

2200/2240/2241 PathAlign-R
Test Set for Microwave Antenna Alignment
User Manual

pendulum
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Test & Measurement by Spectracom



 **spectracom**

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1 General Information

1.1 Introduction

The PathAlign-R™ test set is a high performance, complete test solution designed to quickly and accurately optimize the transmission path between two microwave antenna sites. The PathAlign-R directly drives the site's antennas, allowing the optimization process to be done without the need for on-site radios, complex test equipment, ground technicians, onsite AC power, cell phones, or two-way radios.

1.1.1 About this Manual

This manual contains information pertaining to the specifications, installation, operation, and maintenance of the Pendulum model 2200, 2200A, 2240, 2240A, 2241, 2241A, PathAlign-R Microwave Antenna Alignment Test Sets, hereafter referred to as the PathAlign-R. The 2241/2241A models are identical to the 2240/2241A except that the 2241/2241A includes the Record-R™ Data logging function with imbedded GPS receiver. These models operate on battery power via an internal 12 VDC/2.3 Ah rechargeable sealed Lead Acid battery.

1.1.2 Declaration of Conformity

The complete text with formal statements concerning product identification, manufacturer and standards used for type testing is available on request.

1.2 Preparation for Use

1.2.1 Introduction

Even though we know that you are eager to get going, we urge you to take a few minutes to read through this part of the introductory chapter carefully before using the equipment.

Study this manual thoroughly to acquire adequate knowledge of the instrument, especially the section on Safety Precautions hereafter and the *Installation* section.

1.3 Safety Precautions

1.3.1 Introduction

Personnel assigned to the operation or maintenance of the PathAlign-R are encouraged to review the safety practices given in this section. These are recommended procedures which may prevent a serious accident, save a life, or protect the PathAlign-R from damage.

The warranty commitments are rendered void if unauthorized access to the interior of the instrument has taken place during the given warranty period.

1.3.2 Caution and Warning Statements

CAUTION: Shows where incorrect procedures can cause damage to, or destruction of equipment or other property.

WARNING: Shows a potential danger that requires correct procedures or practices to prevent personal injury.

1.3.3 Symbols



Indicates that the operator should consult the manual.

1.3.4 Battery Safety

The following information concerning the Battery should be observed.

Important safety considerations:

- Do not incinerate battery, may explode if disposed of in fire.
- Do not directly connect the negative and positive terminals.
- Do not use other than the included charger to charge the battery.
- To prevent deterioration or damage to battery:
- Do not drop or subject to strong physical shock.
- Do not use to power equipment other than specified.
- Do not use below -10°C (14°F) or above 40°C (104°F). If the temperature exceeds this upper limit, a safety device will automatically prevent operation of the battery.
- To ensure long battery life:
- Do not discharge completely.
- Recharge battery immediately after use.



Recycling Battery: The sealed Lead Acid battery, shipped with the PathAlign-R, contains Lead (Pb) and must be recycled or disposed of properly after its useful life is exhausted. Do not incinerate this battery or dispose of in garbage container.

1.3.5 Safety Wire

Stainless steel safety wires, with quick-links, are now included with all PathAlign-R's. The safety wire attaches the instrument to the Backpack.

WARNING

To insure the integrity of the backpack to the instrument connection, Spectracom provides a stainless steel wire and quick-link connection between the PathAlign-R and the backpack's 'D' ring. This safety wire connection is designed to prevent the possibility of the instrument separating from the backpack and possibly falling, injuring the instrument or tower/ground personnel. The safety wire is looped thru the instrument's right-hand front panel handle and the quick-link connects the other end of the wire to the backpack's 'D' ring. *This safety wire connection should never be removed or defeated when the unit is being used in the field.* Further, whenever the PathAlign-R is taken up a tower, the unit should always be attached to the tower's superstructure. The recommended attachment method is with a carabiner through the backpack's 'D' ring and a nylon runner looped around superstructure, with the free end attached to the carabiner.

1.3.6 Static Discharge**CAUTION****Internal circuitry may be damaged by static discharge!**

Static discharge, through the front panel SMA connectors, during connection of coax cables may be fatal to the instrument, especially during periods of dry and windy conditions. Personnel should neutralize (discharge) any built-up static charge they carry before connecting coax cables to the instrument **by simultaneously touching the cable's connector shell and one of the instrument's front panel handles with the operator's uncovered hand (no gloves).**

**1.4 General Description**

The PathAlign-R is a high performance microwave Antenna Path Alignment Test Set specifically designed to quickly and easily optimize a microwave antenna link. This optimization process is done *without the need of the individual antenna site's radio* - the PathAlign-R directly drives the

site's antenna. The PathAlign-R's are sold as, and used in, pairs... one at each antenna site. Full duplex voice transmit/receive capability between sites is provided with the enclosed headsets. A Variable Alignment Tone, switch selectable on the front panel, indicates signal strength (path loss) via a variable tone, which can be heard thru the speaker or the headset. Transmit/receive frequencies are selected with the front thumbwheel switches and path loss measurements are displayed on the front panel meter. Four coax cable connectors (Super SMA sparkplug connectors) on the front panel facilitate connection to the Antenna via the appropriate coax-to-waveguide adapter.

The PathAlign-R has four bands of frequency ranges that are available at the front panel via the Super SMA female sparkplug connector (50 ohm impedance). Specific frequencies within these bands are selected with the front panel thumbwheel switches which provide 1-MHz resolution. LEDs located over each connector indicate which output is active (only one band is active at a time). The frequency ranges of the four bands are:

	Band 1	Band 2	Band 3	Band 4
2200	1.5 GHz to 2.5 GHz	5.8 GHz to 6.6 GHz	11.0 GHz to 12.0 GHz	18.1 GHz to 19.4 GHz
2240 / 2241	1.5 GHz to 2.5 GHz	3.5 GHz to 5.0 GHz 5.8 GHz to 6.6 GHz	7.5 GHz to 10 GHz 11.0 GHz to 12 GHz	15 GHz 18.1 GHz to 19.4 GHz 22.0 GHz to 23.5 GHz

The 2200A, 2240A, and 2241A are identical in operation to the model 2200, 2240, and 2241. They differ only in Frequency Band configuration. In the 'A', any combination of the Frequency Bands (1, 2, 3, and/or 4) may be ordered, instead of all four bands found on the model 2200, 2240, 2241.

A 'Master/Slave' toggle switch, located on the front panel, selects whether an individual unit transmits 20 MHz above the selected frequency (Master) or 19 MHz below the selected frequency (Slave). The two PathAlign-R's need to be set differently from one another. It does not matter which unit is which as long as one PathAlign-R is 'Master' and the other PathAlign-R is 'Slave'. The transmit/receive offset (39 MHz) allows for full duplex voice communication and measurement over the link.

An internal microcontroller controls the operation of the PathAlign-R. The PathAlign-R's transmitted frequency derives from a synthesized source which provides for very accurate control of the output frequency. The output signal level is fixed at a constant 0 dBm, enough to drive an antenna directly. This combination of frequency stability and output level makes path alignment possible while severely reducing the possibility of interference to adjacent links. The receive signal is detected via a broadband mixer and processed through a very narrow-band filter, allowing accurate measurements of the receive signal while providing a very high rejection of adjacent signals. Nominal measurements are displayed in dB, to a resolution of 0.1 dB, on the front panel display.

The front panel has well-defined controls and indicators for selecting bands, frequency, and resolution, using the thumbwheel switches. Toggle switches on the front panel select Power ON/OFF and Audio (Alignment Tone or Voice). A 3.5 mm jack on the front panel provides connection to the headset. A speaker is located just behind the circular graphic on the front panel to monitor the audio when not using the headset. An Audio volume control adjusts the headset earpiece volume as well as the speaker's output level.

The PathAlign-R provides a switch-selectable 'Alignment Tone' on the front panel that functions as an audible path loss indicator. This variable-pitch tone is inversely proportional to the path loss of the link (low tone/greatest path loss; high tone/least path loss). The pitch of the tone ranges from approximately 600 Hz to 5 kHz (3-octaves), for a proportional path loss -100 dBm to -30 dBm (the dynamic range of the PathAlign-R). In other words, as the link alignment improves, the tone rises.

The rear panel contains the battery access door allowing for removal or replacement of the internal battery. A rear panel BNC connector outputs 0-2VDC, relative to the front panel meter reading for providing remote reading of path loss (1mV=0.1dB). A rear jack (5.5mm x 2.1mm) allows connection of the Battery Charger for charging the internal battery. **(Note: Use only the Battery Charger supplied with the PathAlign-R, another charger may damage the PathAlign-R or the battery!).** If the charger is lost or damaged a replacement may be purchased from Spectracom.

The Record-R Data Logger found in models 2241/2241A allows the user to record and store an individual data record in the instrument's memory with the push of a button. The memory used for this storage is non-volatile; it is not affected by turning of instrument off. The Data Logger also contains an imbedded GPS receiver to provide location/date/time information to the record. The information stored included the instrument's model number (e.g. 2241), serial number, date and time, location (latitude and longitude), frequency in use and the measured path loss. Up to 250 individual records can be stored in memory.

Included with the Record-R is a software utility called the LogView-R which allows connection to a PC computer running Windows, via RS-232 or USB, for downloading, viewing, saving to disk and printing of the records stored, as well as clearing the instruments memory.

1.5 Specifications

1.5.1 Transmitter

Transmission:	Full-Duplex (simultaneous transmission and reception)
Transmission Output Power:	0 dBm, nominal
Transmitter Stability:	5.1×10^{-9} /day (aging) + 1×10^{-6} (temperature 0°C to 50°C)
Tuneable Frequency Bands:	'A' models must be ordered with a least one Frequency Band Opt
(Opt. 01) Band 1 range:	1.5 GHz to 2.5 GHz
(Opt. 02) Band 2 range:	3.5 GHz to 5.0 GHz, 5.8 GHz to 6.6 GHz
(Opt. 03) Band 3 range:	7.5 GHz to 10GHz, 11.0 GHz to 12.0 GHz
(Opt. 04) Band 4 range:	15 GHz, 18.1 GHz to 19.4 GHz, 22.0 GHz to 23.5 GHz
Transmit / Receive Conn:	(4) Super SMA female sparkplug connectors (front panel)
Modulation:	FM

Deviation:	50-100 kHz
Transmit / Receive Offset:	39 MHz (Transmit offset: Switch set to 'Master' =+20 MHz; Switch set to 'Slave' = -19 MHz of the Thumbwheel Frequency setting)
Modulation Choice:	Voice / Alignment tone, switch selectable on front panel
Modulation Input / Output:	Headset w/10-foot cable, terminated in a 3.5 mm Plug (Mic & Earpiece)
Headset Microphone Input:	3.5 mm front panel jack (tip connector) w/5 VDC thru a 2.2k resistor

1.5.2 Receiver

Receiver Sensitivity:	-100 dBm nom. /1.5-2.5 GHz; -95 dBm nom. /3.5-6.6 GHz; -90 dBm nom./7.5-12.0 GHz; -85 dBm nom./18.1-23.5 GHz
Receiver Bandwidth:	~ 100 kHz, nominal
Receiver Overload Point:	-30 dBm (signals < 30 dB path loss will read 30 dB on meter)
Receiver Damage Level:	+10 dBm
Readout Resolution:	0.1 dB
External Readout:	External readout of path loss with DVM (0-2 VDC), BNC connector, rear panel
Variable Alignment Tone:	600 Hz to 6 kHz, varies with signal strength, switch selectable
Internal Speaker:	350 mW max., variable, behind front panel
Earpiece Output:	250 mW max., variable, 3.5 mm front panel jack (ring connector)
Speaker / Earpiece Control:	Audio Volume, variable pot

1.5.3 Display

Receiver Display:	4-digit backlit LCD direct path loss in dB (equivalent to signal input level in dBm) 0.5" high digits with decimal point and low battery indicator.
Display Resolution:	0.1 dB
Display Update Time:	300 ms
Low Battery Indicator:	Annunciator within LCD display, ON when battery has approx. 15 minutes left.
LED Status Indicators:	BAND1, BAND2, BAND3, BAND4

1.5.4 Internal Frequency Standard (TXCO)

Frequency:	10 MHz
Aging Rate / Second:	$\leq \pm 1$ part in 10^{-10} (root Allen variance)
Aging Rate / Day:	$\leq \pm 5.1$ part in 10^{-9}
Aging Rate / Year:	$\leq \pm 7.6$ part in 10^{-7} after 45 days.
Warm Up Stability:	$\leq \pm 4$ part in 10^{-7} in 5 minutes (ref. freq. @ 1 hour).
Retrace:	$\leq \pm 3$ part in 10^{-7} after 24 hrs. ON, 24hrs. OFF, 1 hr. ON (ref. to previous ON freq.).
Temperature Stability:	$\leq \pm 1$ part in 10^{-6} (0°C to 50°C).
Calibration Schedule:	One (1) year.

