RFOptic
Optical RF Solutions

RFOptic ODL Operating Manual

Progressive Optical Delay Line System

Part Numbers of the form: ODL-xxGHz-Sddd

Table of Contents

Chapter Page

1 INTRODUCTION 3

1.1 OVERVIEW 3

1.2 ODL BLOCK DIAGRAM 4

2 UNPACKING & INSPECTION 5

2.1 LASER SAFETY CONSIDERATIONS 6

3 ODL SYSTEM OPERATION 6

3.1 FRONT PANEL – CONNECTIONS, CONTROLS, INDICATORS 7

3.2 REAR PANEL – CONNECTIONS, CONTROLS, INDICATORS 8

3.3 INITIAL SETUP AND OPERATION 8

3.4 ODL FRONT PANEL CONTROL 9

3.4.1 Navigating and changing values 9

3.4.2 Display screens and values 9

3.5 ODL COMPUTER USB CONTROL 12

3.6 ODL COMPUTER USB API 14

3.7 ODL ETHERNET CONTROL 14

4 WARRANTY 16

4.1 WARRANTY SERVICE 16

5 MAINTENANCE AND SERVICE 16

Table of Figures

Figure 1: Basic ODL block diagram 4

Figure 2: ODL Front panel connections, controls, indicators 7

Figure 3: ODL Rear panel connections, controls, indicators 8

Figure 4: Display - Operation Screen 9

Figure 5: Display - Setup screens with different delay formats 11

Figure 6: RFOptic Modules configuration tool - ODL screen 13

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1 Introduction

This ODL Operating manual contains a general description for RFOptic ODL Systems with part numbers of the form ODL-xxGHz-Sddd where xx designates the maximum operating frequency and ddd is a numeric specification identifier which defines the particular system and its options.

It is recommended to review the ODL System manual which includes the particular details and setup instructions of the ODL System.

Chapter 1 describes the ODL system and the theory of operation
Chapter 2 includes the unpacking instructions and safety considerations.
Chapter 3 covers the startup and operation of the system.
Chapter 4 covers the Maintenance and service**.**

1.1 Overview

The Optical Delay Line (ODL) provides true time delay of wideband RF signals using a low loss optical fiber. The Input RF signal is converted to an optical signal, delayed by one or more single-mode optical fiber sections and is converted back into RF signal at the output. From the perspective of the RF signal, the ODL looks like a long distance wideband RF link with minimum loss and distortion. In its simplest form the ODL system has only one fixed delay section which is always engaged. A progressive ODL has an optical switching arrangement that is capable of cascading a number of fiber section to deliver a range of discrete delays.

RFOptic ODL's can be configured with many features and delay sections which are available in certain models. Such features include Bandwidth up to 40GHz. multiple delay segments, Pre- and Post- RF Amplification, AGC for constant gain, RF Bypass, Digital attenuators and much more. Since the Optical fibers are thin, lightweight and have very low intrinsic losses it is possible to achieve significant time delays ranging from 1ns to over 1ms in a relatively small volume. A common rule of thumb is that each 1km of fiber adds a delay of about 5us. The fiber delay is constant with a minor temperature dependence. The accuracy of the basic delay states can be specified at the time of order. The ODL system includes an interface that allows a selection of the

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time delays from the range of combinations that are available. This range includes 2^n delay states if the n-delay segments are non-degenerate (do not have identical delay values). The system performs the fiber segment switching and can be configured to provide appropriate gain adjustments automatically. This manual uses as an example a typical progressive ODL system with 8 basic delay sections. The particular system is defined in the ODL System manual which includes the system specification, specific connections and setup instructions and the factory performance verification (ATR).

1.2 ODL Block Diagram

The following ODL Block diagram shows the main components of the system and the connections between these components. The RF, Optical and control components are color coded for clarity as are the relevant interfaces. This diagram shows the direction of signal flow with arrows. As mentioned above, the block diagram represents a generic ODL system. Additional functional components may be added to this generic system architecture to meet special custom requirements of signal conditioning.

