TERRESTRIAL REMOTE SENSING
USER MANUAL

Remote Sensing for Geotechnics

University of Arkansas

--

Prepared: May, 2016

By Sean E. Salazar

Updated: September 8, 2017

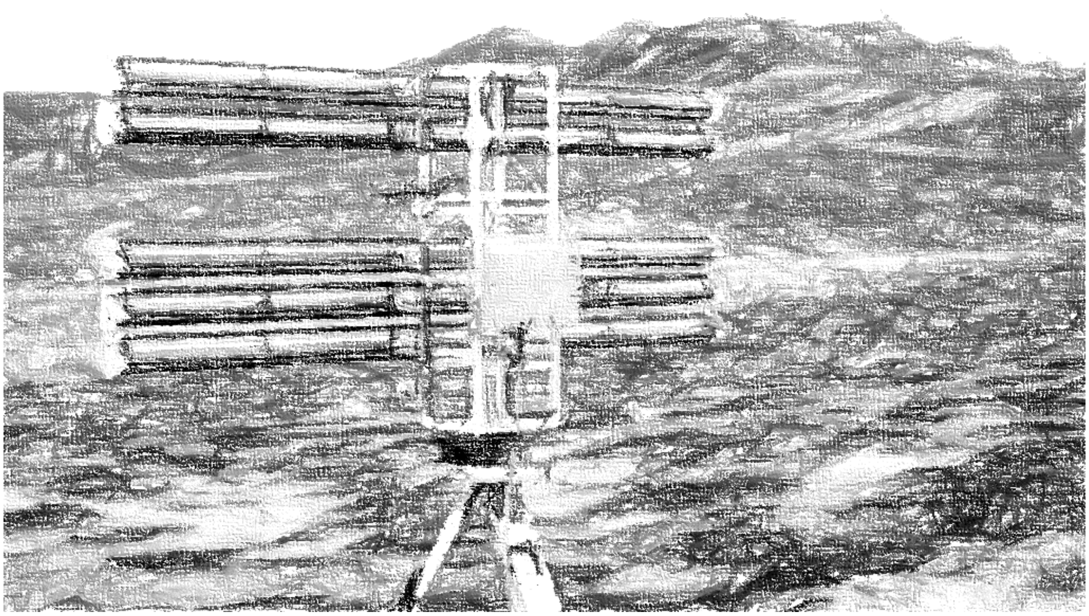


Table of Contents

--

Welcome to the *Terrestrial Remote Sensing User Manual* prepared by the *Remote Sensing for Geotechnics* research group based at the University of Arkansas, Fayetteville.

Contained within this user manual are guidelines and resources for the operation of multiple instruments employed by the research group. Specifically, these instruments include the Portable Gamma-ray Spectrometer (PGIS-2) manufactured by *Pico Envirotec Inc.*, the GAMMA Portable Radar Interferometer (GPRI-II) manufactured by *GAMMA Remote Sensing AG*, and the Soil Observation Topographic Differential Absorption LiDAR (SOTDiAL) developed at the University of Arkansas. Furthermore, best practices for safe operating conditions for each remote sensing instrument, as well as guides to data acquisition and processing are included within this manual.

--

Pico Envirotec Inc.

PEICore

PGIS-2

Operation Manual

Version 5.2.1
April 2014

Table of Contents

Disclaimer

The navigation system used within this apparatus is not a primary type of navigation and serves as a navigation aid only under VFR (Visual Mission Rules) conditions when used in an aircraft Or any other vehicle. Pico Envirotec Inc. neither assumes nor accepts any responsibility for positional errors in navigation caused by GPS system malfunctions, incorrect set up of area navigation files and / or the PEICore system software suite, or failure of the users to operate the system properly.

1 SYSTEM CONFIGURATION

1.1 SPECTROMETER (PGIS-2)

The PGIS-2 is a Portable Gamma-ray Spectrometer based on advanced microprocessor and mobile technologies. The instrument is designed for portable and mobile spectrometry surveys, in both rugged and normal environments.
The system is auto calibrated by natural photo peaks. The system consists of a detector unit, integrated with GPS, and a data logger unit based on state-of-the-art portable devices, such as a smart-phone, a tablet or a note-book. The detector can be equipped with a Thallium-activated Sodium Iodide NaI(Tl) crystal of various volumes ranging from 0.347 liter (21 cu in) up to 4 liter (256 cu in).