1.5.5 Headset Information

Earpiece:	Dynamic, 8 Ohms (ring connector)
Microphone:	Electret, noise cancelling (tip connector)
Cord:	Quick release adapter with right-angle 3.5mm (1/8 in.) plug

1.5.6 Battery Characteristics

Operating Time (approx):	4 to 5 hours continuous @ 25°C (77°F). Low Battery indicator, within LCD display, ON when approx. 15 min. operating time remains.	
Charge Time (approx):	3 hours	
Manufacture:	Panasonic	
Manuf. Part No.:	LCS-2312NC, Rechargeable Sealed Lead Acid Battery	
Nominal Voltage:	12 VDC	
Nominal Capacity:	2.3 Ah	
Capacity affected by Temperature:	40°C(104°F)	102%
	25°C(77°F)	100%
	0°C(32°F)	85%
	-15°C(5°F)	65%
Self-Discharge @ 25°C:	Capacity after 3 month storage:	90%
	Capacity after 3 month storage:	80%
	Capacity after 3 month storage:	60%

1.5.7 Mechanical

Power:	DC, 12 VDC, 2.3 Ah, Rechargeable Sealed Lead Acid Battery.
Weight:	Net: 3.2 kg (7 lbs.) per unit (inc battery and backpack) Shipping: 5 kg (11 lbs.)
Dimensions (HxWxD):	89mm x 213mm x 333mm (3.5 in. x 8.375 in. x 13.1 in.)
Connectors:	
RF In / Out:	Super SMA female sparkplug, field replaceable.
Headset In / Out:	3.5 mm (1/8") front panel jack (earpiece = ring conn. ; mic = tip conn.)
Remote Readout:	BNC rear panel connector (0-2 VDC Out; 1mV = 0.1 dB)
Battery Charger In:	5.5 mm x 2.1 mm rear panel Power jack (15 VDC/ 1A, center positive)

1.5.8 Environmental

<i>Designed to meet EN 61010-1 (IEC 1010-1)</i>	
Operating Temperature:	-10°C to 40°C (14°F to 104°F)
Storage Temperature:	-40°C to 71°C (-40°F to 160°F)
Relative Humidity:	95% ±5% 10°C to 30°C; 75% ±5% to 40°C; 45% ±5% above 40°C
Burn In:	Failure-free burn in of no less than 100 hours at 40°C
Pollution Degree:	1 (no pollution) (EN 61010-1/3.7)
Transient Overvoltage:	Installation Category II (EN 61010-1/J)

1.5.9 Supplemental Specifications

Warranty:	One Year Limited Warranty
Montreal Protocol:	Nil Return
ISO 9001:	All Spectracom sites are registered to ISO 9001:2008 and are regularly audited and improved to provide you the best possible vendor support.
CE (European Union):	EN 55011: 1998 w/A1:1999; Group 1 Class B (emissions) EN 61326-1:1997 w/A1:1998 (immunity)

1.5.10 Battery Charger

A.C. MAINS Input:	90 to 264 VAC / 47 to 63 Hz
DC Output:	15 VDC / 1A

DC Connector:	5.5 mm x 2.1 mm Barrel Power connector, 5 foot cord
Dimensions (HxWxD):	33 mm x 51 mm x 86 mm (1.3 in x 2.0 in x 3.4 in)
Operating Temperature:	0°C to 40°C (32°F to 104°F)

1.5.11 Record-R Specifications (Model 2241 / 2241A Only)

Data Recorded:	Each record contains: Model No, Serial No., Date, Time (UTC), Longitude, Latitude, Frequency, & Path Loss
Data Record Time:	~20 milliseconds
Data Format:	CSV (comma-separated variable)
Max No. of Records	250 (stored in instruments non-volatile memory)
Downloading Records:	Records are downloaded, thru RS-232-C or USB rear panel connectors.
Downloading Baud Rate:	9600 Baud.
Software (included):	LogView-R Data Log Utility software for Windows operating systems. This software allows a remote computer to download, display, and save data records and clear the instrument's memory.
GPS:	
Frequency:	L1 (1575.42 MHz), C/A code (SPS), 8-channel cont. tracking, 32 correlators.
Position Accuracy:	±2 meters CEP (50%)
Timing Accuracy:	±95 nano-seconds
Position Fix Update:	1 second
Time To Lock:	Cold Start: < 130 seconds (90%); Warm Start: <45 seconds (90%); Hot Start: <20 seconds (90%)
Reacquisition Time:	<2 seconds (90%) after loss of signal.
Mechanical:	
RS-232-C Connector:	DB-9 female (rear panel)
USB Connector:	USB type B female (rear panel)

1.5.12 Accessories Furnished

With each of the set's two (2) units:
One (1) Operating/Maintenance Manual with User Information Card
One (1) Headset with noise cancelling mic.
One (1) Weather-resistant Instrument Back-pack

One (1) Coax Cable Assembly, SMA (male) to SMA (male), 3 meters
One (1) Battery, Rechargeable, Panasonic LSC-2312NC, 12VDC/2.3 Ah, Sealed Lead Acid Battery
One (1) Battery Charger, AC MAINS powered, 90 - 264 VAC
With each set of two (2) units, 2241/2241A only:
One (1) RS-232 Cable Assembly, D-sub 9-pin (male) to D-sub 9-pin (female), 3-meters (9.84 ft)
One (1) USB Cable Assembly, USB 'A' (male) to USB 'B' (male), 2-meters (6.56 ft.)

2 Installation

2.1 Introduction

This chapter outlines the procedure for initial inspection and installation of the PathAlign-R. The subject matter includes receiving inspection, power requirements, battery information, installation criteria, mating connectors, and incoming confidence check. Instructions for preparing an instrument for reshipment and storage instructions are also included.

2.2 Receiving Inspection

Prior to accepting the unit from the shipper, inspect the condition of the shipping container for any evidence of freight damage. Any damage should be noted by both the shipper and the receiving customer and reported to the insurance investigator.

Immediately after removing the instrument from the shipping carton, inspect it for any possible physical damage that may have been incurred in shipment. Check for surface scratches and dents; note the condition of switches, buttons, and connectors (carrying bag, battery, cables, etc.) **Should any damaged be detected, notify Spectracom. DO NOT USE THE INSTRUMENT UNTIL INSTRUCTED TO DO SO BY THE FACTORY.**

2.3 Power Requirements

The PathAlign-R is powered by a 12VDC/2.3 Ah rechargeable battery which can be removed via the rear panel Battery Door. Continuous Battery operating time is approximately 4-5 hours @ 25°C (77°F). A 'Low Battery' indicator is contained within the LCD display and is displayed when the battery has approximately 15 minutes of operations remaining. Charging of the battery while inside of the PathAlign-R is accomplished by plugging the battery charger's DC plug into the PathAlign-R's rear panel 'External Charger In' jack (charging time is approximately 3-hours to fully charge the battery). The PathAlign-R Battery Charger operates, when attached to an appropriate AC MAINS source, over an AC line voltage of 90 VAC to 264 VAC, 47 Hz to 63 Hz.



Note: Use only the Battery Charger supplied with the PathAlign-R, another charger may damage the PathAlign-R or the battery! If the charger is lost or damaged, a replacement may be purchased from Spectracom.

2.4 Battery Information

Caution: The PathAlign-R is provided with a Panasonic LCS-2312NC, 12VDC/2.3 Ah Rechargeable Sealed Lead Acid Camcorder Battery. Do not use any other type or size of

battery in the PathAlign-R. Additional batteries are available worldwide or direct from Spectracom. The following information concerning the battery should be observed.

1. Important safety considerations:
 - a. Do not incinerate battery; it may explode if disposed of in fire.
 - b. Do not directly connect the negative and positive terminals together.
 - c. Do not use other than the instrument's charger to recharge battery.
2. To prevent deterioration or damage to battery:
 - a. Do not drop or subject to strong physical shock.
 - b. Do not use to power equipment other than the PathAlign-R.
 - c. Do not use below -10°C (14°F) or above $+40^{\circ}\text{C}$ (104°F). If the temperature exceeds this upper limit, a safety device will automatically prevent operation of the battery.
3. To ensure the longest and most optimal battery life:
 - a. Do not discharge completely.
 - b. Recharge battery immediately after use.



Recycling Battery: The sealed Lead Acid battery, shipped with the PathAlign-R, contains Lead (Pb) and must be recycled or disposed of properly after its useful life is exhausted. Do not incinerate this battery or dispose of in garbage containers.

2.5 Battery Installation

The battery should first be placed into the PathAlign-R's battery compartment through the battery rear panel door, and the door secured with the thumb screw. When inserting the battery into its compartment, orient the battery so that the positive terminal is up and the end with the terminals is inserted first (note: the battery cannot be fully inserted into its compartment if it is incorrectly oriented). The PathAlign-R can now be placed into the Weather-resistant Instrument Back-pack. The battery may be changed out or recharged while it is in the backpack by opening the flap at the bottom of the bag and plugging the Battery Charger's DC plug into the 'External Charger In' jack located on the PathAlign-R's rear panel.



NOTE: The battery must be charged before first use!

2.6 Mating Connectors

The Band 1 through Band 4 front panel in/out connectors are coaxial type female Super SMA sparkplug connectors (3.5 mm compatible) with a $50\ \Omega$ nominal impedance. The rear panel

'Remote Read-out' connector is a coaxial type BNC connector (0-2 VDC). The 'External Charger In' rear panel connector is a 5.5 mm x 2.1 mm male barrel DC power connector, center positive.

Replacing the 'Sparkplug' thread-in Connector

The Band 1-4 female in/out sparkplug connector is "field replaceable" if damaged during use.

Tools required

SMA Female 'Sparkplug' thread-in connectors, P/N 220-500SF, from Southwest Microwave, Tempe, AZ 85284 USA

- Special installation/removal tool for thread-in connectors, P/N T-1020-1, from Southwest Microwave, Tempe, AZ 85284, USA
- Two 5/16" (or 8 mm) open-end/box wrenches, to use with the tool above
- Low-strength removable thread-locking fluid

Thread-locking Fluid: A low-strength removable thread-locking fluid can be obtained from M.G. Chemicals, Toronto, Canada, Cat # 8701 (Mouser P/N 590-8701-10ML). A second-source is Loctite RC/609.

2.6.1 Procedure

Caution must be exercised when removing and replacing the 'sparkplug' connector to ensure that the center conductor of the internal coax is not bent. The following instructions should be followed when replacing the sparkplug connector:

2.6.2 Attaching the Installation/Removal Tool

1. Back the short part of the installation/removal tool out from the longer section by hand until it stops rotating.
2. While holding the tool by the longer section, thread the installation/removal tool onto the sparkplug connector by hand until it bottoms out.
3. While holding the tool by the longer section, back the connector out ½ turn by hand.
4. Holding the longer section stable, tighten the shorter section until it stops by hand.
5. Using the 5/16" open end wrench, carefully hold the longer section stable while tightening the shorter section with the other wrench. Be careful not to stress the sparkplug connector while performing this operation.

2.6.3 Sparkplug Removal

1. Attach the installation/removal tool per the above instructions.
2. Place the 5/16" open-end wrench on the longer section of the installation/removal tool and turn the wrench counter-clockwise, removing the old sparkplug connector from the mixer block.
3. Check to see that the coax center conductor (inside the block) is centered and has not been bent.

Note: If the center conductor of the internal coax (inside the mixer block) is found to be bent, the entire instrument must be returned to Spectracom for repair. Attempting to straighten this center conductor will only deform it and correct mating with the sparkplug will no longer occur.

2.6.4 Sparkplug Installation

1. Attach the installation/removal tool per the above instructions.
2. Apply a single drop of a low strength removable thread-locking fluid only on the threads that will enter the threaded hole in the block of the new sparkplug connector.
3. Using a Q-tip (cotton swab), wipe away 90% of the fluid, so only a trace remains in the threads of the connector that enter the threaded hole in the block.
4. Carefully screw the new sparkplug connector into the mixer block, by hand, until finger tight.
5. Place the 5/16" box-end of the wrench on the shorter section of the installation/removal tool and tighten to a firm but not hard torque. Torque specification is 1.8 N-meters.
6. Using the 5/16" open end wrench, carefully hold the longer section stable while loosening the shorter section with the other wrench. Be careful not to stress the sparkplug connector while performing this operation.
7. When loose, hand-remove the tool from the connector.

Note 2: Using a 3.5 mm terminated cable with the instrument's 2.92 mm front panel connector will mate properly but the physical difference in construction between these two different size connectors will slightly degrade the VSWR specification. The same is true when using a 2.4 mm terminated cable with the 1.85 mm front panel connector.