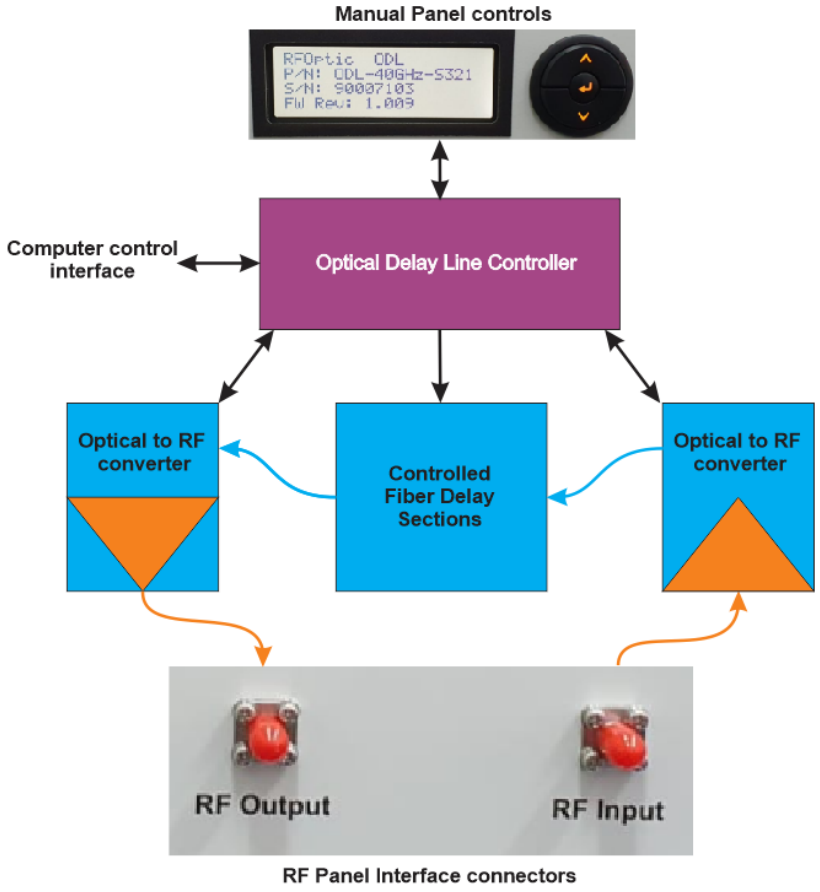


Figure 1: Basic ODL block diagram

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The flow of the signal is illustrated in Figure 1. Starting from the RF Input panel connector, the RF signal is connected to the RF to Optical converter module; the transmitter. This converter may include signal conditioning components to provide custom functionality as required for the input RF signal. The converter modulates the wideband RF signal onto a stable Laser generated optical carrier. The modulated signal is then fed into the Controlled Fiber Delay segments switch module. This module may include some additional Optical conditioning components as necessary to achieve the specified ODL performance. The controller configures the requisite fiber segments to achieve the time delay which can be specified using the front panel LCD display and navigation keypad, under a host computer control with RFOptic's USB GUI or via an Ethernet connection. The available control interfaces of a particular ODL system are defined in the System manual. In certain cases, the signal may be routed to external fiber segments which are housed in additional enclosure(s). Under computer control delay selection is made by specifying the delay state number which is an integer value from 0 to 2^n-1 (rather than the delay value). Once the Optical signal traversed the fiber delay it is delivered to an Optical to RF converter, the receiver, which demodulates the Optical signal and extracts the RF signal. This converter may include additional signal conditioning components to provide custom functionality as required for the output RF signal. Furthermore, a number of additional RF and optical routing and adjustment controls may be integrated to provide such additional function as RF bypass, Optical bypass, controlled attenuator and more.

2 Unpacking & Inspection

The ODL is shipped in a package or packages designed to provide maximum protection during shipping and absorb most of the mechanical shocks of transportation. If the shipping Box is damaged during shipping, notify your shipping department immediately, they may want to contact the carrier and or the local representative for instructions. We suggest that the shipping box(s) be saved for future transportation or storage needs.

After unpacking the ODL system, inspect the enclosure for damage which might have occurred during shipping. Inspect the input and output connectors and any auxiliary

parts that were included. Notify your procurement department immediately and the factory should any damage be observed and do not power up the system.

2.1 Laser Safety Considerations

This section is only relevant for ODL with external fiber segments and optical connectors.

The ODL includes one or more Class 2 Laser sources operating in an invisible infrared wavelength. The invisible light optical power is significant and can be hazardous if viewed directly by the eye. The optical power from the laser may cause retinal or coronal damage. Always observe the following precautions for safe use of the ODL:

I. Never look directly into the output fiber of an operating ODL from a distance closer than 50cm (20”) from your eye.
II. Never look directly into the output fiber of an operating ODL using optical instruments (i.e. a microscope or a magnifying glass).

Observe the Laser warning label attached to the enclosure.



