

FIBEROPTIC Receivers Operator's Manual

Series:

4510A/B, 4515 A/B 4516 A/B, 4518A/B,
10450 A/B, 10455A/B, 10456A/B/C, 10458A/B

MAN- 4510AB Rev E

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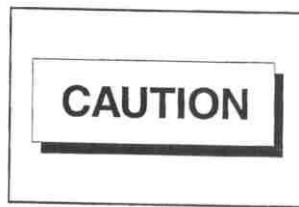
Ortel, A Division of Emcore
Alhambra, California, 91803 USA

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WARNINGS, CAUTIONS, AND GENERAL NOTES

Safety Considerations

When installing or using this product, observe all safety precautions during handling and operation. Failure to comply with the following general safety precautions and with specific precautions described elsewhere in this manual violates the safety standards of the design, manufacture, and intended use of this product. Ortel assumes no liability for the customer's failure to comply with these precautions.



Calls attention to a procedure or practice, which, if ignored, may result in damage to the system or system component. Do not perform any procedure preceded by a CAUTION until described conditions are fully understood and met.

Electrostatic Sensitivity

ESD = Electrostatic Sensitive Device

Observe electrostatic precautionary procedures.

Semiconductor laser transmitters and receivers provide highly reliable performance when operated in conformity with their intended design. However, a semiconductor laser may be damaged by an electrostatic charge inadvertently imposed by careless handling.

Static electricity can be conducted to the laser chip from the center pin of the RF input connector, and through the DC connector pins. When unpacking and otherwise handling the transmitter, follow ESD precautionary procedures including use of grounded wrist straps, grounded workbench surfaces, and grounded floor mats.

Exposure to electrostatic charge is greatly reduced after the transmitter has been installed in an operational circuit.

If You Need Help

If you need additional help in installing or using the system, need additional copies of this manual, or have questions about your system options, please call Ortel's Sales Department.

Service

Do not attempt to modify or service any part of the system other than in accordance with procedures outlined in this Operator's Manual. If the system does not meet its warranted specifications, or if a problem is encountered that requires service, return the apparently faulty plug-in or assembly to Ortel for evaluation in accordance with Ortel's warranty policy.

Ortel uses every reasonable precaution to ensure that every device meets published electrical, optical, and mechanical specifications prior to shipment. Customers are asked to advise their incoming inspections, assembly, and test personnel as to the precautions required in handling and testing ESD sensitive optoelectronic components.

These products are covered by the following warranties:

1. General Warranty

Ortel warrants to the original purchaser all standard products sold by Ortel to be free of defects in material and workmanship for one (1) year from date of shipment from Ortel. During the warranty period, Ortel's obligation, at our option, is limited to repair or replacement of any product that Ortel proves to be defective. This warranty does not apply to any product, which has been subject to alteration, abuse, improper installation or application, accident, electrical or environmental overstress, negligence in use, storage, transportation or handling.

2. Specific Product Warranty Instructions

All Ortel products are manufactured to high quality standards and are warranted against defects in workmanship, materials and construction, and to no further extent. Any claim for repair or replacement of a device found to be defective on incoming inspection by a customer must be made within 30 days of receipt of the shipment, or within 30 days of discovery of a defect within the warranty period.

This warranty is the only warranty made by Ortel and is in lieu of all other warranties, expressed or implied, except as to title, and can be amended only by a written instrument signed by an officer of Ortel. Ortel sales agents or representatives are not authorized to make commitments on warranty returns.

In the event that it is necessary to return any product against the above warranty, the following procedure shall be followed:

- a. Return authorization shall be received from the Ortel Sales Department prior to returning any device. Advise the Ortel Sales Department of the model, serial number, and the discrepancy. The device shall then be forwarded to Ortel, transportation prepaid. devices returned freight collect or without authorization may not be accepted.
- b. Prior to repair, Ortel Sales will advise the customer of Ortel test results and will advise the customer of any charges for repair (usually for customer caused problems or out-of-warranty conditions).

If returned devices meet full specifications and do not require repair, or if non-warranty repairs are not authorized by the customer, the device may be subject to a standard evaluation charge. Customer approval for the repair and any associated costs will be the authority to begin the repair at Ortel. Customer approval is also necessary for any removal of certain parts, such as connectors, which may be necessary for Ortel, A Division of Emcore testing or repair.

