

*Palomar Scientific Instruments*

# DPD-3W-05C/DPD-3W-06C 3-Wave FIR Demodulator

## **DPD-3W-05C & DPD-3W-06C User Manual**

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# Document Revisions

Date	Version Number	Document Changes
5/11/2014	0.90	Initial Draft.
5/14/2015	1.95	Combining 5Ch and 6Ch manuals.

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# 1 Overview

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The PSI-DPD-3W is a prototype digital phase demodulator for use on the Three-Wave Polarimeter-Interferometer Diagnostic at EAST. The system consists of a central unit that contains high-speed Analog-to-Digital Converters (ADC's), a large Field-Programmable Gate Array (FPGA), and Digital-to-Analog Converters (DAC's). The FPGA is configured to act as a custom Digital Signal Processor (DSP), and is used to demodulate the incoming signals.

The PSI-DPD-3W also includes a separate fiber-optically linked output module. This unit is intended to provide real-time density and faraday rotation measurements to a remote location for use in a plasma control system (PCS).

Unlike the first prototype, the PSI-DPD-3W is a stand-alone unit that does not require a computer to operate. As such it does not capture data to a PC. However, a PC can be connected via USB to change configuration settings such as output polarity and scaling. This is done using a simple command-line interface over a TCP connection using standard terminal emulation software (Telnet/PuTTY).

## 2 Hardware

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### 2.1 Contents

The DPD-3W is shipped with several important components, listed in Table 1 – DPD-3W Components.

Item #	Description	Quantity
1	Local 3-Wave FIR Demodulator (PSI-DPD-3W)	1
2	Real-Time Output Module (RTO)	1
3	Power adaptor, 12V	1
4	USB to USB-mini cable (UART)	1
5	USB to USB-micro cable (JTAG)	1

**Table 1 – DPD-3W Components**

## 2.2 Local 3-Wave FIR Demodulator (PSI-DPD-3W)



Figure 1 - DPD

This unit, known as the DPD from here on, serves as the main demodulator. The form factor is a 1U 19” rack-mountable unit, 13” deep. Rack-mount ears are removable for bench-top use.

## 2.3 Real-Time Output (RTO) Module



Figure 2 - Real-Time Output Module

This unit, known as the RTO Module from here on, serves as fiber receiver for the DPD. This unit is provided in case remote monitoring of the signals is needed. The RTO is not needed for normal operations with the DPD. The form factor is a 1U 19” rack-mountable unit, 8” deep. Rack-mount ears are removable for bench-top use.

## 2.4 Input Signals

The DPD unit has several inputs on the front panel including a digital Trigger (TRG). Depending on the model (05C or 06C), the analog signals are: Reference (REF), Ch1-5 or Ch6-11. The analog input signals are connected via SMA connectors, internally configured to be 50Ω single-ended inputs and have a maximum signal magnitude of:  $\pm 1$  V. Each analog input includes a Status LED with indicates the presence of a 0.850 MHz signal of sufficient amplitude ( $>200$ mVpp). The 0.875MHz signal was chosen in order to indicate the presence of the interferometer signal, which is critical for Plasma Control.

The digital TRG is 100-ohm input impedance and is LVTTTL compatible. The unit also includes a manual push-button trigger on the front panel.

## 2.5 Output Signals (Den, Rot)

The measured Interferometer and Faraday phases are output electrically on the front panel, labeled DEN and ROT respectively. The output signals are output via SMB connectors and are configured to be DC-coupled, 50Ω single-ended outputs. When a high impedance system is connected to the output, the maximum signal magnitude of the SMB connector is: ±10 V.

The analog outputs are produced using 16-bit DACs updated at 500kSamples/second. The DAC's are followed by a reconstruction filter band-limited to 250 kHz.