2.7 Incoming Confidence / Verification Check

Prior to packaging the instrument for shipment, extensive operational and calibration procedures were performed by Spectracom to verify that the instrument is operating to specifications. To ensure the electronic integrity of the instrument on your receiving bench, you must perform the following confidence / verification check. **Battery Note: It is necessary to first completely charge the battery.** This may be accomplished by placing the battery in the instrument, connecting the Battery Charger to the PathAlign-R, and connecting the Charger's AC cord to an appropriate AC MAINS supply (charging time is approximately 3-hours to fully charge the battery).

1. Turn on the power. The meter display turns on and displays a number (path loss).
2. Set the thumbwheel switches to a frequency within Band 1 (1.5 – 2.5 GHz) range (shown over Band 1 front panel in/out connector). The appropriate annunciator LED over the connector will illuminate. Using the thumbwheels, change the frequency setting to verify operation throughout the Band 1 range (the Band 1 LED will stay illuminated as long as the selected frequency stays within the Band 1 range). Repeat this step for each of the other three Bands.
3. Next, set the 'AUDIO Alignment Tone/Voice' switch to 'Alignment Tone' and advance the 'AUDIO Volume' knob until the tone can be heard coming from the front panel speaker (located behind the circular front panel graphic). Advance and retard the 'AUDIO Volume' knob to confirm its function. Insert the Headset plug into the front panel

- 'HEADSET' jack. Tone will no longer be heard coming from the speaker but will now be heard in the Headset's earpiece.
4. This completes the incoming confidence check. The instrument can now be placed in service.

2.8 Optional Additional Checks

2.8.1 Transmitter Check

Connect a microwave frequency counter and a microwave power meter, to the Band 1 in/out connector, using the appropriate SMA coax cable. With the PathAlign-R thumbwheel switches, select a frequency that is within the Band 1 range. Using the power meter, verify that the output power level is 0dBm, nominal. Using the frequency counter, confirm the frequency measured agrees with the frequency set on the thumbwheel switches. (Note: the setting of the 'MASTER/SLAVE' switch affects the transmitted frequency. The output frequency will be 20 MHz (± 500 kHz) above the set frequency when the 'MASTER/SLAVE' switch is set to 'MASTER'; 19 MHz (± 500 kHz) below the set frequency when the 'MASTER/SLAVE' switch is set to 'SLAVE'. This 39 MHz offset makes possible the full-duplex voice transmission and measurement of the PathAlign-R). Repeat this step for the other three Bands.

2.8.2 Receiver Check

Connect a microwave signal source (Sweeper, Synthesizer, or Microwave Test Set), with its output deactivated, to the Band 1 IN/OUT connector, using the appropriate SMA coax cable. With the PathAlign-R's thumbwheel switches, select a frequency that is within the Band 1 range. Set the PathAlign-R's 'MASTER/SLAVE' switch to 'MASTER'. Set the signal source to the same frequency as the thumbwheel frequency setting...Minus 19 MHz. Set the source's output to -60 dBm. Activate the source and verify that the PathAlign-R's 'PATH LOSS' meter reading is 60 dB, nominal. (Note: the setting of the 'MASTER/SLAVE' switch affects the received frequency. The input frequency will be 19 MHz below the set frequency when the 'MASTER/SLAVE' switch is set 'MASTER'; 20 MHz above the set frequency when the 'MASTER/SLAVE' switch is set to 'SLAVE'. This 39 MHz offset makes possible the full-duplex voice transmission and measurement of the PathAlign-R). Repeat this step for the other three Bands.

Caution: When connecting the SMA terminated end of the cable to the front panel Band connector, do not over-tighten the SMA cable connector, as it can damage the front panel connector's center pin. A 5/16" open end wrench fits SMA connectors; recommended torque is 8-inch/pounds. A special 5/16" open end is available from Torque Controls, So. El Monte, California. The manufacturer part number is 'A5'.

This completes the OPTIONAL incoming confidence / verification check. The instrument can now be placed in service.

2.9 Field Verification Check

The following operational checks of the PathAlign-R may be made by personnel in the field to confirm proper operation of both PathAlign-R units, their coax cables and the waveguide adapters (transitions). This confirmation may be made prior to climbing the towers or whenever

an operational confidence check needs to be made in the field, without access to test equipment or electronic technicians. The Band 1 (1.5 – 2.5 GHz) check is given first, using a 40 dB attenuator. Bands 2, 3, and 4 are given next, using the appropriate waveguide adapters. Figures 2-1 (Band 1) and 2-2 (Bands 2, 3, and 4) illustrate the setups.

2.9.1 Band 1 (1.5 - 2.5 GHz) Field Verification Check

1. First, using two SMA terminated coax cables, connect one end to the Band 1 connector on each PathAlign-R. Connect the other end of each cable to a 40 dB in line attenuator. **Note: Without the attenuator, the input circuits of the PathAlign-R would overload. The attenuator needs to pass frequencies from DC through 18 GHz. An appropriate attenuator is manufactured by Mini-Circuits, model BW-S40W2.**
2. Using the thumbwheel switches, select any Band 1 frequency. **Note: The 2240's thumbwheels must be set to the same frequency on both units.**
3. Set one PathAlign-R to 'MASTER' and the other PathAlign-R to 'SLAVE' and then power up both units.
4. Observe that the LED over the Band 1 connector on each unit is lit, indicating operation of that band.
5. The path loss indicated on the meter should be close to 40 dB. If the loss is significantly different, check or replace the coax cables or attenuator and repeat the test. **Note: The two PathAlign-Rs should typically read within 4 dB of one another.**
6. This completes the field operational confidence check of Band 1.

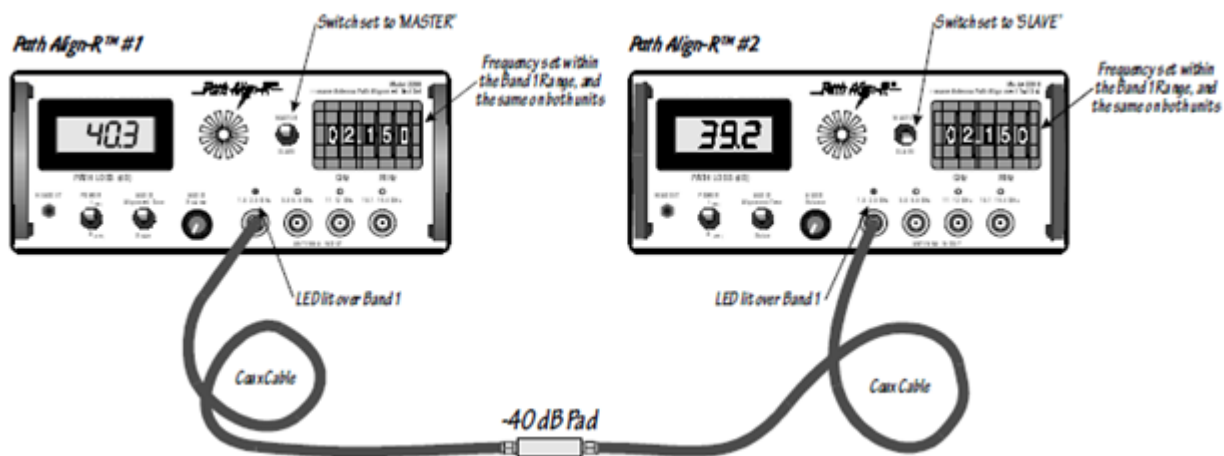


Figure 2-1. Band 1 Field Verification Check Test Setup

2.9.2 Band 2, Band 3, and Band 4 Field Verification Check

1. First, connect the coax cable to the proper Band connector on each PathAlign-R and then, connect the waveguide adapter (transition) to the other end of this coax making sure that the waveguide adapter band is appropriate for the PathAlign-R's frequency band range. **Note: It is absolutely necessary for the proper waveguide to be used. Waveguides are designed to work within a limited frequency range and a**

waveguide's cutoff frequency WILL NOT allow frequencies to propagate below this cutoff frequency! Frequencies above the waveguide's passband will encounter multi-mode effects and their throughput will be unpredictable.

2. Using the thumbwheel switches, select the appropriate Band frequency on both PathAlign-R's (thumbwheels must be set to the same frequency on both units).
3. Set one PathAlign-R to 'MASTER' and the other PathAlign-R to 'SLAVE' and then power up both units.
4. Observe that the LED over the appropriate band connector on each unit is lit, indicating operation of that band.
5. Face the opening of each waveguide adapter towards the other, with approximately a 3-foot space between them.
6. If both PathAlign-Rs, coax cables, and waveguide adapters are operating correctly, you should observe the following path loss (displayed on each PathAlign-R's meter):

For Band 2 (5.8 – 6.6 GHz) & a WR-137 waveguide adapter: approx. -40dB;

For Band 3 (11 - 12 GHz) & a WR-90 waveguide adapter: approx. -50 dB;

For Band 4 (18.1-19.4 GHz) & a WR-42 waveguide adapter: approx. -60 dB.

Note: The two PathAlign-Rs should typically read within 4 dB of one another.

7. The path loss you observe should be close to the above numbers. If the loss is significantly different, check or replace the coax cables or waveguide adapters and repeat the above test.
8. This completes the field operational confidence check.

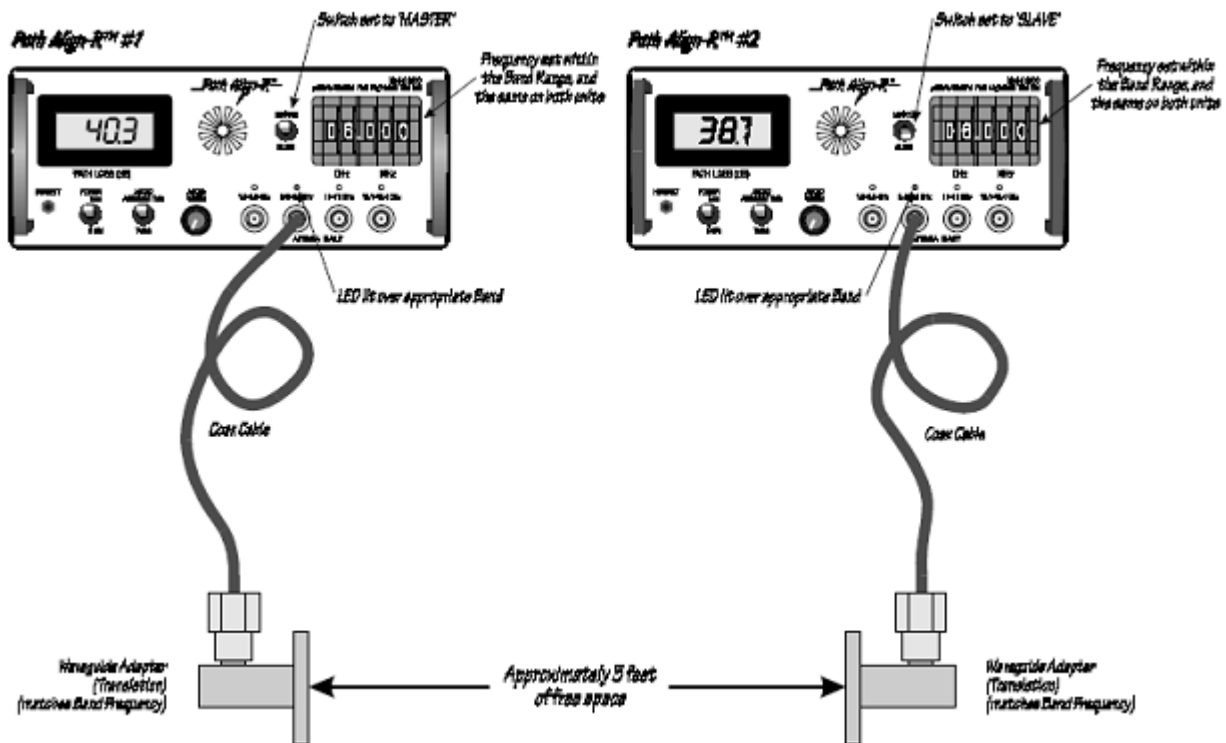


Figure 2-1. Bands 2, 3, & 4 Field Verification Check Test Setup

2.10 Preparation for Reshipment

When packing the instrument for reshipment, use the original packing materials that the instrument was shipped in.

Pack the instrument using the following package procedures:

1. Attach an identification tag to the unit indicating model number, serial number, name and address of instrument owner, and a summary of the service or repairs required. **Battery Note:** Do not reship the battery, carrying case or accessories to the factory, as these items are not covered by the warranty and Spectracom does not repair these items.
2. Wrap the instrument in heavy paper or plastic prior to placing it in the shipping container.
3. Select a strong carton or wooden box as a shipping container.
4. Use an adequate layer of shock absorbing materials on all six sides of the unit. Protect the instrument front panel with added layers of cardboard. Ensure that the unit does not move in the container.
5. Seal the shipping container with strong tape or metal bands; attach a packing list to the outside surface.
6. Mark the shipping container “**FRAGILE – DELICATE INSTRUMENT,**” and also affix appropriate handling symbols to the carton to ensure maximum care in transit.

