zero time delay position for the interferometer.

Where PMD exists in the fiber connecting the light source to the interferometer this additional delay will cause the interferogram to be broadened in proportion. In the case of a highly mode coupled fiber excited by a single state of polarization a quasi-Gaussian distribution of time delays will be produced and the PMD will be equal to the second moment of this distribution.

The pulse broadening may also be normalized for fiber length that is entered manually at the start of the measurement by the user. In fact, because of the strong mode coupling that normally dominates the intrinsic effects, the length dependence is not linear but generally increases in proportion to the square root of fiber length. Thus PMD is quoted in $\text{ps}/\text{km}^{1/2}$.

For a simple birefringent artifact, such as hi-bi fiber, two responses will be produced, one on either side of the central autocorrelation peak. The time delay between the central peak and either of these responses will give the delay of the artefact. The PMD for such devices is proportional to length, not the square root of length as for a highly mode coupled fiber.

Appendix C: PMD440 Remote Control

Symantec pcANYWHERE is a communications software package designed to allow remote control of one PC from another, and includes the ability to transfer disk files to and from the PCs.

The PC running the PMD440 software runs the pcANYWHERE program and is configured as a host computer. Once configured, it may be accessed by a remote PC also running pcANYWHERE. The PMD440 series software runs on the host PC but all screen views, mouse and keyboard operations are reflected onto the remote PC, allowing the remote operator to control the PMD440 using the remote keyboard and mouse.

Connecting a host and remote PC

The host and remote PCs may be physically connected by a number of cable connection options:

- For short spans, direct parallel port and serial port connections are best.
- For longer spans, modem - phone lines and networks are used.

When controlling the PMD440 over distances greater than a few meters, it is recommended that either a network or modem-phone line connection is used.

A network connection requires that both the PMD440 host and the remote PC are connected to a network. This installation will require a network card and appropriate network support software to be installed in both PCs. TCP/IP, Netware IPX/SPX, NetBios, Banyan Vines, ISDN, and Netware Connect (NASI) connections are supported.

A modem connection requires a modem to be configured on each PC. A recommended option is to utilize an external modem on the PMD440 host PC, connecting it to the serial port. This provides a robust physical connection for reliable operation.

The pcANYWHERE software recognizes the hardware options available on the PC and provides “connection wizards” for setting up and configuring the connection.

Main Remote Functions

When pcANYWHERE is run, a main window is displayed showing the following buttons, six of which correspond to pcANYWHERE's primary functions:

Quick Start. Displays a wizard for each of the primary functions. The wizard is an executable file that automatically prompts you for information necessary to accomplish the related task. The button configures "Be a Host PC," "Remote Control," "File Transfer," "Be A Gateway," and "Call On line service" options.

Be a host PC. Creates a list of one or more host connection items, establishing the computer as a host to be accessed by a remote PC. Each connection item configures a communications protocol that will be used for the connection between the host and remote PC. This includes modem selection and phone numbers selection etc.

Remote Control. Creates and manages a list of one or more remote sessions allowing a host to be selected and controlled from the PC. Once selected, the host PC screen appears as a window or full size on the remote, and the remote keyboard and mouse may be used to control the host PC. Files may be transferred between the PCs in this mode of operation.

File Transfer. Establishes a connection with a host and displays a file manager showing directories on the host and remote PC. Files may be selected and transferred between PCs.

Be a Gateway. Establishes a PC as a gateway on the network, allowing its communication device to be shared by the PCs on the network. It allows remote users to access a pcANYWHERE host on the network via the gateway modem.

Remote networking. Establishes the PC as a remote node on a network with access to network files and directories, as if it was connected to the network directly. Performance is restricted by the relatively slow speed of telephone lines compared with direct local area network connections however.

Call On-line service. Connects to bulletin board and other external information services.

Configurable options

In addition to the six main functions, pcANYWHERE provides a number of utilities that simplify or automate the remote control and file transfer processes:

- The PMD 400 series PC may be configured to power up into the host mode.
- The host PC screen may be blanked to improve security.
- The host keyboard and mouse may be locked to improve security.
- Password protection may be used to prevent unauthorized use from canceling a waiting host.
- Remote users may be established with access privileges including ability to blanking the host screen, canceling the host, uploading files, downloading files, and specifying hard drive access.
- The host PC may be restarted under command from the remote.
- Messages may be passed between the host and remote in a “chat mode.”
- Files may be automatically transferred to and from the host, or synchronized on both the host and remote. A user defined AutoXfer procedure controls this process. This may be executed automatically when the host and remote initially connect at the start of a session, or at any time on command from the remote.

System Requirements

- HARDWARE**
- Pentium 166 processor, 16 MB ram or higher, SVGA or higher resolution display adapter, hard disk drive, CD ROM drive, 20MB free hard disk space.

Appendix C: PMD440 Remote Control

- To optimize screen displays, it is recommended that windows is configured for a 256 color palette in the control panel display configuration item using 800 x 600 screen resolution.

SOFTWARE

- Windows 95, and Symantec pcANYWHERE 32 version 8.0
- The software license permits pcANYWHERE to be installed on two PCs, one to be used as a host, the other to be used as a remote.

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