The relationship of output voltage to phase depends on programmable scalars. The base output range is ±10V corresponding to phase measurements of ±π. Therefore, on the base scale, an output of +10V corresponds to +π radians, or Scale = 10V/π radians. These values can be scaled to accommodate phases larger than ±π using programmable scalars described in the Section 2.7.

## 2.6 Phase Accumulators (Internal)

The DPD employs a quadrature demodulation technique which can produce phase measurements ranging to and from ±π with very high accuracy. When tracking large evolving phase shifts that typically occur in interferometry, this typically results in real-time measurements that “wrap” into the range ±π. The DPD prevents this wrapping using phase ‘accumulators’ that track each time the evolving phase crosses a ±π boundary.

Loss of signal will cause the accumulators to produce uncertain results or even overflow. Prior to plasma shot the accumulators should be reset to zero. This is done each time an external trigger is received.

## 2.7 Scalars

The base output range is ±10V corresponding to phase measurements of ±π. In order to accommodate interferometer phases greater than ±π, the outputs are scaled using a parameter called DS (density scale.) The output signal is divided by two raised to the power of DS. The following conversion may be useful:

$$\text{Interferometer phase (radians): } \phi_{INT} = V_{out} \times 2^{DS} \times \left( \frac{\pi \text{ rad}}{10 \text{ V}} \right)$$

**Equation 1**

The density scalar (DS) should be set appropriately in order that the output does not exceed the ±10V limit while also utilizing as much of the 16-bit digital word as possible. When delivered the unit was set to DS=2, making the full scale output (±10V) correspond to ±4π radians (1.26 rad/V) . A summary is shown in the table below.

DS	±10V Range	Scale
0	±1π	0.314 rad/V
1	±2π	0.628 rad/V
2	±4π	1.26 rad/V
3	±8π	2.51 rad/V
4	±16π	5.02 rad/V
5	±32π	10.0 rad/V
6	±64π	20.1 rad/V
n	use equation above	

**Table 2 – Density Scalars**

The polarimeter outputs follow a similar scheme, but in order to accommodate the very small phase measurements a multiplier is used. In order to accommodate polarimeter phases significantly smaller than ±π, the outputs are scaled by a parameter called RS (rotation scale.) The output signal is multiplied by two raised to the power of RS. The following conversion may be useful:

$$\text{Polorimeter phase (radians): } \phi_{ROT} = \left( \frac{V_{out}}{2^{RS}} \right) \times \left( \frac{\pi \text{ rad}}{10 \text{ V}} \right)$$

**Equation 2**

The Faraday Rotation scalar (RS) should be set appropriately in order that a significant portion of the 16-bit word be used. When delivered the unit was set to RS=3 making the full scale output (±10V) correspond to ±π/8 radians (39.2 mrad/V). A summary is shown in the table below.

RS	±10V Range	Scale
0	±1π	314 mrad/V
1	±π/2	157 mrad/V
2	±π/4	78.5 mrad/V
3	±π/8	39.3 mrad/V
4	±π/16	19.6 mrad/V
5	±π/32	9.82 mrad/V
6	±π/64	4.91 rad/V
n	use equation above	

**Table 3 – Faraday Scalars**

## 2.8 Status

The front panel of the DPD unit has different status LEDs. The REF status LED will be green when a 0.850MHz signal is found, else the status will be red. Channel status LEDs will turn green when a signal of sufficient level is present at the SMA connector, approximately 200mVpp. The 0.850MHz signal was chosen in order to indicate the presence of the interferometer signal, which is critical for Plasma Control.

On the RTO Module, the channel status LEDs are identical to that of the local unit. These statuses are copied to the SMB connectors located below the LED's. There is an additional LED on the RTO Module to indicate link status. Green indicates a good link.

## 2.9 Trigger

The TRG input SMA is provided for hardware trigger of the DPD. The unit triggers on a rising edge LVTTTL compatible signal. The trigger will offset the output by the average of 1024 samples at 10MHz.