- c. Repaired products are warranted for the balance of the original warranty period, or at least 90 days from date of shipment.

3. Limitations of Liabilities

Ortel's liability on any claim of any kind, including negligence, for any loss or damage arising from, connected with, or resulting from the purchase order, contract, or quotation, or from the performance or breach thereof, or from the design, manufacture, sale, delivery, installation, inspection, operation or use of any equipment covered by or furnished under this contract, shall in no case exceed the purchase price of the device which gives rise to the claim.

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Ortel will not be responsible for loss of output or reduced output of optoelectronic devices if the customer performs chip mounting, ribbon bonding, wire bonding, fiber coupling, fiber connectorization, or similar operations. These processes are critical and may damage the device or may affect the device's output or the fiber output.

Ortel test reports or data indicating mean-time-to-failure, mean-time-between-failure, or other reliability data are design guides and are not intended to imply that individual products or samples of products will achieve the same results. These numbers are to be used as management and engineering tools, and are not necessarily indicative of expected field operation. These numbers assume a mature design, good parts, and no degradation of reliability due to manufacturing procedures and processes.

Ortel is not liable for normal laser output degradation or fiber coupling efficiency degradation over the life of the device.

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Chapter 1

1.0 GENERAL INFORMATION

1.1 Description

This manual covers the operation of the following fiberoptic receiver models:

MODEL #		Frequency	Max. Photo-current
Flange-mount	Plug-in (For 19" rack)		
4510A	10450A	DC - 3 GHz	2 mA
4510B	10450B	DC - 6 GHz	2 mA
4515A	10455A	0.1 - 10 GHz	2 mA
4515B	10455B	0.1 - 12 GHz	2 mA
4516A	10456A	1 - 20 GHz	2 mA
4516B	10456B	1 - 18 GHz	2 mA
4516C	10456C	1 - 15 GHz	2 mA
4518A	10458A	0.5 - 15 GHz	12 mA
4518B	10458B	0.5 - 10 GHz	12 mA

These receivers are intended for the reception of RF and microwave analog signals on single mode optical fiber at 1300 nm to 1600 nm wavelength. They contain InGaAs high-speed photodiodes in a proprietary high-speed package, which features a coaxial 50-ohm output and a guaranteed low optical reflection coefficient.

The receiver contains electronic circuits to operate the photodiode and monitor the dc photocurrent over a wide range of operating conditions. An alarm circuit is included for use in systems requiring self-diagnosis and failure analysis.

CAUTION: Carefully read all of the installation section of this manual before attempting to operate the optical receiver.

The signal output is via a coaxial SMA connector in a 50 ohm output circuit. The optical input is via a single-mode optical fiber. Several optical connectors are available as options.

1.2 Specifications

For detailed specifications and performance options, consult the individual product specifications at the end of this manual.

Specifications apply over the entire specified operating range of the product and are guaranteed for 1 year after the date of shipment.

1.3 Identification and Model Numbers

Each receiver is assigned a unique model number and serial number that appears on the label.

These receivers have performance options, which are designated by numeric suffixes to the model number, separated by a hyphen. For example:

10455B-003 describes a 12 GHz bandwidth receiver with the input ac coupling capacitor deleted (Option 003).

Products with modified performance can be bought in accordance with individual customer requirements. They are designated by an alpha-numeric suffix,

-ANN where A is alpha, and N is numeric. Such custom options should be discussed in advance with your Ortel sales representative for detailed performance and pricing.

1.4 Instructions for Service Returns

If the fiberoptic receiver does not meet its warranted specifications, it must be returned to Ortel for test and evaluation, in accordance with Ortel's warranty policy. When returning the receiver for service or repair, include the following information: owner, model number, serial number, return authorization number (obtained from Ortel Customer Service, 626-293-3400), service required and/or a description of the problem encountered.

For safe shipment of the receiver, use anti-static materials. The original packing material is reusable.

1.5 Additional Manuals

Additional copies of this manual are available through the Ortel Sales Department. Specify the Model Number from the title page or from your fiberoptic receiver.

Chapter 2

2.0 SAFETY PRECAUTIONS

Fiberoptic receivers are high performance electronic devices that provide highly reliable performance when operated in conformance with their intended design.

For best results when using this product, general safety precautions must be observed during handling and operation.

Failure to comply with these general safety precautions and with the specific precautions described elsewhere in this manual would violate the safety standards of the design, manufacture, and intended use of the device. Ortel assumes no liability for the customer's failure to comply with these precautions.