2.11 Storage

Remove the battery from the unit. The instrument should be shelved in a reasonably clean environment and protected from dirt and moisture. Storage temperature is -40°C to 71°C (-40°F to 160°F). Place the instrument in its carrying bag or a cardboard container and seal it from dirt and moisture. **Do not wrap air-tight with plastic.**

For extended storage (periods in excess of one year), the shelf life of electrolytic capacitors must be considered. The shelf life of electrolytic capacitors is governed by the storage temperature. At a storage temperature of 25°C to 30°C the shelf life will be two years or more. At temperatures below 25°C the shelf life will be several years. When storage conditions are unknown, capacitors should be reconditioned every six months or before they are put in service. Capacitors stored for long periods, especially at high temperatures, may show significantly increased DC Leakage (DCL). The DCL can usually be decreased to original limits (capacitor restored to normal operating specifications) by application of voltage, increasing in steps to the capacitors working voltage.

At six-month intervals, the instrument's electrolytic capacitors may be reconditioned by inserting a charged battery into the unit, turning the instrument on, and allowing it to run for one hour. After reconditioning, return the instrument to storage.

3 Operation

3.1 Introduction

This section describes the operation of the PathAlign-R, Microwave Antenna Path Alignment Test Set. This description includes the front panel and the rear panel controls, indicators, and connectors, general instrument operating procedures or each mode and function, and instrument operation. **Note:** This instrument is not waterproof. To minimize weather related problems, keep instrument within its carrying bag.



Figure 3-1. Model 2240 Front Panel

Front Panel Controls, Indicators, Display, and Connectors

Figure 3-1 depicts a typical 2240 Front Panel.

3.2 Front Panel

3.2.1 Mode Selections

The following modes of operation are selectable by setting the appropriate switch [XXX] or switches. Appropriate LED indicators light (where provided) to indicate selection or operation of a function.

Name	Function
POWER On/Off:	Toggling the [POWER] switch turns power to the 2240 ON and OFF. When power to the 2240 is ON, the unit's LCD display lights and transmit power is automatically output through one of the SMA front panel connectors (provided the Thumbwheel

	Switch is set to an appropriate frequency).
AUDIO Alignment Tone:	Toggling the [AUDIO] switch selects either the internal variable alignment tone or transmitted voice from the headset or speaker.
AUDIO Volume:	AUDIO volume is a knob that adjusts the volume heard in either the hidden front panel speaker (located behind the circular front panel graphic), or the headset's earpiece. The speaker is only active when there is no headset plugged into the 'Headset' jack.
MASTER/SLAVE:	The setting of the [MASTER/SLAVE] switch affects the transmitted frequency of the 2240. The transmitted frequency will be 20 MHz above the set frequency (set by the thumbwheel switches) when the [MASTER/SLAVE] switch is set to 'MASTER'; 19 MHz below the set frequency when the [MASTER/SLAVE] switch is set to 'SLAVE'. This 39 MHz offset makes possible full-duplex voice transmission and measurement between the two 2240s.

3.2.2 Front Panel Path Loss Display

The 4-digit display shows the received measured path loss in dB.

Name	Function
PATH LOSS	The PathAlign-R has a 4-digit, 0.5 inch high numerical in-line backlit LCD display with decimal point. The display shows 4 digits of received Path Loss measurement information. Path Loss is displayed in dB with 0.1 dB of resolution. The high contrast LCD provides good readability in bright ambient light and the back-lit LCD panel provides good contrast in low light. All dB indications are negative (loss).

3.2.3 LED / LCD Indicators and Annunciators

This section identifies the PathAlign-R front panel indicators and annunciators.

Name	Function
1.5-2.5 GHz (Band 1)	Red LED. Illuminates when Band 1 is active (thumbwheel switch has selected a frequency that is within the Band's range).
3.5-5.0 & 5.8-6.6 GHz (Band 2)	Red LED. Illuminates when Band 2 is active (thumbwheel switch has selected a frequency that is within the Band's range).
7.5-10 & 11-12 GHz (Band 3)	Red LED. Illuminates when Band 3 is active (thumbwheel switch has selected a frequency that is within the Band's range).

	range).
15 GHz 18.1-19.4 GHz 22-23.5 GHz (Band 4)	Red LED. Illuminates when Band 4 is active (thumbwheel switch has selected a frequency that is within the Band's range).
Battery Charge Indicator	Icon in LCD Display. The front panel LCD meter has a low battery annunciator in its upper left hand corner. This battery annunciator will be displayed when the battery has approximately 15 minutes of its charge left. Additionally, when the battery charge becomes insufficient to properly operate the unit.

3.2.4 Connectors

This section identifies the front panel connectors.

Name	Function
HEADSET	3.5 mm (1/8") 3 conductor jack provides the Headset connection for both the microphone and the earpiece. The 'Sleeve' connector is common (Gnd.); the 'Ring' connector outputs the received modulation for 8-ohm earpieces, and the 'Tip' connector received the voice modulation from the headset's electret microphone. 5 VDC, in series with a 2.2k resistor, on the 'Tip' connector provides the electret microphone's bias voltage.
1.5-2.5 GHz (Band 1)	Super SMA female sparkplug type connector provides antenna Transmit/Receive frequencies from 1.5 GHz to 2.5 GHz/ 50Ω.
3.5-5.0 & 5.8-6.6 GHz (Band 2)	Super SMA female sparkplug type connector provides antenna Transmit/Receive frequencies from 3.5 GHz to 5.0 GHz and 5.8 GHz to 6.6 GHz/ 50Ω.
7.5-10 & 11-12 GHz (Band 3)	Super SMA female sparkplug type connector provides antenna Transmit/Receive frequencies from 7.5 GHz to 10.0 GHz and 11.0 GHz to 12.0 GHz/ 50Ω.
15 GHz 18.1-19.4 GHz 22-23.5 GHz (Band 4)	Super SMA female sparkplug type connector provides antenna Transmit/Receive frequencies from 18.1 GHz to 19.4 GHz and 22.0 GHz to 23.5 GHz and 15 GHz/ 50Ω.

Caution: When connecting the SMA terminated end of the cable to the front panel Band connector, do not over-tighten the SMA cable connector as it can damage the front panel connector's center pin. A 5/16" open end wrench fits SMA connectors; recommended torque is 8-inch/pounds. A special 5/16" open end is available from Torque Controls, So. El Monte, California. The manufacturer part number is 'A5'.

Caution: Damage may be sustained by the PathAlign-R if greater than +10 dBm is applied to the SMA connectors.

3.3 Rear Panel

Figure 3-2 depicts the PathAlign-R rear panel connectors and battery access door.

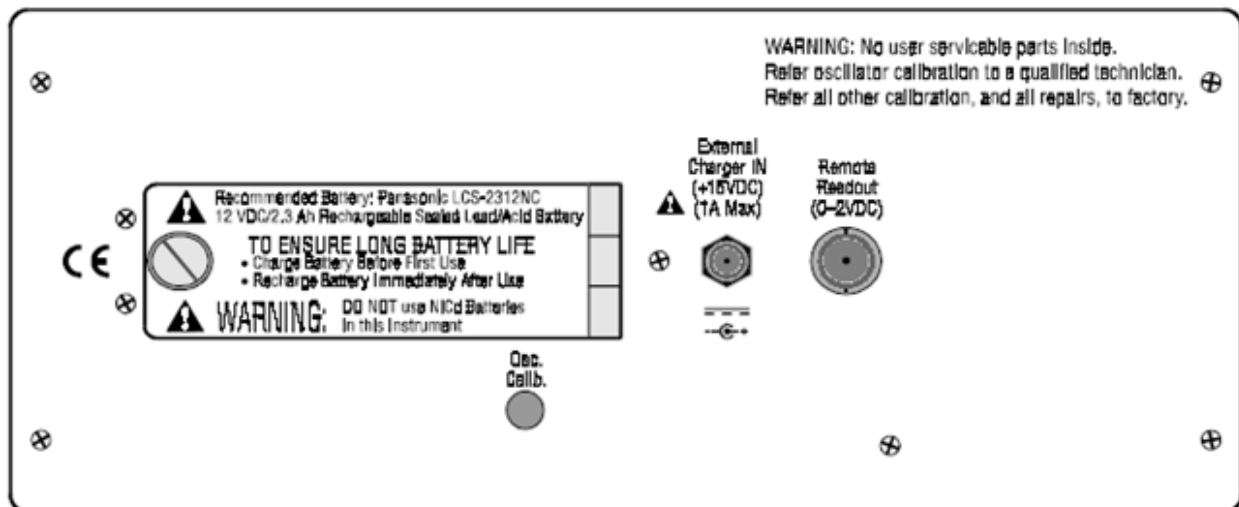


Figure 3-2. Model 2240 Rear Panel

Name	Function
Battery Access Door	Hinged battery access door provides for removal/replacement of internal battery. Door latches via a thumbscrew.
Osc. Calib.	Access hole allowing the use of a trim pot adjusting tool to fine-tune the internal oscillator during yearly calibration. Note: Refer oscillator calibration to a qualified technician!
External Charger IN	Type 5.5 mm x 2.1 mm, two-terminal battery power connector connects the external 15VDC/ 1A Battery Charger to the PathAlign-R (center pin is positive, maximum charge current: 1 amp).
Remote Readout	BNC type connector. Provides a 0-2 VDC output that tracks the front panel LCD Path Loss Meter (1 mV = 0.1 dB). Allows for external readout of path loss using a handheld DVM.

3.4 Operating Characteristics

The following paragraphs describe the operating range, band resolution, dynamic range, and overload characteristics.

3.4.1 Operating Ranges

There are seven operating ranges available: Band 1: 1.5 GHz to 2.5 GHz; Band 2: 3.5 GHz to 5.0 GHz and 5.8 GHz to 6.6 GHz; Band 3: 7.5 GHz to 10.0 GHz and 11.0 to 12.0 GHz; Band 4:

18.1 GHz to 19.4 GHz and 22.0 GHz to 23.5 GHz. The Transmit/Receive frequency range, in all four bands, is manually selected via the five front panel thumbwheel switches. Frequencies in all four bands are transmitted/received through the four 50 female Super SMA sparkplug connectors [3.5 mm] compatible].

3.4.2 Band Resolution

Resolution is defined as the value represented by the least significant digit (LSD) displayed on the thumbwheel settings. The Frequency resolution for all 4 bands is 1 MHz.

3.4.3 Dynamic Range

3.4.3.1 Transmitter

The transmitter section (signal source) of the PathAlign-R is a synthesized signal source that provides the accuracy and stability found in signal sources of this type. The output of all four band ranges is fixed at 0 dBm (1 mW) which provides for a known signal level for the second (receiving) PathAlign-R to measure against. The PathAlign-R's very stable low level signal greatly reduces the possibility that the path alignment process will interfere with nearby active sites.

3.4.3.2 Receiver

The receiver section of the PathAlign-R is a broad-band receiver followed by a very narrow-band tuned filter section. The broad-band receiver provides the necessary tuning range required of each band. The filter section allows for high sensitivity of the selected receive signal (-100 dBm, nom./1.5-2.5 GHz; -95 dBm nom./ 3.5-12.0 GHz; -90 dBm nom./ 18.1-23.5 GHz) while attenuating nearby frequencies/noise due to its narrow bandwidth (~ 100kHz, nom.).

3.4.4 Overload Characteristics

The overload point on the PathAlign-R is -30 dBm. Signals received that are less 30 dB path loss (0 dB to -30 dB) will read 30 dB on meter, regardless of level (i.e., the path loss needs to be more than 30 dB for the 2240 to read correctly).

Caution: Damage may be sustained by the PathAlign-R if greater than +10 dBm is applied to the front panel SMA connectors.

3.5 Instrument Operating Procedures

Caution: *This instrument is not waterproof. To minimize weather related problems, keep instrument within its Weather-resistant Backpack.*

Prior to operation, establish that the PathAlign-R's battery is installed and fully charged (refer to Section 2 for battery charging instructions).

3.5.1 Pre-Climb Checklist and Set-up

The following information may be used as a basic PathAlign-R checklist for technicians prior to climbing the antenna tower. A copy of this list may be found in the User Information Card that was included with the PathAlign-R. This check list is in addition to any safety issues regarding personnel and equipment that may be relevant. Safety issues regarding personnel and equipment are beyond the scope of this manual.