## 2.10 Fiber Link

An ST-Type fiber connector is provided on the front panel of the DPD. This is a Transmitter port intended to be connected to the RTO Module unit via multi-mode fiber (62.5um core). Unit is expected to operate at up to 200m distance through fiber.

An ST-Type fiber connector is provided on the front panel of the RTO Module. This is a Receiver port intended to be connected to the DPD unit. When a proper connection is made with the DPD unit, the status light will be green. A red light indicates that it is not connected or an error linking.

# 3 Software

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The DPD uses scaling values in order to be able to accommodate different signal levels. These have been preset to values that have been specified by the user. The following is a description of how to use the DPD Control Application.

## 3.1 Configuration Parameters

The configuration parameters of the DPD are set using a command line interface. Parameters are set using the SET command and can be read back using the GET command. Settings are stored in non-volatile memory and will remain after power down. The following parameters can be set



### 3.1.1 Density Scale (SET DS) [1, 2, 3, ...n]

This sets the exponent of the density scalar using the equation in Section 3.5. See Table 2 – Density Scalars for further detail.

### 3.1.2 Rotation Scale (SET RS) [1, 2, 3, ...n]

This sets the exponent of the faraday scalar using the equation in Section 3.5. See Table 3 – Faraday Scalars for further detail.

### 3.1.3 Density Polarity (SET DP) [0 | 1]

If set to 1, this will invert the density output signal.

### 3.1.4 Rotation Polarity (SET RP) [0 | 1]

If set to 1, this will invert the rotation output signal

### 3.1.5 Lowpass filter (SET FILTER) [0 | 1]

A 1KHz lowpass filter can be enabled upon the request of the user. This filters the output signals while maintaining the 250kHz bandwidth of the instrument. The command SET FILTER is followed by a toggle flag (0 or 1). For example; SET FILTER 1 will activate the filter.

## 3.2 Command line

In the following documentation, spaces and/or capitals are not necessary but will be used for readability.

### 3.2.1 SET [parameter]

This command will set a parameter such as DS, RS, DP, and RP. For example SET DS 3 will set the density scaler to 3. Other examples include:

```
SET DS 5           #Sets Density Scalar exponent to 5
SET RS 3           #Sets Rotation Scalar to 3
SET DP 1           #Sets the Density Polarity to 1, inverting the signal
SET RP 0           #Sets the Rotation Polarity to 0 (non-inverting)
SET FILTER 1       #Turns on the 1kHz output filter
```

### 3.2.2 GET [parameter]

This command will display the current setting of the parameter. For example GET DS will return the current density scalar. Other examples include:

```
GET DS            #Gets Density Scalar exponent
GET ID            #Gets the DPD Id
GET FILTER        #Gets the status of the lowpass filter
```

## 3.3 Connecting

Two approaches may be used to connect to the DPD Control Application. An OS independent method may be used from any computer having Ethernet access to the DPD by way of Telnet. Alternatively, the use of the provided application can be used.

### 3.3.1 ARP

It may be necessary to add the DPD to the host computer ARP table. To do so, use Table 4 – MAC and IP address of the DPDs to appropriately create a static ARP entry within a terminal by using the command:

```
ARP -s [IP] [MAC]
```

Model	IP	MAC
05C	192.168.1.7	00-0A-35-02-80-1E
06C	192.168.1.8	00-0A-35-02-D0-FE

Table 4 – MAC and IP address of the DPDs

### 3.3.2 Telnet

Using a terminal, connect to the DPD by using telnet on port 23370. Once connected successfully, a message displaying **Entering DPD Control Application** will appear as in **Error! Reference source not found.**