Depending on ground survey requirements and the size of the detector crystal, PGIS-2 can be carried by hand, in a back-pack or mounted on a vehicle.
The PGIS-2 embedded AGRS advanced gamma-ray spectrometer is widely used in geological and geophysical exploration and mapping, as well as in environmental and nuclear surveillance.
Individual and independent detector processing provides real time gain and linearity correction. The AGRS is fully automated and self-stabilizing on natural radioactive elements. This eliminates the requirement for regular and time consuming system checks and recalibration and assures accurate and reliable gamma-ray measurements.
Individual crystal detector signal processing provides an accurate control over the sensor providing the user with the best possible spectra alignment for the complete system. New design techniques for the peak detection electronics (DPD-1) has completely eliminated 'pulse pile up' and 'Dead Time' effects.

A high sensitivity GPS receiver is integrated in detection module that allows operator to be up to 50 20 meters from the measuring device. This gives an extra opportunity when installing PGIS-2 system in a different size vehicle

Technical Specifications

Detector	Support NaI(Tl) or BGO scintillation detector volumes from 0.3 to 4 liter (from 21 to 256 in^3)
MCA	ADC 256/512/1024 channels (physically 8192 channels)
Detector Resolution	Detector volume dependent - for NaI(Tl) better than 8.5% @ for 662 keV of Cs-137
Energy Range	From 20 keV to 3 MeV
Spectra measurement	1 sec spectra and data recording or data preset time of accumulation
Data Logger & Control Unit	Developed for Android based device (Tablet, Smart Phone, Laptop, etc.)
Communication	Wireless Bluetooth connection between detector and Control Unit
Stabilization	Real time (1sec) linearization and gain stabilization. Automated calibration and self-stabilization routine using natural radionuclides peaks K40, Th232 or U238. Start-Up stabilization (tuning) time less than 60 seconds
DSP Processing	DSP/FPGA MCA technology. The baseline is established for each individual pulse for maximum pulse height accuracy. Digital Pile up Rejection. Data complies with NASVD processing requirements. Fully linearized output (the Poisson Distribution is unaffected).

Spectra Analyses	Real-time spectra processing, full spectra peak analysis, automatic natural isotope in spectrum analyses, real-time calculation of spectroscopy parameters, natural a selected artificial isotopes concentration analyses. Combination of Energy Windows method & Net Peak Area method. Definition of artificial isotope detection by user (up to 20 selectable windows with bar graph and confidence calculation.
Dose Rate	Real time Dose Rate calculations in n nSv/h from spectra. Extremely wide dynamic range: more than 250,000 cps.
Non-Linearity	Differential nonlinearity <0.03%. Integral nonlinearity <0.02%. Digital (IPBR) Individual Pulse Baseline Restoration
GPS Data	Built-in precise GPS navigation with GPS Ultra-sensitive Fastrax UP501D with dual SAW filter, positioning with 1 pps synchronization, data are automatically synchronized and recorded with GPS time and location
Operating temperature	From –20° to 50° C
Battery	Build-in his capacity Polymer Li-ion battery 7.4V/9 Ah, full operation more than 12h, built-in processor charger with input 9-30VDC, external charger 12 VDC 0.5A (CE).
Visualization	LCD Graphic display, high contrast & resolution, side view, user friendly SW graphic interface. Data is displayed in real-time mode, graphic visualization of data history, full spectra display and isotope lines, real time navigation and guidance. Real time GPS data (positions, signal, speed etc.), information about battery capacity, application switching.

1.2 PGIS-2 + GEIGER MULLER (GM) DETECTOR

For the extesion of measured dose range the additional sensor was added The sensor is a proportional dual Geiger Muller (GM) detector to cover the range of the measurement from the background levels (50nSv/h) that could be detected by spectrometer up to 0.4 Sv/h in a continuous way, without the need to manually adjust the scale.

To cover such a dynamic range, spectrometer and two different volume GM detectors (tubes) are used with the intelligent detection of the ambient radioactivity to decide spectrometer, or one of the GM should be used (see **Spectrometer - GM tube switching section**). For proper operation, the range of both tube overlays is about 10% of the range, to maintain the smooth and reliable transition from a lower to higher level of measured radiation.