1. Review the Engineering Profile to determine the expected RSL (received signal level, or path loss) for the link under test (this should include the free space path loss and the gain of the antennas). Note: The loss exhibited by the installed cable or waveguide transmission lines should be included in this figure if you are connecting the PathAlign-R through these lines. When connecting the PathAlign-R directly to the back of the antenna with a short coax cable the insertion loss is minimal.
2. Both tower technicians should go over their check lists, prior to climbing the tower, to assure that, included with the Path Align-R, they have:
 - A charged battery installed! (possibly a spare if you are planning to be up for over 4-5 hours);
 - The proper waveguide-to-coax adapter for the antenna;
 - A coax cable (SMA to appropriate coax connector on the waveguide adapter);
 - The supplied headset; and,
 - A carabiner and a nylon runner of appropriate length to attach the bag strap to the tower.
3. Set one PathAlign-R unit to 'Master' and the other PathAlign-R unit to 'Slave' (it does not matter which is which, as long as they are different).
4. Using the front panel thumbwheel switches, select the proper link frequency (Note: both units must be set to the same frequency, e.g., 6.200 GHz).

3.5.2 Antenna Path Alignment Procedure

The following procedure may be used as a guide in path alignment when utilizing the PathAlign-R test sets. A copy of this procedure may be found in the User Information Card that was included with the PathAlign-R.

1. After reaching the antenna, check that the antenna polarization is properly setup (polarization should be the same for both transmitting and receiving antennas).
2. Locate each PathAlign-R unit near the back of the antenna.
3. Attach the coax-to-waveguide adapter at the back of the antenna's waveguide flange.
4. Connect the coax cable from the appropriate output connector on the Path Align-R to the adapter.
5. Connect the headset to the Path Align-R.

6. Turn the Power Switch ON. An LED will indicate which output connector is active (make sure the cable is connected to that connector) and begin talking. Typically, the antennas can be off alignment by as much as several beamwidths and the voice channel will still operate.
7. While one technician simply observes the reading of the path loss meter at his/her site, the other site commences Azimuth (horizontal) adjustment. As the voice channel is full duplex (FM), each technician can communicate with the other during the alignment process. Check for both side lobes as well as the main lobe response to ensure that the antenna is being aligned to the main lobe and not one of the side lobes. The Path Align-R sets have enough sensitivity (to -100 dB) and update speed (300 ms) to quickly check for side lobe and main lobe response.
8. To use the 'Alignment Tone' function, the technician who will adjust his antenna first, sets his front panel 'AUDIO' switch to the 'Alignment Tone' position. He now adjusts his antenna's azimuth using the alignment tone as an indicator of the resultant path loss (the front panel meters of both units are always operational). When he gets the highest tone possible, he then uses the Path Align-R's meter reading to fine tune the adjustment. One-way voice communication from his unit to the second Path Align-R is still operational, but to carry on a two-way conversation he would need to switch to 'voice' position on his 'Audio' switch. The second technician sets his front panel 'AUDIO' switch to the 'Voice' position. This provides the ability to hear the first technician's voice while he waits his turn to align.
9. Once Azimuth has been optimized, the Elevation adjustment is performed.
10. When steps 7 & 8 have been completed at the first site, the technicians switch roles and steps 7& 8 are repeated by the other technician at the second site.
11. Once step 9 is completed, for both Azimuth and Elevation, the link is aligned. As a record, note the final path loss value displayed on the meter.

3.5.3 Frequencies outside the PathAlign-R's Band Range

An antenna system whose link frequency is designed outside the frequency band edge of the Path Align-R (e.g., 6.800 GHz) can still have its path alignment correctly adjusted, as long as the antenna system (antenna, waveguide, etc.) can operate at both the link frequency (6.800 GHz) and a nearby frequency covered by the Path Align-R (e.g. 6.600 GHz).

3.5.4 Aligning Antenna Links Using Frequencies Outside of the PathAlign-R Band Range

An antenna system whose link frequency is designed outside the frequency band edge of the Path Align-R can still have its path alignment correctly adjusted, as long as the antenna system uses a waveguide which can operate at both the link frequency and a nearby frequency covered by the Path Align-R.

The main purpose of path alignment is to physically align the antenna's azimuth and elevation for maximum signal transfer (minimum path loss). All that is required is that a signal can be transmitted and received over the link so that the path loss can be measured and the antenna

adjustment optimized. The Received Signal Level (RSL) can be as low as -90 dBm and the Path Align-R can still optimize the link. If the test signal presented to the antennas is not the same frequency the antenna has been ideally tuned for (to give minimum VSWR), but is within the waveguide's frequency pass band, this test signal will still be transmitted and received over the link, with only a few dB difference in path loss from the intended link frequency...the link can still be optimized.

As an example, take a link designed to operate at 5.315 GHz using WR-159 waveguides. 5.315 GHz is between the lower and upper frequencies of Band 2's range on the Path Align-R, but the WR-159 waveguide can also accommodate 5.800 GHz (a frequency available in the upper range of Band 2). Using the Path Align-R, set to 5.800 GHz, with the WR-159 waveguide, will allow precise alignment of this 5.315 GHz link.

Of the fourteen EIA designated waveguides that span the 1.45–26.5 GHz microwave frequency range, thirteen can be used with the model 2240/2241 (ten for the model 2200) Path Align-R for link alignment. In the following section is a chart displaying the thirteen waveguides through which the Path Align-R can launch a signal and achieve optimum path alignment.

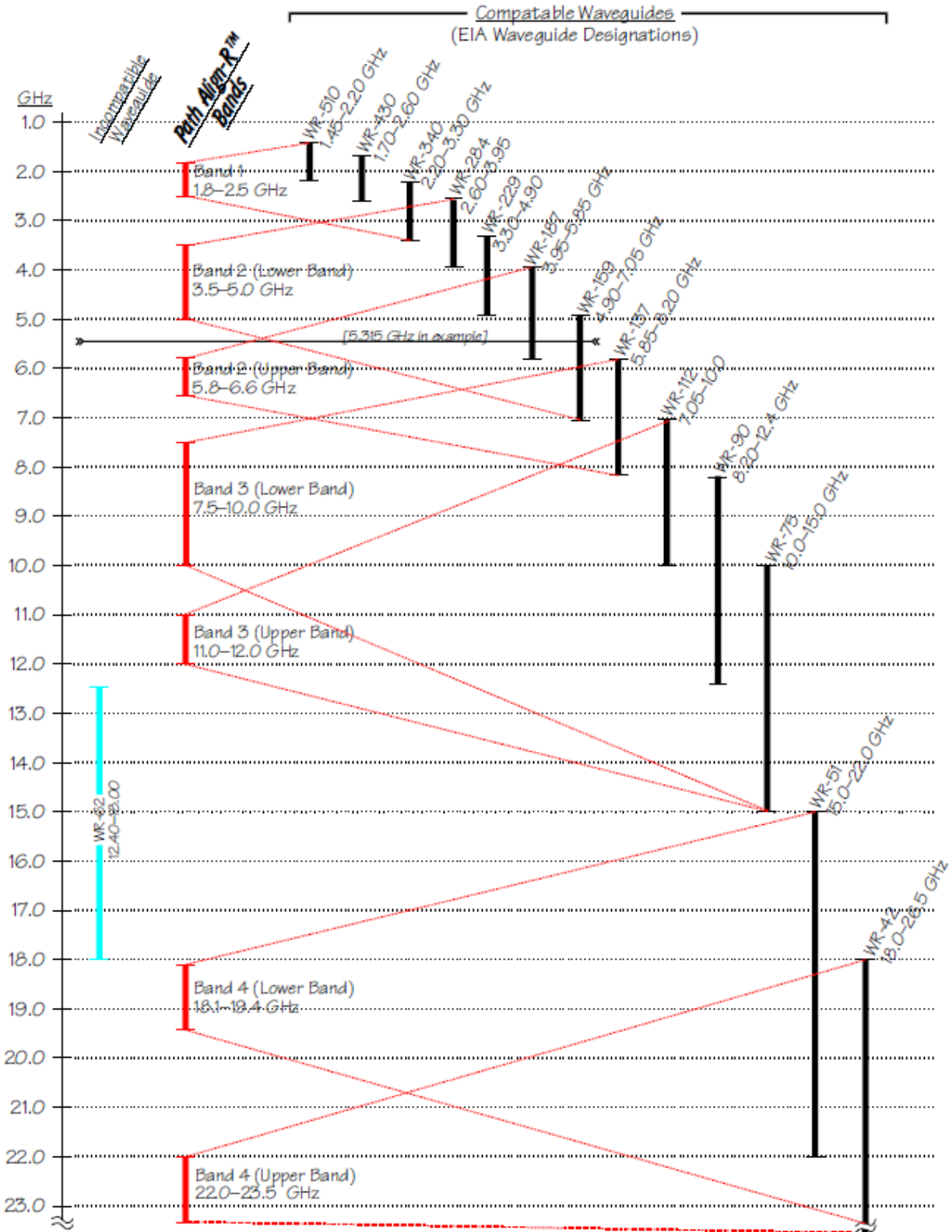


Figure 3-3. PathAlign-R to Waveguide compatibility for out-of-Band Alignment

3.6 Maintenance

Warning! *There are no user serviceable parts inside the PathAlign-R. Refer oscillator calibration to a qualified technician. Refer all other calibration, and all repairs, to the factory.*

3.6.1 Cleaning

Accumulated dirt on the exterior of the instrument or on the Weather-resistant Instrument Backpack may be removed with a soft cloth or a small soft brush dampened with a mild detergent and water solution. Abrasive cleanser should never be used.

3.6.2 Troubleshooting and / or Performance Verification

The Incoming Confidence / Verification Check procedure may be used for troubleshooting / performance verification, as a confidence check for incoming inspection, and to verify the need for recalibration, maintenance or repair.

3.6.3 Maintenance Schedule

The 2240 does not require any regular maintenance except for the recommended annual calibration of the internal oscillator.

3.7 Oscillator Calibration Procedure

Spectracom recommends that the 2240's internal reference oscillator (TCXO) be calibrated annually to a traceable Reference Frequency Standard (such as NIST) in order to maintain the PathAlign-R's guaranteed specifications.

Using a fully charged battery, turn the PathAlign-R power ON and allow the instrument to warm up for 30 minutes.

Using a 20 GHz (or better) CW microwave frequency counter, connect the traceable Reference Frequency Standard to the 'External Reference IN' BNC jack on the Frequency Counter.

On the front panel of PathAlign-R, set the thumbwheel switches to read 19.000 GHz, and the 'MASTER/SLAVE' toggle switch to 'MASTER'.

Using a nonconductive tuning tool, adjust the 'Osc. Calib.'" Trimmer, R28, on the PathAlign-R's rear panel until the frequency counter reads 19.020,000,000 GHz, ± 10 kHz.

4 Record-R Data Logging Operation

4.1 Introduction

Data logging allows the user to record the current path loss reading, physical location and data/time for later downloading to a PC, allowing for viewing, saving to disk and printing a permanent record of the results of the link alignment. This chapter describes the operation of the Record-R Data Logging function found in PathAlign-R model 2241.

4.2 Record-R Data Logging Information

The Record-R allows the results of antenna alignment, done with the Path Align-R, to be logged into internal memory. The Record-R also contains an embedded GPS receiver, which provides accurate UTC date/time and position information to be added to the above data. This logged data is saved in non-volatile memory (it is not affected by turning the instrument off) for later transfer (download) to a PC computer. Up to 250 separate data records can be saved in the field.

4.3 Front Panel Record-R Controls and Indicators

The following figure depicts a typical PathAlign-R front panel with Record-R.

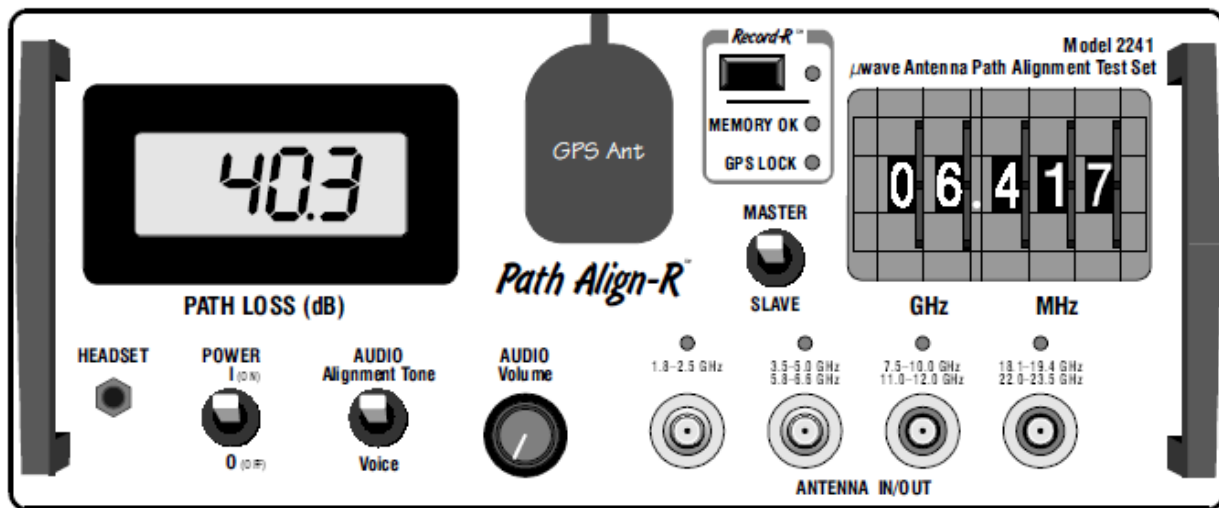
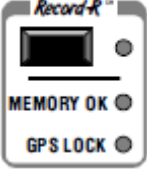


Figure 4-1. Model 2241 Front Panel

4.3.1 Front Panel Mode Selections

The Data Logging mode of operation is selected by pressing the Record-R pushbutton. Appropriate LED indicators light to indicate selection or operation of the Record-R function. Standard PathAlign-R front panel mode selections are described in Section 3.