2.1 Safety Symbols

ESD Sensitive Device: Observe electrostatic precautionary procedures.

DANGER: Indicates a hazard. This heading calls attention to a procedure or practice that, if ignored, could lead to personal injury. Do not continue beyond the *DANGER* sign until the described conditions are fully understood and met.

CAUTION: Indicates a hazard. This heading calls attention to a procedure or practice that, if ignored, could lead to damage to the fiberoptic receiver or other equipment. Do not continue beyond the *CAUTION* sign until the described conditions are fully understood and met.

2.2 ESD Sensitive

Semiconductor photodiodes and integrated circuits are static sensitive devices, and products containing them should be treated accordingly. Static electricity can be conducted to the photodiode chip from the center pin of the rf input SMA connector, and through the dc connector pins. When unpacking and handling the fiberoptic receiver prior to installing it, use ESD precautionary procedures, such as grounded wrist straps and grounded work mats.

After the receiver is installed in an operational circuit, these pins are protected from unintentional contact and ESD sensitivity is greatly reduced.

2.3 RF Connector

Do not apply excessive torque to the SMA connector. The use of standard wrenches can lead to a damaged connector. Use 7-9 inch pounds of torque. The use of a torque wrench is *strongly recommended*.

2.4 Power Supply

Operating the receiver outside of its maximum ratings may cause device failure or a safety hazard. It is recommended that supply voltages be turned on after the 9 pin connector is inserted.

2.5 Grounding

All power supplies should be connected to an earth ground.

2.6 Input Optical Power

The receiver can be overdriven and damaged by the application of excessive optical input power. Refer to the installation procedure for acceptable values.

2.7 Storage

Observe ESD precautions while storing the fiberoptic receiver (i.e. anti-static containers) and store away from corrosive materials. Storage temperature: -40°C to +85°C for flange-mount units and -20°C to 65°C for plug-in packages.

2.8 Do Not Attempt to Modify or Service

Do not attempt to modify or service any part of the device. Doing so will void the warranty. If problems do arise, contact the Ortel Customer Service Department for a return authorization number.

Chapter 3

3.0 THEORY OF OPERATION

Ortel microwave fiberoptic receivers use high speed photodiode modules to convert an intensity modulated optical signal of 1300nm to 1600nm wavelength to a microwave signal. For more complete information on the operating principles of analog fiberoptic links, consult Ortel's publication *A System Designer's Guide to RF and Microwave Fiber Optics*.

3.1 External Displays and Controls

The fiberoptic receiver needs no external controls or adjustments. The operating bias point is preset at the factory to provide optimum performance according to the specifications published in the Product Specification Table.

3.1.1 LED Displays

There are two external visual LED displays that provide information about the operating state of the receiver. These LED's are on in normal operation. If any of the LEDs is off after applying dc power to the receiver and waiting for a few seconds, recheck all power connections. If the condition persists, consult with Ortel's Customer Service department.

Power On: This LED is normally ON, and indicates that +15 V is present at Pin #1 of the dc 9-pin connector.

Optical Power (plug-in units only): This LED is normally ON, and indicates that the photodiode is receiving optical power above a factory-set minimum of approximately 0.1 mW.

3.1.2 Status Monitor

A single monitor voltage is available on the dc connector. It is designed to provide information about the level of received optical power for routine operational maintenance.

PIN 6: Photodiode Current. 1 V/mA, $\pm 2\%$ (1.0 M Ω load). Provides a buffered voltage proportional to the photodiode current. Measuring and recording this voltage provides a record of the received laser power over time, as measured by the photodiode.