Other safety practices

III. Make sure your power supply is grounded to avoid electrical shock.
IV. Do not use the ODL in a manner not specified by the manufacturer.
V. Use help from another individual and proper body mechanics to prevent injury when lifting and positioning the ODL enclosure(s) as some ODL enclosures with long fiber delay sections may be very heavy.
VI. Do not open the ODL enclosures. There are no serviceable parts inside the units. Warranty will be voided if units are opened other than by the manufacturer.

3 ODL System operation

This chapter describes the startup and operation and ODL system.
If the specific ODL system includes interfaces for external fiber delay sections, it is recommended to make all the fiber connections prior to activating the system so that all

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external optical ports are connected and / or covered. Before making any optical connection it is important to use appropriate special optical fiber cleaning tools to clean the fiber connection to avoid excessive interface losses. Please follow the connections diagram which is found in the System manual and corresponds to each particular ODL system configuration. Patch connection SMF fibers are included with the ODL.

Note that in some ODL systems the fiber interfaces may be damaged by the intense optical signal if the connections are dirty or Improperly made.

3.1 Front panel – connections, controls, indicators



Figure 2: ODL Front panel connections, controls, indicators

The front panel of the ODL features the following:

1. Power Switch and indicator
2. Backlit LCD Display
3. Backlit Navigation keypad
4. Input & Output RF Connectors
5. Left and right mounting brackets with handles

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3.2 Rear panel – connections, controls, indicators



Figure 3: ODL Rear panel connections, controls, indicators

The rear panel of the Optical Delay Line System features the following:

6. HP 220V/110V Power socket
7. AC Power Switch and indicator light
8. AC 220V/110V Fuse
9. Ground connection lug
10. Optional USB or Ethernet control interface connector
11. Optional FC/APC connector pairs for external fiber delay segments.

3.3 Initial setup and operation

a) Connect the ground lug (9) to an appropriate ground terminal.
b) If any external delay enclosures are part of the ODL system, please follow the setup instructions in the ODL System manual to make sure that such fibers are connected properly prior to turning the ODL on.
c) Plug a suitable power cable into the AC HP 220V/110V power socket (6) and plug the other end to a power source.
d) Turn on the AC power switch (3) and verify that the AC indicator (7) is lit indicating that AC power is available.
e) Connect the RF signal source to the RF input (4) of the ODL and connect the RF output of the ODL as needed using suitable RF coaxial cables appropriate for the ODL bandwidth. These connectors are normally SMA for ODLs with up to 20GHz bandwidth or 2.92mm for ODLs with bandwidths exceeding 20Ghz.

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f) Turn On the ODL using the On/Off button (1) and verify that the indicator is lit, and the display (2) shows the ODL part serial numbers for a few seconds before switching to display the operating screen.

g) Set the desired delay value which is selectable from the available delays in the particular ODL using the navigation ^ and v buttons.

3.4 ODL front panel control

In most ODL's a 3 button navigation keypad is used to control the ODL. This section describes front panel manual ODL control.

3.4.1 Navigating and changing values

The keys are illuminated and marked ^, v and ↵. The ^, v are used to increase and decrease respectively the value of the field that is currently selected. A cursor → in the display shows the current selected field. The → cursor can be moved to the next field using the ↵ center button.

A key combination is used to switch from screen to screen in the display. Press and hold the ↵ button and press the v button simultaneously to switch to other screens which allow access to special options if configured. To return to the operation main screen press and hold the ↵ button and press the ^ button simultaneously.

3.4.2 Display screens and values



Figure 4: Display - Operation Screen

3.4.2.1.1 Display operation screen top line

The ODL display (2) operation screen indicates on its first line the status of the ODL system and its internal temperature in degrees C. The internal temperature steady state indication can be used to assess ODL temperature dependent delay variation due to the optical fiber coefficient of thermal expansion (CTE). Typical CTE for the optical fibers that are used for ODL delay sections is 0.096ps/m °C. It should be noted that the

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temperature sensor is not directly in contact with the delay fibers therefore the measurement should be taken as a spot ambient temperature in the enclosure.

The ODL status indication can be one of the following:

a) Stabilizing – This status indicates that the ODL is stabilizing and calibrating itself and is not operating. This status should clear within a few seconds after the ODL is powered up.
b) Ready – This status indicates that the ODL is now operating.
c) Optical Signal Lost – This status message indicates that a delay section of optical fiber is disconnected or faulty. This message could appear when an ODL has external fiber delay sections that are missing or improperly connected.