Pushbutton Name	Function
Record-R™ 	When the [Record-R™] pushbutton is pressed, an individual data record is created and stored in the instrument's memory, provided the MEMORY OK LED is continuously illuminated. The memory used for this storage is non-volatile; it is not affected by turning the instrument off.

4.3.2 Recording Data with GPS Lock

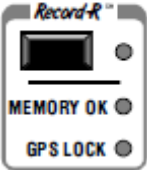
If the GPS LOCK LED is illuminated continuously when the [Record-R] button is pressed, the information stored will consist of the instrument's model number, serial number, UTC date and time, location (latitude and longitude), Frequency in use, and the measured Path Loss power in dBm. The data recorded is the information displayed at the instant the Record-R LED illuminates.

4.3.3 Recording Data without GPS Lock

If the GPS LOCK is flashing (no lock), position is not known and cannot be recorded. If the [Record-R] button is pressed and held for three seconds, until the Record-R LED illuminates, a data record will be recorded along with frequency, path loss, date and time. The data recorded is the information displayed at the instant the Record-R LED illuminates.

4.3.4 LED Indicators

This section identifies the PathAlign-R with Record-R front panel indicators.

Pushbutton Name	Function
Record-R™ 	The Record-R LED illuminates for 1-2 seconds when a data record is being recorded. When logging a data record, the data recorded will be identical to the data displayed on the instrument the moment the Record-R pushbutton is pressed.
MEMORY OK	LED illuminates to indicate that there is room in the instrument's memory to store additional records. If this LED is not illuminated, internal memory is full and records must be downloaded, via the instrument's USB or RS-232 ports, a PC and the Log View-R software utility, before further data records can be recorded.
GPS LOCK	LED has two 'ON' states: (1) The LED illuminates continuously when the internal GPS receiver is locked to three or more satellites, giving a two-dimensional solution: latitude and longitude with UTC date/time (this could take 2-3 minutes from a 'cold' start) and indicates that UTC date/time and position will be added to the recorded

	<p>data.</p> <p>(2) The LED flashes briefly once every 4 seconds when the GPS receiver is attempting to acquire satellites, indicating that there are not enough satellites locked onto to provide a fix. Date may be recorded without GPS lock but will lack position information. If this LED is not illuminated in one of the previously described ways it indicates a failure of the GPS receiver.</p>
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Note: The GPS antenna, the small plastic block located on the front panel of the instrument, should face up to the sky for best signal acquisition and GPS lock.

4.4 Rear Panel

The following figure depicts the rear panel connectors found on PathAlign-R with Record-R. Standard 2241 rear panel connectors are described in section 3.

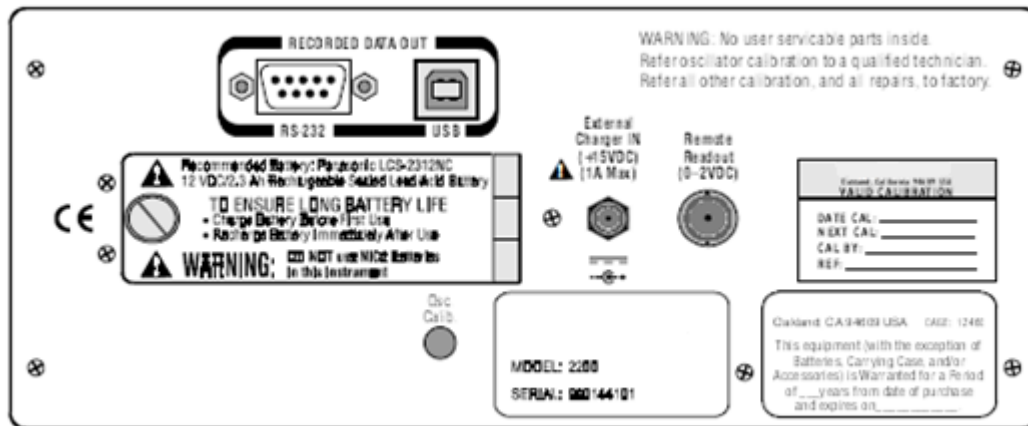


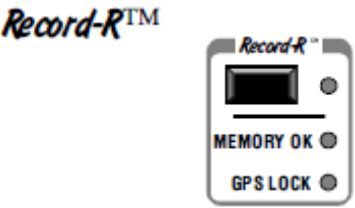
Figure 4-2. Model 2241 Rear Panel

Connector Name	Function
RS-232 RECORDED DATA OUT	DB-9 connector. The RS-232 RECORDED DATA OUT connector provides a means for connecting a PC computer to the instrument to download recorded data. This connector conforms to the EIA RS-232-C Recommended Standard. The correct cable to use is a D-sub 9-pin male to female Extension Interface Cable (not a Null Modem cable).
USB RECORDED DATA OUT	USB Series 'B' connector for peripherals. The USB RECORDED DATA OUT connector provides a means for connecting a PC computer to the instrument to download recorded data. This USB Series 'B' connector conforms to all revisions of the Universal Serial Bus Specifications. The USB data from the PathAlign-R conforms to Revision 1.1 of the specification for Low-Speed peripherals, 1.5 Mb/s.

	The correct cable to use is a USB Series 'A' male to USB Series 'B' male. Specified maximum USB cable length for Low-Speed peripherals is 3-meters (9.84 ft.).
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4.5 Incoming Confidence Check

The following information concerns the model 2241/2241A with Record-R function and is in addition to the checks detailed previously in this document. Turn on power. The three LEDs next to the Record-R pushbutton alternately turn ON and OFF in the following order:

Pushbutton Name	Function
 <p>The image shows a rectangular pushbutton labeled 'Record-R™'. Below the button are two circular LEDs labeled 'MEMORY OK' and 'GPS LOCK'.</p>	<ol style="list-style-type: none"> 1. 'GPS LOCK' on 2. 'GPS LOCK' and 'MEMORY OK' on 3. 'GPS LOCK', 'MEMORY OK' and Record-R on 4. 'GPS LOCK' off; 'MEMORY OK' and Record-R on 5. 'GPS LOCK' and 'MEMORY OK' off; Record-R on 6. All three OFF, 7. 'MEMORY OK' on (to indicate room in memory, if available) and the 'GPS LOCK' LED will pulse once every four seconds to indicate the receiver is attempting to acquire satellites.

4.6 Operating Procedures

The following paragraphs describe the procedures for recording data using the Record-R function on the PathAlign-R and downloading and saving logged data using the LogView-R Data Log Utility software and a PC computer.

4.6.1 Recording Data

When the [Record-R] button on the PathAlign-R is pressed, an individual data record is created and stored in the instrument's memory. The memory used for this storage is non-volatile; it is not affected by turning the instrument off. The information stored includes the instrument's model number, serial number, date and time, location (latitude and longitude), frequency in use and the measured path loss. The LogView-R utility allows you to access this, save all of the data records to a disk file and save individual data records to separate disk files. The data files generated are in a format suitable for importing into a spreadsheet program (.CSV).

4.6.2 Connecting a Computer to the PathAlign-R

Prior to connecting the instrument to a computer the LogView-R Data Logging Utility needs to be installed in the computer because the USB drivers that Windows needs are located on the utility disk.

The PathAlign-R can be connected to any Windows computer containing an RS-232 or USB port. When the instrument is connected to a PC computer through the USB port, the instrument

will automatically go into the talk/listen mode and normal signal acquisition will be disabled. When the USB cable is removed the instrument will automatically return to acquisition. If the instrument is connected to a PC through the RS-232 port, once the PC sends a message to the instrument, the instrument will automatically go into the talk/listen mode and normal signal acquisition will be disabled... but, removing the RS-232 cable does not cause the instrument to revert to acquisition mode, as with the USB connection. The instrument will need to be powered down and re-powered to return to signal acquisition mode.

Important Notes:

1. The proper cable to use is a USB Series 'A' male to USB Series 'B' male. Specified maximum USB cable length for Low-Speed peripherals is 3-meters (9.84 ft.).
2. The proper cable to use is a D-sub 9-pin male to female Extension Interface Cable (not a Null Modem cable).
3. If both the USB and RS-232 ports are connected at the same time, only USB port will operate as USB is inherently faster than RS-232.

4.6.3 Using the LogView-R Utility

With the supplied LogView-R software, any computer using the Windows operating system that contains a USB or RS-232 port can download data records logged into the PathAlign-R. First, install the supplied LogView-R Data Log Utility software into your computer system. Ensure that the computer and the PathAlign-R are connected. Next, run the LogView-R utility, and in the lower left corner of the utility's display, near "Connection", select the appropriate "COM1" or "COM2" for RS-232 or "USB" for USB. After a few seconds the circle next to the "Connection" will turn green, indicating that the program is communicating with the instruments.

4.6.4 Download / Save Data Records

Once communication has been established, the [Read Instrument and Save Data] soft-button will be enabled. Selecting (clicking on) the [Read Instrument and Save Data] soft-button initiates the download/save function and all records stored in the memory of the PathAlign-R instrument will be saved as a composite file to your hard drive (in the same location that LogView-R resides) and displayed in the LogView-R program (displaying fifteen records at a time). Scrolling up and down will show all the records downloaded. This operation does not clear the instrument's memory, but simply downloads and saves a copy of the logged data to the computer.

Note: If the GPS receiver was not locked at the time of the original recording, the Latitude and Longitude data will have the word 'Unknown' in those data fields. If Date and Time data are captured, the data will appear, otherwise, the word 'Unknown' will also appear in those data fields.

4.6.4.1 Viewing Previously Saved Records

Records previously saved may be recalled to the screen by selecting the [Load Records From Disk] soft-button. The PathAlign-R does not need to be connected to a computer to perform this operation.

4.6.4.2 Saving Data Records

While downloading a copy of the recorded data from the PathAlign-R the composite data is automatically saved to your hard disc under a single unique composite file name. In addition, the software also provides two soft-buttons to save data, currently being displayed in Log View-R, to your hard drive. You can save all of the records displayed under a single composite file name, or, by selecting an individual record from the composite set, under an individual file name.

4.6.4.3 Saving All Data Records

To save the composite data files displayed to a single disk file name, click on the [Save All Records to Disk] soft-button. This soft-button will be grayed out (not active) unless you have deleted some of the individual files from the previously saved composite file. Once this soft-button is active, selecting it will initiate the save function and all records displayed will be saved to disk with a unique composite file name (in the same location the Log View-R resides). Since the file name used to store composite data records is derived from the serial number of the unit and the date of the last record of this set of records, you may not change its name or location when saving it. This default file naming convention prevents confusion caused by the possibility of multiple locations of the same record or the same record existing in more than one location.

The file name for composite records is in the form:

XLnnnn_yymmdd?.CSV

Where:

'**nnnn**' is the last four digits of the unit's serial number, '**yy**' is the last two digits of the year, '**mm**' is the month and '**dd**' is the day. The '**?**' is a variable letter used to distinguish records with the same date. The first file with any given serial number/date combination is assigned the letter '**A**'. Further files with the same serial number/year/month/day combination are assigned the next sequential letters (to a maximum of 52 separate file names per day, A–Z plus a–z). When the day value changes, the sequence starts over for the new year/month/day combination.

The saved format of a composite data record file is:

Model number Line 1: **XL-2261** and firmware version (Vx.x) <CR><LF>

Serial number Line 2: **nnnnnnnnnn** (the instrument's 9-digit serial number) <CR><LF>

Record #1 Line 3: date, time, latitude, longitude, frequency, level, mode <CR><LF>

Record #2 Line 4: date, time, latitude, longitude, frequency, level, mode <CR><LF> (additional records follow, one record per line)

Note on Date/Time: Date and Time recorded within the instrument are UTC values from the GPS satellites. The time displayed in Log View-R is the local time format set in the connected PC, converted from the UTC time recorded in the instrument. In Windows, this time format choice is set through:

Windows/Control Panel/Regional Settings - Coordinated Universal Time (UTC) is the international time standard. It is the current term for what was commonly referred to as Greenwich Meridian Time (GMT). Zero (0) hours UTC is midnight in Greenwich England, which lies on the zero longitudinal meridian. Universal time is based on a 24 hour clock; therefore, afternoon hours such as 4 pm UTC are expressed as 16:00 UTC (sixteen hours, zero minutes).