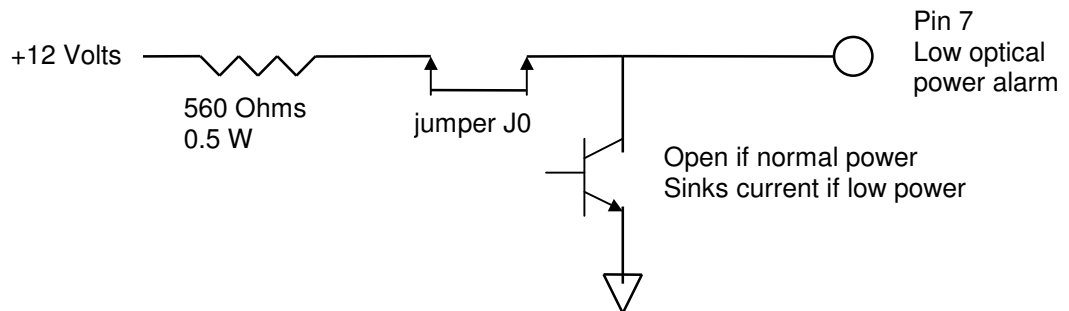
3.1.3 Alarm Functions

In addition to the LED visual displays of receiver operational status, there is one alarm circuit in the receiver, which can be used to drive remote indicators. It is designed to provide a positive interrupt capability if the operating conditions at the receiver are not within nominal values.

PIN 7: Low Optical Power. This alarm is *ON* (sinks current) if the receiver photodiode current monitor voltage drops from its factory set value of approximately 0.1 mW. The alarm is not activated if the photocurrent is *HIGHER* than the set point.

The alarm is designed to interface with user-supplied circuits. The alarm is an open collector output capable of sinking 20mA when ON and withstanding 15 Vdc when OFF. Normal operation of the alarm circuit is the off state.

A suggested use of the alarm circuit would be a series connection of an external LED, or a relay, from the system 15 V supply through a 1k Ω resistor. Assuming negligible voltage drop through the LED or relay, this would provide a 15mA activation current when the alarm is active. Some models also include a pull-up resistor of 560 ohms connected to 12 V and the alarm pin, in which case the pin can be used either to source current or provide a voltage indicator directly. This option is enabled with jumper J0, as indicated below.



If this alarm is activated, several solutions exist. In most cases the low power is a result of poor optical connections to the transmitter or receiver. If a power meter is available, measure the optical power from the fiber. If it is less than approximately 0.1mW, then check the laser power; laser optical connector, and fiber losses. (For especially long or lossy fibers, the alarm will always indicate a fault because the power is so low, therefore the alarm may be ignored.) If the fiber is producing more than 0.1 mW then mostly likely either the connector is dirty and should be cleaned as described in the installation section or the connector key did not align with the mating slot. If the key is not aligned, the connector can appear connected even though it has not fully reached the fiber.

Chapter 4

4.0 INSTALLATION

4.1 Unpacking and Visual Inspection

CAUTION: ESD Sensitive Device

The fiberoptic receiver was inspected before shipment and found to be free of mechanical and electrical defects. Observe ESD precautions while handling the receiver and unpack and examine the device for any damage due to transit. Keep all packing materials until your inspection is complete. Verify that the pins and connectors are free from obvious shipping or handling damage.

If damage is discovered, file a claim with the carrier immediately. Notify the Ortel Sales Department as soon as possible.

4.2 Operating Conditions

This product is designed and tested to withstand harsh environmental operating and storage conditions. The basic design and manufacturing processes have been subjected to rigorous product qualification tests of temperature cycling, mechanical shock, and vibration. However, the device can be permanently damaged by severe mechanical shock. Please handle carefully while unpacking and installing.

4.3 Connections

4.3.1 DC Power Connection

User supplied power supply

Connect pin 1 to +15 V DC and pin 4 to ground using a standard 9-pin DSUB connector.

CAUTION: Do not solder wires directly to the pins of the dc connector.

As the receiver contains internal regulator and transient suppression circuits, most high quality power supplies will provide excellent results. Grounded, shielded cable provides cleanest performance. For best results, make the dc connection to the receiver and verify that the power supply is correctly adjusted before switching on the supply.

The reference ground provides a separate ground path for more accurate use of the monitor and alarm circuit, although it may be connected to pin 4 and then the two used together as a common ground.

9 Pin D-sub Connector	
Pin	Function
1	+15 V DC
2	NC
3	NC
4	Power ground
5	Reference ground
6	Optical current monitor
7	Low optical power alarm (open collector output)
8	NC
9	NC

Ortel model 10990A chassis and 10901A/B power supplies

Plug-in style units may be used with an Ortel provided rack mount chassis and power supply. With these products, simply slide the receiver into any slot in the chassis. Blind-mate connectors on the back plane are wired to the power supplies. Units may be inserted with the power supply turned on or off, although it is recommended that the power supplies be plugged into a wall circuit to guarantee a good ground.

LEDs

Once the power supply is turned on, verify that the receiver LED is lit. If not, double checks the power supply connections. If the trouble persists, contact Ortel Customer Service for advice.