Switching the individual detectors ON and OFF saves valuable battery power and extends the operating time of the instrument.

GM detector	2 x GMT (energ. compensated, overlap 10% of range)

1.3 SOFTWARE MODULES

Module	Android Package Name	Designation	Description
PEICore	PEICore.apk	*Main Application*	Portable Ground Information System
PGIS-2	AGRS1.apk	*Service*	Advanced Gamma-Ray Spectrometer (1 crystal)

For a detailed description of the configuration files see the **ESSENTIALS\Configuration files** section.

2 OVERVIEW

PEICore (**PEI Instruments Core System**) is advanced, software driven instrumentation specifically designed for portable or mobile geophysical or environmental ground survey work.

PEICore is a fully integrated system incorporating sensors/detectors, an advanced Satellite (GPS) navigation, real-time path information that can be displayed over a map image (georeferenced BMP format) of the area, and a reliable data acquisition software package. Automatic synchronization of acquired data to the GPS position and time provides very close correlation between data and geographical position.
PEICore is equipped with a sophisticated software suite allowing easy maintenance and upgrades.

NOTE	We are continuously working on improvements to the performance of the program, which may cause the manual to differ slightly from the delivered software version. Any major changes in the operation procedures will be indicated and supplied with the delivered product. We are constantly endeavouring to maintain the manual as up to date with software advancements as possible. If any discrepancies or disagreements between the manual and the real operation are noted it would be appreciated if they would be reported to the manufacturer
Getting Started	*In the manual we have included the information about available detectors that could be connected to the Android smartphone. Unless otherwise specified the instructions are related to all used detectors.Detector list may expand.*

3 GENERAL INFORMATION

PEICore provides great flexibility in survey applications. It can be used to guide the operator on a pre-defined track or path plan designed to ensure comprehensive coverage of the target area. Grids can be generated using either UTM or Latitude/Longitude coordinates.

3.1 SURVEY PLANNING

A predefined survey grid plan should be designed prior to the start of the project. The **PEIConvert** application allows you to generate the area of interest. The survey area is delineated by entry of survey area corner coordinates, survey line directions and line separation. These features provide versatility of PEICore, enabling it to produce instant, effective and detailed results.

3.2 NAVIGATION

PEICore provides highly accurate navigation information, based on the satellite Global Positioning System (GPS). A GPS receiver accepting real-time differential corrections will provide high positional accuracy according to the receiver specifications. PEICore relates all collected data to the instant position from the GPS receiver and overlays real-time data over the area map. For more accurate position determination, the more sophisticated GPS receivers can be used that supports recording the raw GPS data for post-mission differential position processing. The post mission differential correction requires a set of stationary positional raw data - called “Base station raw data”. Additional software is required to process these data sets.

3.3 GEOGRAPHICAL DATABASE – MAPS

Both UTM and Lat/Long are used with PEICore. Geographical data base, as well as survey planning, is done by the **PEIConvert** program. For detailed information on this program and its usage please refer to the **PEIConvert** manual.

3.4 REAL TIME DATA PRESENTATION

PEICore displays survey path or geophysical data as it is recorded; aiding data quality control and real time navigation guidance. Real time GPS data (positions) is displayed as a path over the geographical map on the screen of the device. Real-time geophysical data is represented in charts.

3.5 DATA ACQUISITION

The PEICore application provides a multifunctional system that is used to control data acquisition, display acquired data and represent real-time navigation guidance. Acquired data, positional information and other reference data are stored in a compressed binary data format and written in up to two different data files.

Foot-path Data	This file has position data stored in it as long as the data acquisition system is running. This file cannot be turned off by the operator. It contains position, date, timing and altitude information. If no equipment is connected, only Path Data will be recorded.
Survey Data	The Data file contains geophysical data from enabled sources and all reference information (GPS position and time). Operator controls when data is recorded.

The PEICore data acquisition software performs a number of complex mathematical calculations in real time but the data collection and storage takes the highest priority. Read more in the **Data Retrieving** section.

3.6 DATA RETRIEVAL

Collected data can be retrieved from the storage media (SD Card).