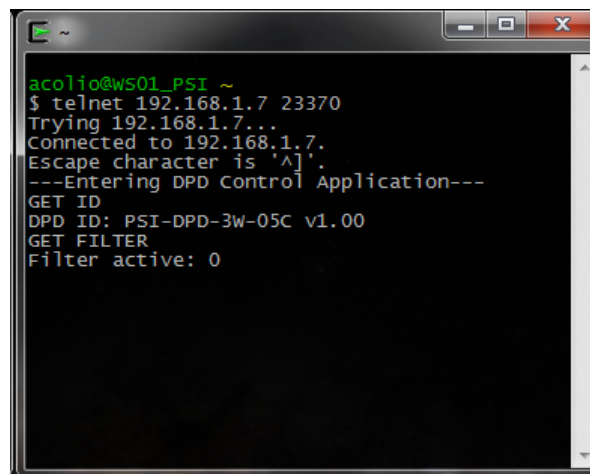


Figure 3 – Telnet connection to DPD

### 3.3.3 GUI

Using the OS specific application available at [www.palomarsci.com/Downloads](http://www.palomarsci.com/Downloads), the application will prompt the user to select the model wished to connect to upon launching (Figure 4 - GUI Model Select). A successful connection will be indicated by a green icon within the Status box (Figure 5 - DPD Control GUI).

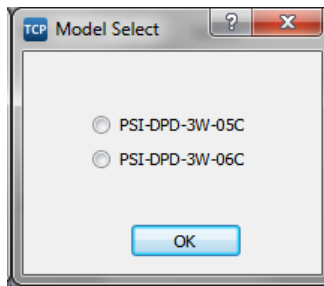


Figure 4 - GUI Model Select

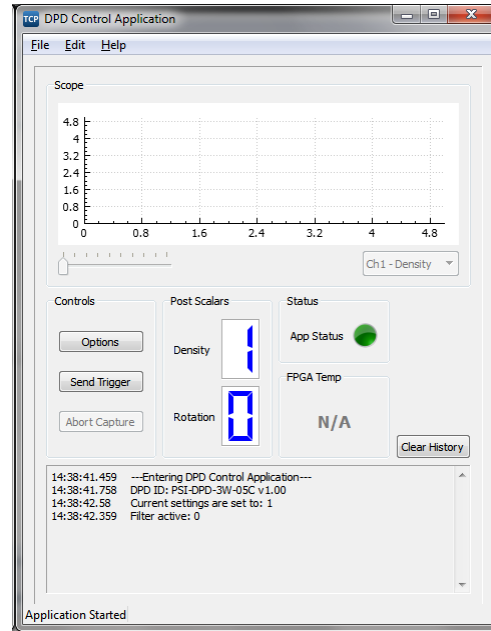


Figure 5 - DPD Control GUI

To change any settings, open the Options dialog (Figure 6 - Options dialog) by click the Options button in the control group. Selecting OK will save the settings.

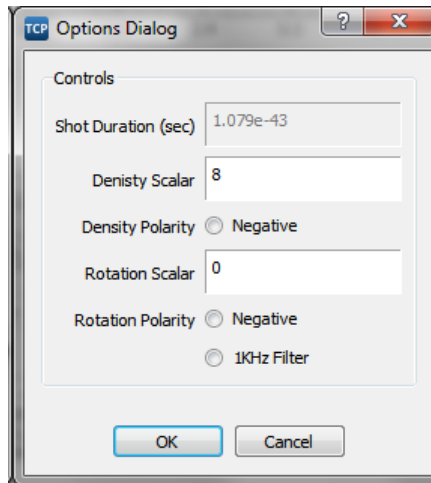


Figure 6 - Options dialog

### 3.4 Shipping defaults

The DPD has been preconfigured on all channels with the Density Scalar (DS) of 6, and with the Rotation Scalar (RS) of 3.

## 4 Re-Programming

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The DPD can be reprogrammed via a special JTAG cable shipped with the unit. Instructions are within the Programming Guide, available at [www.palomarsci.com/Downloads](http://www.palomarsci.com/Downloads).

## 5 Appendix / Notes

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**If you encounter issues not addressed by this user guide, please contact PSI for additional support.**