4.6.4.4 Saving an Individual Data Record

You may wish to save an individual record under its own unique file name and the Log View-R software utility provides for this. After checking the appropriate 'Save' box next to the individual data record(s) you want to save, the [Save Selected Records to Disk] soft-button will become active (not grayed out). Selecting this soft-button will initiate the save function and the individual data record(s) selected will be saved with unique individual file names to a default location (the same location the Log View-R resides). Since the file name used to store an individual data record is derived from the date and time in that record, you may not change its name or location when saving it. If saving more than one individual record at a time, each record selected will be saved individually with its own unique file name. Once an individual file has been saved, the word 'Saved' will appear next to the Save box for that file and the Save box will be grayed out. This default file naming convention prevents confusion caused by the possibility of multiple locations of the same record or the same record existing in more than one location.

The file name for individual records is in the form:

XLmm_dd_hh_mm?.CSV

Where:

The first 'mm' is the month, 'dd' is the day, 'hh' is the hour. The second 'mm' is the minute. The '?' is a variable letter used to distinguish records with the same date and time. The first record at any given date/time combination is assigned the letter 'A'. Further records with the same month/day/hour/minute value are assigned the next sequential letters. When the minute value changes, the sequence starts over for the new month/day/hour/minute combination.

The saved format of an individual data record file is:

Model number Line 1: **XL-2261** & firmware version (Vx.x)

Serial number Line 2: **nnnnnnnnnn** (the instrument's 9-digit serial number)

Date Line 3: mm/dd/yyyy ('mm' is the month, 'dd' is the day, 'yyyy' is the year)

Time Line 4: **hh:mm:ss** ('hh' is the hour 'mm' is the minutes, 'ss' is the seconds)

Latitude Line 5: ('N' or 'S' followed by 'dd' degrees and 'mm.mmm' minutes)

Longitude Line 6: ('E' or 'W' followed by 'ddd' degrees and 'mm.mmm' minutes)

Frequency Line 7: **fffff** (the frequency, in MHz, of the measurement)

Level Line 8: **111.1** (the RSL, in dB, resolved to 1/10 dB)

4.6.4.5 Deleting Selected Records

The Log View-R utility allows you to delete selected records from the composite record being displayed. This operation does not delete records from the hard drive but only from the display. Once deleted, these records no longer appear in the display and a new composite record, without the deleted individual records, can now be saved (see "*Saving All Data Records*"). To delete a record(s), check the appropriate 'Delete' box next to the individual data record(s) you want to delete. The [Delete Records] soft-button will now become active (not grayed out). Selecting this soft-button will initiate the delete function and the individual data record(s) selected will be deleted from the display. Records below the deleted records will move up on the display so all displayed rows will be contiguous.

4.6.4.6 Printing Displayed Records

The records currently being displayed in Log View-R can be printed at any time by pressing the [Print Screen] soft-button in the upper right of the screen.

4.6.4.7 Clearing the Memory

In order to clear the memory in the Analyze-R of all data, you must first download/save all data records currently in the instrument's memory (see "*Download/Save Data Records*"). After downloading/saving all data records the [Clear Data in Instrument] soft-button will be enabled. Selecting this soft-button will initiate the clear operation and you simply follow the prompts.

4.6.4.8 Copying, Deleting, Renaming, or Moving Data Files on the Hard Drive

The Log View-R software utility cannot copy, delete, rename or move data files on the hard drive of your computer. This prevents accidental erasure, alteration or relocation of original data, which could not be recovered once the instrument's memory has been cleared. If it is desired to copy, move, rename or delete data files on the hard drive, these file operations should be performed using Windows Explorer.

4.6.4.9 Working with Data Files in Other Applications

To view data records saved to disk, using Windows Excel, Word, Notepad or similar applications, go to: C:/Program Files/LogView/ and highlight the file, hold down the [SHIFT] key and right click the mouse, then select "Open with...", select "NOTEPAD", "Excel", "Word" or other appropriate application; [OK]. This will display the data file in the Windows

program selected. The file can then be printed, formatted, modified, saved under a different file name, copied, exported, etc. from the selected application. The Log View-R utility saves data records in the '.CSV' (Comma Separated Variable) file format, which allows them to be imported into a spreadsheet such as Microsoft Excel. Each portion of a data record will be placed in a separate cell of the active worksheet.

4.7 GPS, Global Positioning System

The Record-R data logger, within the 2241, contains an imbedded GPS receiver that, along with the front panel GPS antenna, provides position/date/time data for incorporation into a data record. The following information is provided to aid in understanding how the GPS system operates.

4.7.1 NAVSTAR Global Positioning System (GPS)

The Global Positioning System is designed and deployed by the U.S. Department of Defense as an all-conditions, world-wide, 24-hour, three-dimensional navigation system. The system is composed of a constellation of at least 24 operational satellites, in six different orbital planes at an altitude 10,900 nautical miles, circling the earth twice a day, broadcasting radio navigation signals. This is sufficient to provide a clear view of at least four satellites at all times. One satellite is required to acquire time (once position is established), and four satellites are required for a complete four-dimensional solution latitude, longitude, altitude, and time. The GPS land based control stations track the satellites and upload orbital information (ephemera) and clock corrections. There are five monitoring stations, three up-link stations, and one master control station. The U.S. Air Force has the responsibility for this segment of the system.

The satellites transmit two spread-spectrum modulated carriers: L1 (1575.42 MHz) and L2 (1227.6 MHz). There are two 20 MHz wide spread spectrum PRN strings transmitted: Course Acquisition (C/A), broadcast on the L1 carrier, and Precision (P), broadcast on both the L1 and L2 Carriers (P code is encrypted and for military use only). At least four satellites are within sight of any ground station, 24 hours a day. Satellite position and time are derived from on-board celestial navigation equipment and atomic clocks, accurate to one second in 300,000 years however, the heart of the GPS system is ranging.

The GPS receiver determines time and position with a process that starts with measuring the time of arrival of the satellite signals. Each GPS satellite transmits its own position, its time, and a long pseudorandom noise code (PRN). The noise code is used by the receiver to calculate the range (precise travel time of the signal) from satellite to receiver. The receiver's time and position are calculated using this range data, the satellite's position and current time, and a model of the transmission path characteristics. Since the receiver knows the precise position of the satellite, and its range from the receiver, a simple triangulation calculation can give two-dimensional position (latitude & longitude) from three satellites and additional elevation information from a fourth satellite. The final solution yields an exact three-dimensional position of the receiver's antenna, as well as time, as determined on the UTC time scale (note: the Record-R does not record altitude information).

Note: An accuracy of one (1) second in 300,000 years is approximately the equivalent of an oscillator aging specification of 1 part in 10^{-13} /year. There are approximately 9.467×10^{12} seconds in 300,000 years.

4.7.2 GPS Reference Information

Almanac: An annual publication including astronomical information.

C/A: Course Acquisition.

Ephemeris: A transitory or short duration table showing the computed positions of the satellites at certain intervals of time.

P-code (Precise Code): A very long sequence of pseudo random, binary, bi-phase modulations on the GPS carrier at a chip rate of 12.23 MHz which repeats about every 267 days. Each one-week segment of this code is unique to one GPS satellite and is reset each week.

PRN: 'PRN Number' refers to a satellite's unique 'pseudo random noise' code.

Pseudo random code: A signal with random-like properties. It is a very complicated but repeating pattern of 1's and 0's.

SV: 'SV Number' refers to 'space vehicle' number.

SPS: Standard Positioning Service (civilian use C/A code).

4.8 LogView-R Logging Utility Installation

4.8.1 Software Installation

Before installing the supplied Log View-R Data Log Utility software into your computer (the computer must use the Windows 95/98 or later operating system and contain a USB or RS-232 port), ensure that the computer and the PathAlign-R are not connected. Windows 95 does not support USB, only Windows 98 and later operating systems support USB. If you are running Windows 95 use the RS-232 cable between the instrument and the COM2 port (RS-232) in your PC. Your computer display should be set to 600 x 800 or higher.

The following instructions should be followed in the order given.

1. Close all running programs before installing utility. If you are running Windows 2000 or XP on a network see note below.
2. Insert the CD into the CD drive.
3. Go to 'Start', select RUN and enter the appropriate drive letter (e.g.: D:\setup.exe) and click [OK].
4. At the "close any applications you may be running", click [OK].
5. At the "change directory", click on the computer box icon in the upper left corner.
6. At the "Choose Program Group" {Log View-R}, click [CONTINUE].
7. At the "Set-up was complete", click [OK].
8. Remove the CD from the drive. The utility install is now complete.

Note: Installation under Windows 2000 and XP on a network may need to be done while logged in as an 'Administrator' rather than as a normal user. Windows 2000 install shows a message that file `HID.DLL` is newer than the one in the install package. You will be asked if you want to keep the newer file. You should answer 'Yes' to this question.

4.8.2 Windows USB Driver Installation

After installing the logging utility, the first time the instrument/computer connection is made through USB; Windows will detect a new device and launch its "Hardware Wizard" and search for "USB Human Interface Device" drivers for the instrument. The following instructions apply:

1. In The "Hardware Wizard" window, select [Next].
2. Select "Search for the best driver for your device" (top selection) and specify the C:\Program Files\LogView (default).
3. Select "Install the updated driver"
4. If required, insert the Windows 95/98 CD and follow the on-screen instructions.
5. If required, reboot your computer to activate the drivers. The USB driver install is now complete.

5 Wireless Supporting Information

5.1 Free-Space Loss

The Friis free-space propagation equation is commonly used to determine the attenuation of a signal due to spreading of the electromagnetic wave.

Free space loss is given as:

$$\begin{aligned} \text{Attenuation (dB)} &= 92.467 + 20 \log_{10}(f\text{GHz}) + 20 \log_{10}(D\text{km}); \text{ or,} \\ \text{Attenuation (dB)} &= 96.6 + 20 \log_{10}(f\text{GHz}) + 20 \log_{10}(D\text{mi}) \end{aligned}$$

Where:

$f\text{GHz}$ = frequency in GHz, and
 $D\text{km}$ = distance between antennas (link) in kilometers; or,
 $D\text{mi}$ = distance between antennas (link) in miles.

5.1.1 Frequencies above 10 GHz

For frequencies above 10 GHz, there are several additional issues that affect propagation, including:

- Absorption due to gasses or water vapor
- Attenuation due to mist, fog, or rainfall.

Many gasses and pollutants have absorption lines in the millimeter bands but, due to their low densities, their effect is negligible in microwave and millimeter wave frequencies below 30 GHz. Water vapor, though, has an absorption line at 22.235 GHz and can affect microwave frequencies above 10 GHz. The amount of water vapor in the atmosphere at sea level can vary from 0.001 gram per cubic meter in a cold, dry climate to as much as 30 grams per cubic meter in hot, humid climates. In addition, the effects of precipitation can be significant at microwave frequencies above 10 GHz. The attenuation due to rainfall is dependent on the size and distribution of the water droplets. Because snowfall rates are generally less than rainfall rates, propagation is less effected by snowfall. For both snow and fog, the attenuation loss is a function of temperature and can vary by a factor of 3 between 0°C and 40°C [1].

Total transmission loss for a microwave/millimeter link is given by Freeman [2] as:

$$\text{Attenuation (dB)} = 96.6 + 20 \log_{10}(f\text{GHz}) + 20 \log_{10}(D\text{mi}) + \text{excess attenuation (dB) due to water vapor, mist, fog, and rainfall.}$$

Where:

$f\text{GHz}$ = frequency in GHz, and $D\text{mi}$ = distance between antennas (link) in miles.

Below is a chart showing specific attenuation versus frequency for various rainfall rates including Drizzle, Light Rain, Moderate Rain, and Heavy Rain [1].