4.3.2 Optical Connection

The receiver is designed to operate with single mode optical fiber for wavelengths of 1300 to 1600nm. Receivers are available with various optical connector and fiber cables, as described in the options list in the appendix.

CAUTION: Before inserting light into the receiver, verify that the optical power falls below the maximum allowable.

DANGER: The light emitted from laser diodes used with these receivers is invisible and may be harmful to the human eye. Avoid looking directly into the fiber pigtail or into the collimated beam along its axis when the device is in operation.

Maximum Optical Power

The fundamental limit of optical power is determined by the DC photocurrent, which is a function of both the incident power and the responsivity of the particular device. The table below lists the maximum allowable current, as monitored with pin 6. The proportionality factor is 1 V/mA of receiver photocurrent. Typically, 1 mW of optical power will result in 0.7 to 0.8 mA of photocurrent, resulting in a measured voltage of 700 to 800 mV.

If a non-Ortel transmitter is used in the link, an external power meter should be used to measure the power directly from the fiber. For this case, or any case where the optical power is verified with a power meter, the reading should fall below the last column of the table below. This direct number is smaller than the typical power to allow a safety margin for especially efficient photodiodes and/or discrepancies between power meters.

Model	Max. DC Current (pin 6)	Typical Power	Max Power if measured with an external power meter
4510A/B 4515A/B 4516A/B/C 10450A/B 10455A/B 10456A/B/C	2 mA	2.0mW	2.5mW
4518A/B 10458A/B	12 mA	15 mW	16 mW

With the high power versions of the receivers (4518A and 10458A), if too much power is sent to the receiver, the internal electronics will automatically limit the current to a safe level. If this happens, the RF signal quality may be degraded until the optical power is reduced to the preferred level.

If the optical power is too high for the given receiver, optical attenuators must be inserted. Several varieties exist including fixed and variable, but for all a low optical reflection should be specified to maintain the quality of RF and optical performance.

Keeping the optical power below the maximum recommended level ensures both optimal RF performance and long device life.

Optical connectors

When inserting light into a receiver, if optical connectors are used, repeatable performance requires that the connector end surface be kept free of dirt and dust.

Before mating, clean with a cotton swab and alcohol, and blow dry with a lint free aerosol air spray. Many high quality connectors use keying polarity, and it is important to observe such mating requirements.

Should the internal connector of a bulkhead connector become dirty, the mating sleeve assembly must be removed. Removing the small setscrews and then gently sliding the assembly out of the receiver a few inches accomplish this. The connector will still be connected to the mating sleeve and can then be loosened and cleaned.

Some connectors can be improved by the use of index matching fluid, although in most cases this is not used. Consult with the connector manufacturer or Ortel for recommendations regarding specific connectors. In general, tighten the connectors' finger tight. Do not use a wrench, as it will cause excessive optical loss and can damage the connector end faces.

If a non-connectorized fiber option is provided, the fiber tip must be cleaved well and the tip must be clean. If not properly cleaved or cleaned, optical power may be scattered and the insertion loss may be high. For temporary splices, the use of index matching fluid is recommended to reduce reflections.

4.3.3 RF Connection

The output impedance of the receiver is resistively matched to 50 Ω . Use RF connections with the same characteristic impedance.

CAUTION: *Do not* apply excessive torque to the SMA connector. The use of standard wrenches can lead to a damaged connector. Use 7 to 9 inch pounds of torque. The use of a torque wrench is **strongly recommended**.

CAUTION: Ortel microwave frequency optical receivers can be supplied with either ac or dc-coupled outputs. The dc-coupled versions can affect equipment following the receiver due to the dc voltage present at the RF connector, or, conversely, a change in the bias point of the receiver can result from the dc characteristics of the external circuits.

4.4 Basic Performance Verification

For initial operation of the receiver, the use of a simple test circuit as shown in **Figure 1** is recommended. A fiberoptic transmitter of sufficient bandwidth is required to convert the electrical signal to optical form. Because of their superior operating characteristics for analog signals, the use of Ortel transmitters is recommended. Choose a bandwidth that matches the frequency range of the receiver.