Additional status messages which can only appear only under computer API control

d) Standby – This status indicates that the ODL has completed the stabilization and calibration procedure but is not operating.
e) Laser is off – This status message indicates that the ODL was programmatically turned off.

3.4.2.1.2 Display operation screen second line

The second line of the display shows the delay value in the selected unit which is normally µs. Fixed delay ODL's display a delay value which cannot be changed. For a progressive ODL, the delay value can be selected from the combinations of available custom delay segments when the ÷ cursor points to the Delay field using the navigation ^ and v buttons. The delay selection rolls back to the zero delay state after it reaches the maximum. Note that due to particular custom delay segments, the resulting delay values may not be monotonously increasing with increasing delay state.

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3.4.2.1.3 Display operation screen third and fourth lines

The third and Fourth lines of the display are dedicated to optional features which may not be configured in some ODL systems. These features include

- RF Bypass – option which provides the shortest possible path between the RF input and output ports. RF Bypass is implemented using an RF switch which can be turned On and Off using the navigation ^ and v buttons when the → cursor points to the RF Bypass field.
- RF Amplifier – option which provides additional RF gain used to improve the noise figure or compensate for excess losses. Such RF Amplifier can be turned On and Off using the navigation ^ and v buttons when the → cursor points to the RF Amp field.
- RF Digital Attenuator (DCA) – Option which provides control of the signal amplitude in the RF section of the ODL and is typically placed at the output. Various DCA;s are supported and the attenuation can be set within the range of the particular DCA that is configured using the navigation ^ and v buttons when the → cursor points to the Att field.

3.4.2.1.4 Display setup screen

From the Operation screen, Press and hold the ↵ button and press the v button simultaneously to reach the Setup screen. To return to the Operation screen Press and hold the ↵ button and press the ^ button simultaneously.

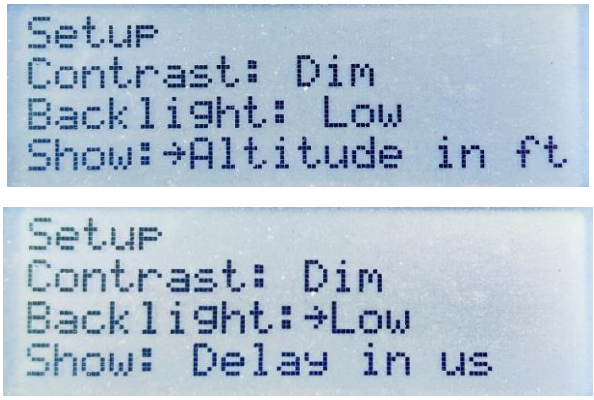


Figure 5: Display - Setup screens with different delay formats

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The second and third lines of the setup screen can be used to select the contrast of the display and specify the backlight settings. For each property there are 4 options ranging from minimal visibility and no backlight to high brightness and contrast for convenient viewing in all ambient light conditions.

3.4.2.1.5 Delay format and unit's setup

The forth line of the setup screen allows the selection of the display format of the delay value. This can be cycled between the following options:

a. Delay in µs or in ns
b. Full Distance in meters or feet (total two-way)
c. Range in meters or feet – (one-way, distance to a target)
d. Altitude in meters or feet – (one-way, distance to ground or an object)

Additional setup options may be displayed for special ODL configurations.

3.5 ODL computer USB control

Optionally the ODL can be controlled using a PC with a free interface program. The main display screen of this program is shown in Figure 6. The PC interface provides easy access to all the ODL functions and more. It can control multiple ODL's and RFOptic RFoF links with each assigned to a separate tab. This section describes the GUI and capabilities of this software tool.

Depending on frequency and requirements an ODL may occupy one or more tabs. In some cases, the ODL will be represented with a Transmitter tab, an ODL tab and a Receiver Tab.