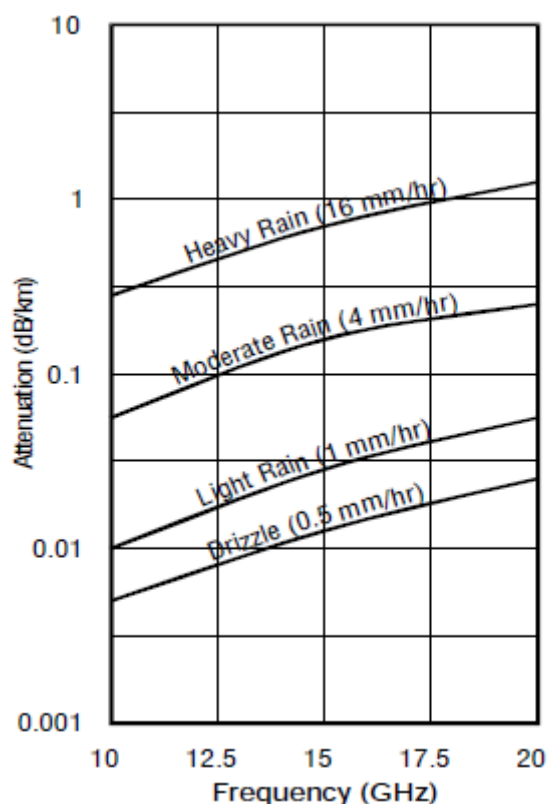


Figure 5-1. Attenuation / Frequency Chart

5.1.2 Total Path Loss

The total path loss (dB) is the gain of both antennas (dB) added together, minus the free space loss (dB) and any additional loss (water vapor, mist, fog, rainfall, and Fresnel reflection loss).

5.1.3 Fading

Fades, or variations with time, in path loss are encountered during abnormal propagation conditions. The most common type of fading is that due to multipath transmission. Combinations of irregularities and fluctuations in atmospheric temperature, humidity, and pressure cause more than one and often many propagation paths to exist between the transmitting antenna and the receiving antenna. As the atmospheric conditions vary, the routes and distances of paths also vary, causing signals of differing phases and amplitudes to arrive at the receiving antenna at the same instant. Multipath, or interference, fading is characterized by rapid fluctuations of received carrier power.

5.1.4 Fade Margin

Fade margin is the depth of fade, expressed in dB that a microwave receiver can tolerate while still maintaining acceptable circuit quality [4].

5.2 Fresnel Loss

The primary component to path loss is the free-space signal loss from the transmitting antenna to the receiving antenna. But additional path loss may also exist from multi-path reflections (sometimes called Fresnel reflective loss) due to reflective surfaces such as water near the direct wave, and intervening obstacles such as buildings, mountain peaks, etc., in the Fresnel zone.

5.2.1 Fresnel Zone

Fresnel (frä nel'), named after Jean Augustin Fresnel, 1788-1827, French physicist. The Fresnel zone is an elliptically shaped conical zone of power that propagates from the transmitting antenna to the receiving antenna due to cancellation of some part of the wavefront by other parts that travel different distances. If the total path distance between the transmitting antenna, mountain peak, and receiving antenna is one wavelength greater than the direct distance between antennas, then the clearance is said to be two Fresnel zones [4].

5.2.2 Fresnel Boundaries

The outer boundary of the first Fresnel zone is defined as the additional path length of all paths, which are one-half wavelength of the frequency transmitted longer than the direct line-of-sight path between antennas. If the total path distance is one wavelength longer than the direct path, then the outer boundary is said to be two Fresnel zones. There are an infinite number of Fresnel zones located coaxially around the center of the direct wave path. Odd number Fresnel zones reinforce the direct wave path and even order number Fresnel zones cancel the direct wave path.

5.2.3 Clearance

For reliability, point-to-point links are designed to have at least 0.6 of the first Fresnel zone clearance from any obstruction from all sides (top, bottom, left and right of the first Fresnel zone).

5.2.4 Refraction

The earth's curvature, as well as atmospheric conditions (temperature, pressure, and water vapor), can refract or bend electromagnetic waves either up, away from, or down toward the earth's surface. This bending can change frequently, hour to hour, day to night, season to season, and weather pattern to weather pattern. Refractivity is usually greatest close to the earth's surface and becomes smaller the higher above the surface you go. To compensate for this effect, a refractivity gradient, or 'K' factor, is used when designing point-to-point communication links. The 'K' factor is the ratio of the effective Earth radius to the actual Earth radius.

A 'K' factor of 1 indicates no bending of the signal; a 'K' factor of less than one means the electromagnetic wave is bent up, away from the surface. A 'K' factor greater than one indicates a slight bending downward, towards the earth. The 'K' factor value commonly used for microwave links is 1.333 (4/3) for normal atmospheric conditions, which means that the radio horizon is further away than the visual horizon.

5.2.5 Link Design

Links should be designed, using the above information, to accommodate obstructions (mountains, buildings, trees) and atmospheric conditions (large bodies of water, weather conditions, and other natural reflectors and absorbers of electromagnetic energy).

The following image displays a typical microwave point-to-point link and the basic formulas for reliable link design.

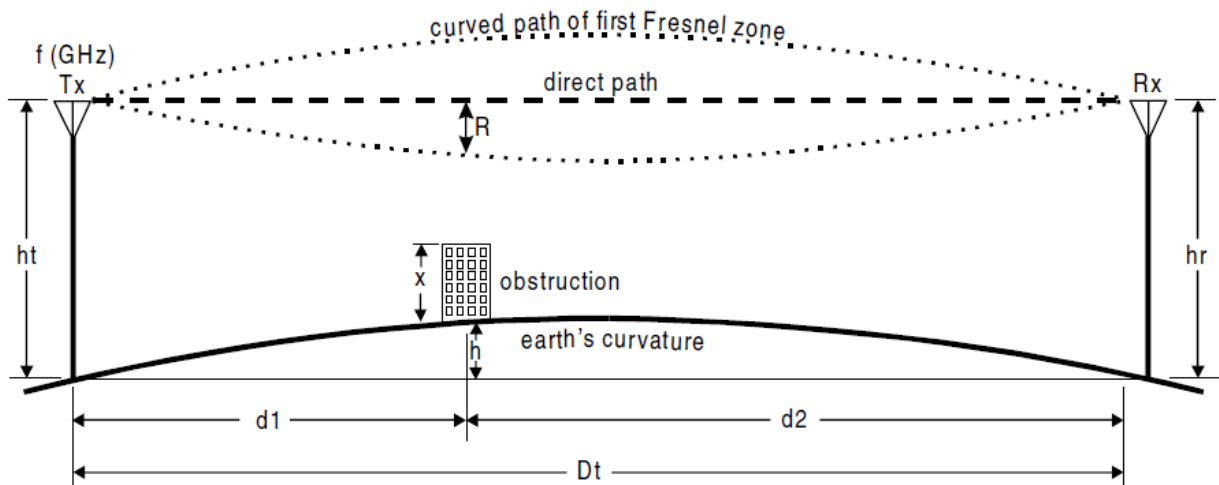


Figure 5-2. Typical Point-to-Point Link Design

Where:

- R = Curved path of the first Fresnel zone radius (at the obstruction)(in feet)
- ht = Height above the earth's surface at the transmitting antenna (in feet)
- hr = Height above the earth's surface at the receiving antenna (in feet)
- x = Height of obstruction (in feet)
- h = Earth's curvature, from a flat plane between antennas, at the obstruction (in feet)
- $d1$ = Distance from transmitting antenna to obstruction (in miles)
- $d2$ = Distance from receiving antenna to obstruction (in miles)
- Dt = Total path distance between antennas (in miles)
- f = Transmitted frequency (in GHz)

As an example, where:

- $d1$ = 1.6 miles
- $d2$ = 2.1 miles

$Dt = 3.7$ miles
 $x = 100$ feet
 $f = 0.880$ GHz (880 MHz)

The first Fresnel zone:

$R = 72\sqrt{(d1)(d2) / (Dt)(f)}$
 $R = 72\sqrt{(1.6)(2.1) / (3.7)(0.88)}$
 $R = 72\sqrt{3.36 / 3.256}$
 $R = 73.14$ feet

For 0.6 clearance from the first Fresnel zone = $(73.14)(0.6) = 43.9$ feet

Earth's curvature $h = ((d1)(d2) / (1.5)(K))$
 At obstruction: $h = ((1.6)(2.1) / (1.5)(4/3)) = 1.7$ feet

If Tx and Rx antennas are the same altitude above sea level:

The earth's curvature: 1.7 feet
 0.6 first Fresnel clearance for 880 MHz: 43.9 feet
 Obstruction height: 100.0 feet

Then the minimum h_t and h_r (antenna height above ground): 145.6 feet.

5.3 Definitions

5.3.1 Wave Length (λ)

The wavelength for a microwave frequency is given as: $30 / f\text{GHz} = \lambda$ cm

Where:

$f\text{GHz}$ = Frequency in Giga Hertz, and
 λ cm = wave length in centimeters
 e.g.: 30 GHz = 1 cm λ 20 GHz = 1.5 cm λ ; 10 GHz = 3 cm λ .

5.3.2 Antenna Gain

For a paraboloid reflector microwave antenna (greater than 960 MHz) consisting of a dish-shaped surface illuminated by a feed horn mounted at the focus of the reflector, the antenna gain is given as [6]:

$Antenna\ Gain\ (dBi) = 20 \log_{10}(Dft) + 20 \log_{10}(f\text{GHz}) + 7.5$; or,
 $Antenna\ Gain\ (dBi) = 20 \log_{10}(Dm) + 20 \log_{10}(f\text{GHz}) + 17.82$

Where:

dBi = decibels over an isotropic radiator
 Dft = Antenna dish diameter in feet; or,
 Dm = Antenna dish diameter in meters, and

fGHz = Frequency in GHz.

Note: The above formula is based on the efficiency of a parabolic antenna being on the order 55% [6]. Some manufacturers may be able to improve on this number; therefore, the gain given by a manufacturer for a specific antenna should be used, when available, otherwise the above formula will suffice.

The general formula for computing the gain of any antenna is given as: $4\pi A / \lambda^2$

Where:

A = effective area of antenna (??55% for a parabolic dish reflector antenna)

λ = wave length

Area and Wavelength must be in same unit (feet, meters, etc.)

5.3.3 Beamwidth

Antenna beamwidth refers to the width of the main radiated beam (main lobe) between two equal power levels that are 3 dB down from the peak power of the center of the main beam. Antenna gain and beamwidth are interrelated quantities and are inversely proportional; thus the higher the gain an antenna has, the smaller the beamwidth[3]. Therefore, increased care must be taken when aligning high gain antennas to insure that the antenna is accurately aligned on the center of the main beam...which could be only few degrees wide. For example; a 6-foot parabolic dish antenna at 6 GHz has an antenna gain of 38.63 dB and a beamwidth of only 1.91°.

Beamwidth is given as:

$(70 * \lambda \text{ cm} \div 100) \div (\text{antenna } \emptyset \text{ft} * 0.3048)$, or
 $(70 * \lambda \text{ cm} \div 100) \div \text{antenna } \emptyset \text{meters}$

Where:

$\lambda \text{ cm}$ = wave length in centimeters

5.3.4 Radiation Fields

The space around any antenna is usually divided into three traditional radiation fields (regions) in free space as a result of the radiated power of an antenna. These three radiation fields, where the boundary r (radius) around the antenna, are known as:

1. The **near-field**, also called the reactive near-field region, is that region that is closest to the antenna and for which the reactive field dominates over the radiative fields.
2. The, **Fresnel zone**, also called the radiating near-field, is that region between the reactive near-field and the far-field regions and is the region in which the radiation fields dominate and where the angular field distribution depends on distance from the antenna (see earlier definition of Fresnel Zone).

- The **far-field**, or **Rayleigh distance** (historically called the Fraunhofer region), is that region where the radiation pattern is independent of distance.

These distances, where D is $\gg \lambda$, and r is \gg than λ , can be summarized as follows:

Region:	Distance from antenna (r)
Near-field	0 to $0.62\sqrt{D^3/\lambda}$
Fresnel zone	$0.62\sqrt{D^3/\lambda}$ to $2(D^2/\lambda)$
Far-field	$2(D^2/\lambda)$ to ∞

Where:

D = The maximum dimension of the antenna;
 r = The distance from the antenna (boundary radius); and,
 λ = Wavelength [5].

5.3.5 Polarization

The polarization of an antenna refers to the orientation of the electric field vector in the radiated wave. For linear polarization (horizontal or vertical), the vector remains in one plane as the wave propagates through space. To eliminate polarization mismatch loss, the receiving antenna must have the same polarization orientation as the transmitting antenna [3] (*Note: If the waveguide connection at the antenna is vertically oriented, the antenna is said to have horizontal polarization and vice-versa*).

5.3.6 Order Wire

The term 'Order Wire', or 'Engineering Order Wire', is currently used with spread spectrum radios to describe the ability to have voice communications over the radio link. This term comes from the telegraph/telephone days when an 'order wire' was equipment and the circuit (specific cable pair within multi-pair cable) providing a telephone company with the means to establish voice contact between the central office and carrier repeater locations [4].

5.3.7 References

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A	2674	<i>Initial release of manual for PathAlign-R product models.</i>	June 2011
B	2702	<i>Updated address information.</i>	October 2011
C	2725	<i>Minor document maintenance and corrections.</i>	October 2011
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