The recommended test equipment for an initial evaluation follows:

- Signal Generator
- Power Supply (+15 Volts)
- Spectrum Analyzer
- Optical Power Meter
- RF Amplifier (optional, as required)
- Fiberoptic Transmitter
- Fiberoptic Cable
- Fiberoptic Attenuator (optional, as required)
- Voltmeter

Since the insertion loss of most Ortel optical links falls in the 30-45 dB range, an amplifier improves the measurement by raising the signal level to the spectrum analyzer. An amplifier is usually required to measure the output noise floor of the link. The amplifier is usually not required to make basic operating measurements of the link, since most spectrum analyzers will easily display signal levels of -45 dBm, which is the expected output power from a link with 0 dBm input level.

Preset the signal generator to 1 GHz at 0 dBm, or to some convenient frequency within the operating range of the receiver. It is advisable to calibrate the signal generator and spectrum analyzer by making a direct connection to set a zero dB reference measurement level.

Apply the signal to the transmitter and measure the output of the receiver on the spectrum analyzer. Verify that the output signal is clean with no amplitude jitter or spurious signals.

Measure the power level of the receiver output. The gain of the fiberoptic link will depend on the transmitter characteristics, as well as the optical loss of the test cable. For 2 mW of light incident on the receiver, the link insertion loss should be approximately 40 dB. Variations of ± 5 dB in this value can occur due to variations in transmitters and fibers, and should not be considered unusual.

The measured frequency response of the receiver necessarily includes the response of the transmitter. In the factory, Ortel uses calibrated transmitters to reduce measurement errors due to the laser.

4.5 Detailed Performance Verification

The following procedures are based on the factory test procedure.

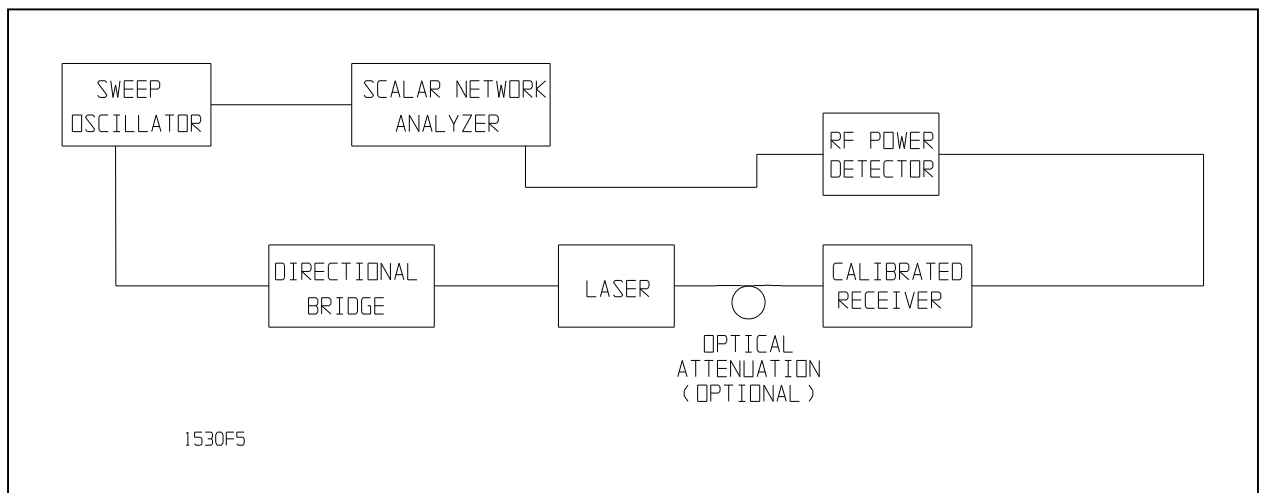
4.5.1 Frequency Response

The frequency response is measured by measuring the response of the receiver, a calibrated transmitter, and RF cables, and correcting for the transmitter and cable response. The first step is to measure the frequency response of interest of the measurement system (see Figure 1) including cables. The sweep oscillator should be set to a nominal output power of +10 dBm. This response is then stored. The receiver and calibrated transmitter are then inserted into the link. The link response is now measured using the input-memory mode. The resulting curve represents the frequency response of the receiver.

4.5.2 VSWR

The Voltage Standing Wave Ratio characterizes the RF reflections from a microwave component. It can be determined by measuring the microwave return loss or S_{22} . A system for making this measurement is shown in **Figure 1**. The network analyzer is pre-calibrated using the open/short/load routine. This calibration is usually stored continuously in memory.