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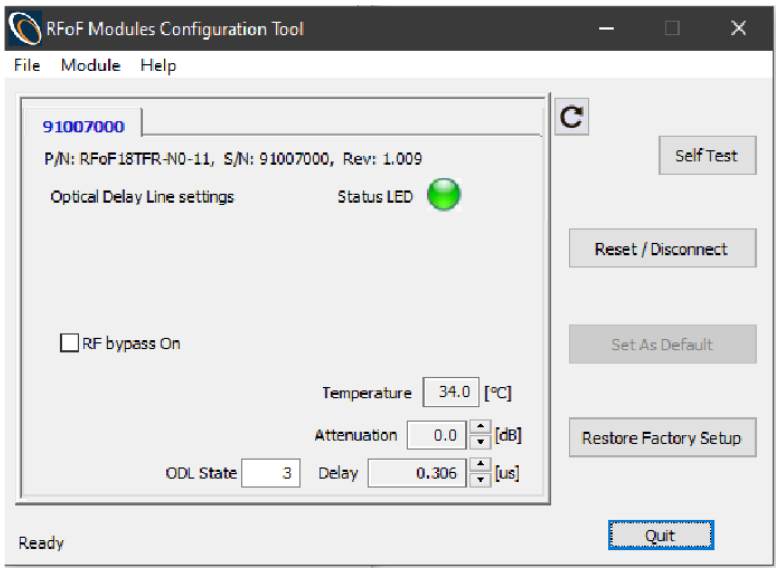


Figure 6: RFOptic Modules configuration tool - ODL screen

The RFoF Modules configuration tool; RFoFconfig.exe tool can be downloaded from RFOptic's website. It requires a PC with the Windows operating system and does not require special installation. The RFoFconfig.exe program can be placed anywhere on a local hard drive along with the associated help documentation file; RFoFconfig.chm. Operating from a Cloud or Dropbox path is not supported.

The tool interfaces to an RFOptic ODL over a USB connection. When an ODL is connected to the PC the RFoFconfig tool will display a tab headed by the serial number of the ODL. The tab heading displays the part number and firmware version of the ODL as well. The tab area displays all the options which are supported by the ODL and enables adjustment of each parameter. The Delay selection can be done from two fields. In the ODL State box ODL State 3 an integer numeric index of a delay state can be entered. Alternatively the Delay field Delay 0.306 [us] has standard Up and Down controls that step through the available delay values in the particular ODL. This delay selection rolls back to the zero delay state after it reaches the maximum.

The delay field may be represented in different formats as mentioned in section 3.4.2.1.5 above. The Units button cycles between the various optional formats.

Additional fields are displayed if the relevant options are configured in the ODL and can include Attenuator control, RF bypass as well as RF amplifier controls.

For complete description of the RFoFconfig tool please reference the Help documentation accessible from the Help -> Tool Help menu option.

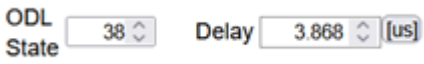
The RFoFconfig tool provides an option to define the initial startup state of the ODL and save Setup settings of the ODL display as the preferred default startup state. Note that these display parameters can only be adjusted from the ODL Setup screen and cannot be adjusted from the PC tool.

3.6 ODL computer USB API

Optionally the ODL may be controlled by customer program using the USB connection. The communication is based on standard 64bit USB packets and includes full access to all the ODL options and settings. An API documentation of this control mode is available upon request from RFOptic. This interface option requires substantial knowledge of the USB protocols as well as programming and is capable of providing automated control of the ODL System from any computer platform including Linux and Windows hosts.

3.7 ODL Ethernet control

Optionally the ODL can be controlled over an Ethernet connection. This interface option includes a web-server interface that is available from any web browser such as Chrome, Firefox, Internet Explorer and Brave/ Additionally the ODL system supports an REST with Web Socket interface as well as SNMP. Complete documentation of all these protocols and options is found in the Remote Management & Control Manual. The ODL component controls are shown in Figure 7. It is very similar to the controls of the RFoF HF module described above with the addition of ODL component controls. These controls are defined below focusing on the group of ODL controls:



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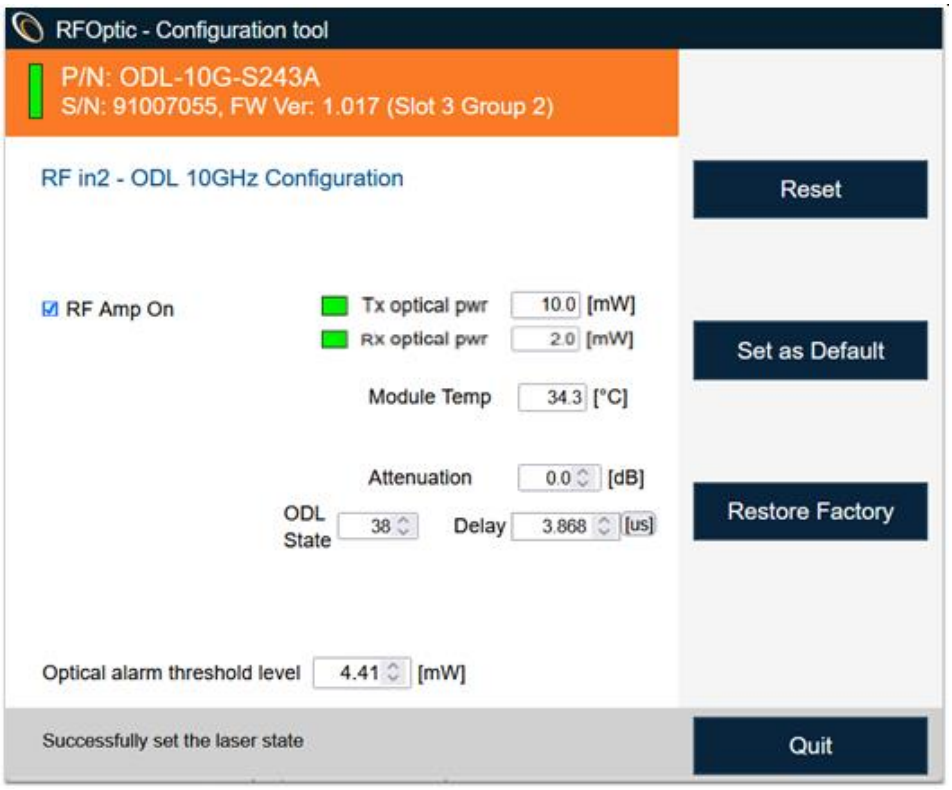


Figure 7: Configuration page for an ODL

- **ODL State** – A numerical state which is available for a progressive ODL. It controls the ODL stste as an integer number ranging from 0 to 2n-1 where n is the number of delay segments of the particular the ODL. At the the 0 state all the delay segments are taken out and the observed time delay of the ODL is minimal. Each incremental state introduces more delay segments and increases the overall ODL delay. The ODL state can be entered from the keyboard or clicking on the increment / decrement arrows. The ODL Delay field on the right in the selected units is updated after the M&C server updates the ODL state and computes the correct delay.

- **ODL Delay** – is another way to set the ODL delay value. Using the up and down arrow buttons it is possible to step up and down in the configuration of delay segments which are engaged. It is important to note that these delay steps (and their sequence) are unique and customized to each ODL. Therefore, in some cases the ODL delay steps will not be monotonous and will have discrete values depending on the custom primary delay segments.

- **ODL unit** – The ODL unit is a button that can switch the ODL Delay units between several predefined options which are suitable for particular applications. The units and delay format will cycle among the available options by clicking the ODL unit button repeatedly. These display formats include:
  - **Delay** measured in [**ns]** or [**us].**

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- **Distance** (free space / air) – is the equivalent of the time delay but expressed in **meters [m]** or **feet [ft]**.
- **Range** (free space / air) – is the one way distance to a target, where Distance is the round trip and can be expressed in **meters** or **feet**.
- **Altitude** (free space / air) – is similar to Range and is convenient for ODLs that are used in the Altimeter industry. Agin it is the one way distance to the ground in that case and can also be displayed in **meters** or **feet**.

4 Warranty

A one-year manufacturer warranty is provided from the date of purchase. Extended warranty may be procured.

Do not open the ODL enclosures! The manufacturer Warranty will be voided if enclosure(s) are opened other than by the manufacturer or with manufacturer written authorization.

4.1 Warranty Service

In case of ODL failure to meet its specifications within the warranty period, the buyer shall notify RFOptic with fourteen days of discovery of the failure and obtain a Return Material Authorization Number (RMA#) by sending a mail to service@rfoptic.com RMA# shall be provided only for goods which were fully paid by the buyer. In such case the buyer will return the goods to RFOptic in a proper Packaging, freight prepaid, and marked with the RMA#, and RFOptic will either repair or replace the failed unit, at its option.

5 Maintenance and Service

If the ODL system does AC power indicator (2) on the rear panel not turn on. Disconnect from the power cable from the outlet and check the fuse in the socket (3). Please report such fault to the RFOptic service department by sending an e-mail to service@RFOptic.com for determination of the cause. The fuse must be replaced by an identically rated part. Do not use fuses with higher rating as this may risk further damage to the ODL.

The ODL system is designed to be maintenance free. There are no user-serviceable parts inside the units. No further calibration is required to meet its accuracy specifications over the lifetime of the product (except for the calibration of the customer RF cables). If it is determined that factory service is necessary, please contact RFOptic service department by sending an e-mail to service@RFOptic.com.