Standard copying procedures from the Android devices are used. Retrieved data should be safely stored and verified for integrity before the original data in the PEICore unit is deleted. Read more in the **Data Retrieving** section.

3.7 QUALITY CONTROL

Quality control of collected data is provided by the **PEIView** program. Any loss of GPS position or spectrometry data or data that exceeds contract specifications can be detected promptly. The **PEIView** program also allows data or subsets of acquired data to be exported into ASCII and Geosoft GBN format.

3.8 NAVIGATION RE-PLOT

There is an application (implemented as a part of **PEIConvert**) that can be used to display selected survey data along the mission-path in a post-mission mode. It serves for instant QC of the instrument track-path. This is a Microsoft Windows based program and is supplied as part of the PEICore software suite.

During data acquisition, a foot-path position file is generated along with the geophysical data. The file name is prefaced with the letter "**F**" as its leading character. It contains all the track path information acquired for that particular project. In other words, each mission will have its position data appended to this file. This file can then be imported into the **PEIConvert** application supplied with the data system and can be displayed over the preplanned XYZ area file for the project.

Details of this procedure are provided in the **PEIConvert** manual.

NOTE	Since the PEI Binary file, recorded during the data acquisition process, also contains navigation information, it can be imported into the **PEIConvert** program as well and displayed over the preplanned area .xyz file for the project. Details of this procedure are provided in the **PEIConvert** manual.

4 INSTALLING AND UPGRADING SOFTWARE ON YOUR ANDROID DEVICE

Connect the USB cable to the computer; select “USB connected' and turn on USB storage to be able to copy files to/from your computer. On your computer select “Open folder to view files...” The content of the SD card will open in Windows Explorer.

You may skip this section if you have PEICore already installed on your Android device.

You need to modify your Android’s settings to allow the installation of applications from other sources. Under “*Settings*” select “*Application Settings*” and then enable “*Unknown Sources*.”

Connect the Android device to the computer (see **Connecting an Android device to the computer**).

Copy apk (Android Package) files (PEICore.apk and AGRS1.apk) to SD Card, close Explorer, and turn off USB storage.

A file manager application (ASTRO File Manager for example) should be installed which will allow you to open up the file you want to install on SD Card. If you don't have one, you can download it from the Android market. Install AGRS1.apk and PEICore.apk. Close file manager.

Creating an icon on the android main screen

From the Home screen, press the **Menu** key **>** touch **Add >** touch **Shortcuts>** touch **Applications>** select PEICore

Turning ON selected detector unit and connect and pair devices

How do I turn Bluetooth ON/OFF on my Android device?

From the Home screen, press the **Menu** key **>** touch **Settings >** touch **Wireless & networks >** touch **Bluetooth** to turn Bluetooth ON/OFF

How do I pair my device with another Bluetooth device?

From the Home screen, press the **Menu** key **>** touch **Settings >** touch **Wireless & networks >** touch **Bluetooth** to turn Bluetooth ON.

Next, ensure that the other device is in discoverable mode and then on your device, touch **Scan for Devices.**

Once the scan is complete, you will be presented with a list of devices that were found, touch on the one that you would like to pair with , type the PIN (“1234”). and touch **OK**

For **PGIS-2:**
Find the PGIS-2 (PGIS…) detector and pair with the device (password: “1234”).

NOTE The BT device name may be different.

Turning on the GPS

From the Home screen, press the **Menu** key **>** touch **Settings >** touch **Location and security settings >** touch **Use GPS satellites** to turn GPS ON (If GPS is OFF you will get a message “No internal GPS” and GPS will be turned ON silently)

5 OPERATING

Start the PEICore application by touching the PEICore icon.

IF you don't have an icon, create it via:

Menu->Add->shortcuts->Applications->PEICore.