Figure 1: Frequency Response, VSWR



APPENDIX A: Product Specification Tables

Specifications describe warranted performance. Typical values, indicated by "typ.", provide expected level of performance, but are not guaranteed.

A.1 RF Parameters¹

Flange-mount Plug-in	4510A/B 10450A/B	4515A/B 10455A/B	4516A/B/C 10456A/BC	4518A/B 10458A/B
Max. Frequency, f_{max}				
A version	3 GHz	10 GHz	20 GHz	15 GHz
B version	6 GHz	12 GHz	18 GHz	10 GHz
C version	--	--	15 GHz	--
Min. Freq. for meeting RF parameters	0.1 GHz	0.1 GHz	1 GHz	0.5 GHz
AC or DC coupled output	DC	AC	AC	AC
Amplitude Flatness ²	± 2.0 dB	+1,-3 dB	± 2.0 dB	+1.5,-3dB
Options -003 & -004, 0.01 GHz to f_{max}	NA	± 2.0 dB	NA	NA
Output VSWR, ⁵ Max	2.0: 1	2.0: 1	2.0: 1	2.0: 1
18 to 20 GHz			2.5: 1	
Output Impedance	50 Ω	50 Ω	50 Ω	50 Ω
RF Connector	SMA (F)	SMA (F)	SMA (F)	SMA (F)

A.2 Optical Parameters¹

Flange-mount Plug-in	4510A/B 10450A/B	4515A/B 10455A/B	4516A/B/C 10456A/B/C	4518A 10458A
DC Photodiode Responsivity, (pin 6) 1310 nm, 25 °C	> 0.75 mA/mW		> 0.65	> 0.70
RF receiver efficiency/DC photo. resp., ³ typ.	50% (6 dB RF loss)			
Optical return loss ⁴	> 45 dB			
Fiber	Singlemode (9/125) Corning SMF-28 or equivalent			
Pigtail length (where applicable)	> 1 meter			

A.3 DC Power

Pin 1 +15 Volts nominal @ 0.2 A max.

A.4 Temperatures

	Flange-mounts	Plug-ins
Operating Temperature of Baseplate	-40°C to +70°C	0 to +50°C
Storage Temperature	-40°C to +85°C	-20°C to +65°C

A.5 Maximum Power

Model	Max. DC Current (pin 6)	Typical Power	Max Power, if measured with an external power meter
4510A/B 4515A/B 4516A/B/C 10450A/B 10455A/B 10456A/B/C	2 mA	2.0 mW	2.5 mW
4518A/B 10458A/B	12 mA	15 mW	16 mW

A.6 Options ("x" indicates that option is available)

Options	Descriptions	Flange-mount	Plug-in
-003	No internal matching resistor, AC-coupled ⁵	x	x
-004	No internal matching resistor, DC-coupled ⁵	x	x
-020	FC/APC bulkhead optical connector	x	x
-021	FC/SPC bulkhead optical connector ⁶	x	x
-022	FC/APC optical connector, 3 mm fiber cable pigtail	x	
-023	FC/SPC optical connector, 3 mm fiber cable pigtail ⁶	x	
-026	FC/PC bulkhead optical connector	x	x
-028	FC/PC optical connector, 3 mm fiber cable pigtail	x	

¹Specified for 50% modulation depth.

²Relative to value at 1 GHz.

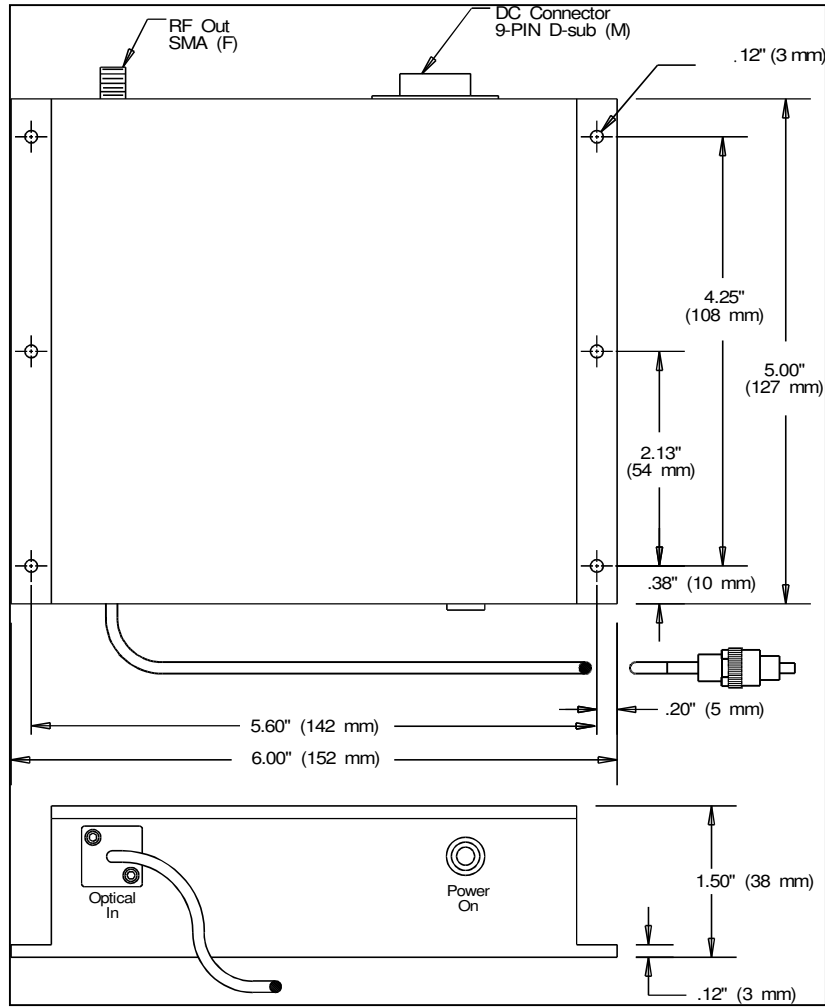
³The photodiode current splits evenly between the internal matching resistor and the external load, except in options 003 and -004. (See Ortel's *A System Designer's Guide to RF and Microwave Fiber Optics*.)

⁴For FC-APC fiber connectors or fusion splices. Other connection types may degrade optical return loss.

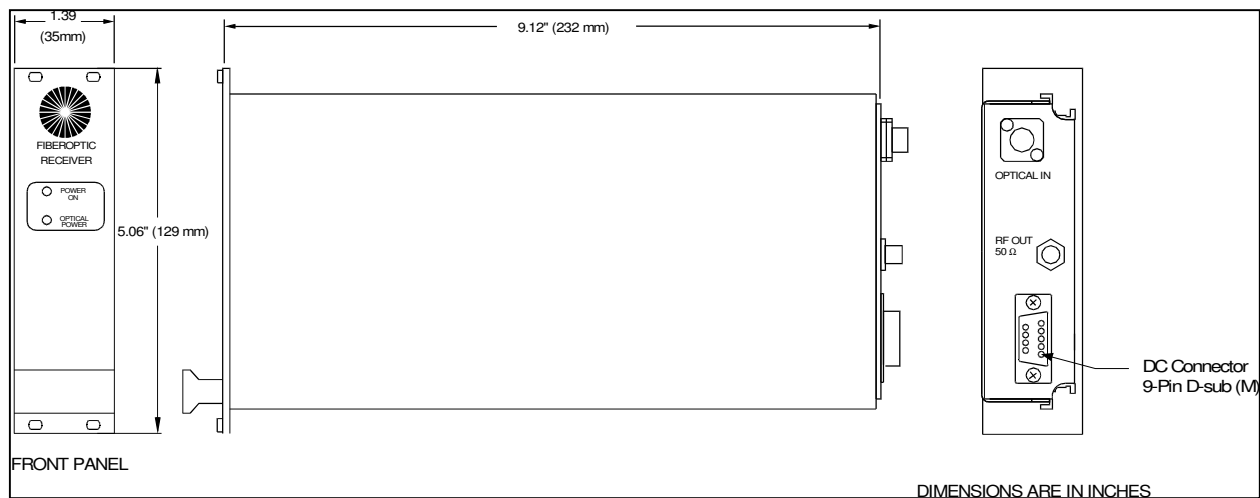
⁵VSWR spec. Not applicable for options -003 and -004. Options -003 and -004 only available for 4515A/B and 10455A/B.

⁶FC/SPC connectors are a higher-grade version of FC/PC and are compatible with them.

APPENDIX B: Outline Drawings



4510A/B, 4515A/B, 4516A/B/C, 4518A/B



10450A/B, 10455A/B, 10456A/B/C, 10458A/B