OR select the **Install App Shortcut** option from the Shared Preferences (see **Shared Preferences).**

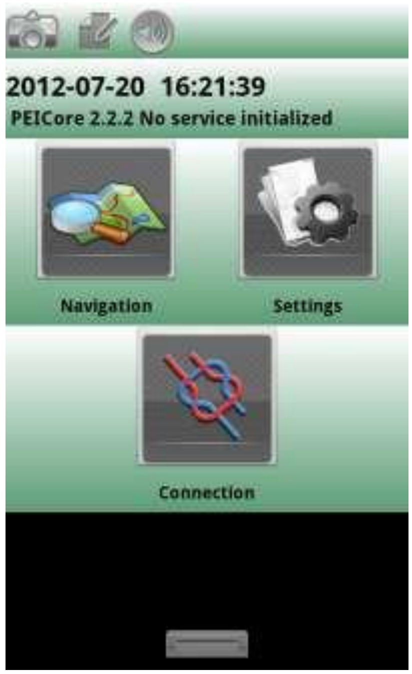
5.1 CONNECTION TO THE DETECTOR (DEVICE)

Check the detector LED sequence – before communication starts you should see only green (and red – depends on battery level) . If you see blue light – detector is connected and it's better to restart it.

Light Connection on application start is done automatically.

If the smartphone (Android device) is unable to connect the BT device (detector) or you want to connect to the different BT device (detector) press Back button to exit from the "Connecting…" Progress Dialog. You will get the message "Unable to connect device" This message will continue to appear until the new connection will be established You may touch the Connection icon  on the main dashboard and then EXIT from application and START over again.

In this case when you start PEICore you will see the following screen.



Touch the Connection icon  on the main dashboard . In case only one service (PGIS,) service is installed the list of paired BT device will appear on the screen. Make sure that the BT device s ON and select it.

If there is more then one service installed select one of the sensors/detectors (shown below).

Select the appropriate detector (dosimeter, spectrometer or magnetometer) and press the "Connect" button.

The available device list will appear:

NOTE

When you select a sensor/detector the icon should pop up. The proper detector name **(PGIS-2 (spec))** will fade in and the appropriate settings will be available.
Once the device is selected it will be stored in the configuration file and there will be no need to select it for the same detector.

Wait until the connection procedure has finished and the **"…Service Started"** message appears. Close the Connection View (you may also touch the color ball in the center to close the current view).

NOTE1

If the device is undetectable you will see the following message:

Make sure the BT device has power. Restart both the detector and the Android device. Try to connect again.
Check the detector LED sequence – before communication starts you should see only green (and red – depends on battery level) . If you see blue light detector is connected and it's better to restart it.
Try to Unpair- Pair back the detector unit.
Check if services : AGRS1.apk (PGIS-2) is running. Force the applications close.

Sometimes this message will appear just once at the beginning of communication, which could be caused by a start delay.

If the BT device is connected but no data could be delivered, you will receive the following message:

NOTE2

That may happen if the application is trying to connect to a device different from the selected BT detector/sensor or if it was not closed correctly in the previous session. Make sure the BT device has power. Try to unpair the device and pair it back. Restart both the detector and the Android device. Try to connect again.

Sometimes this message will appear just once at the beginning of communication, which could be caused by a start delay.

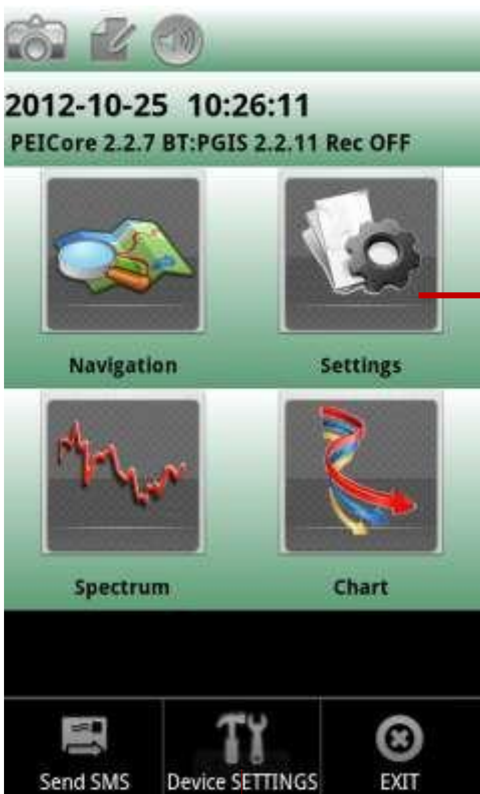
5.2 MAIN (DASHBOARD) VIEW

The Main (dashboard) view allows you to use navigation (no connection required), connect to the sensor/detector and obtain information for the current configuration.

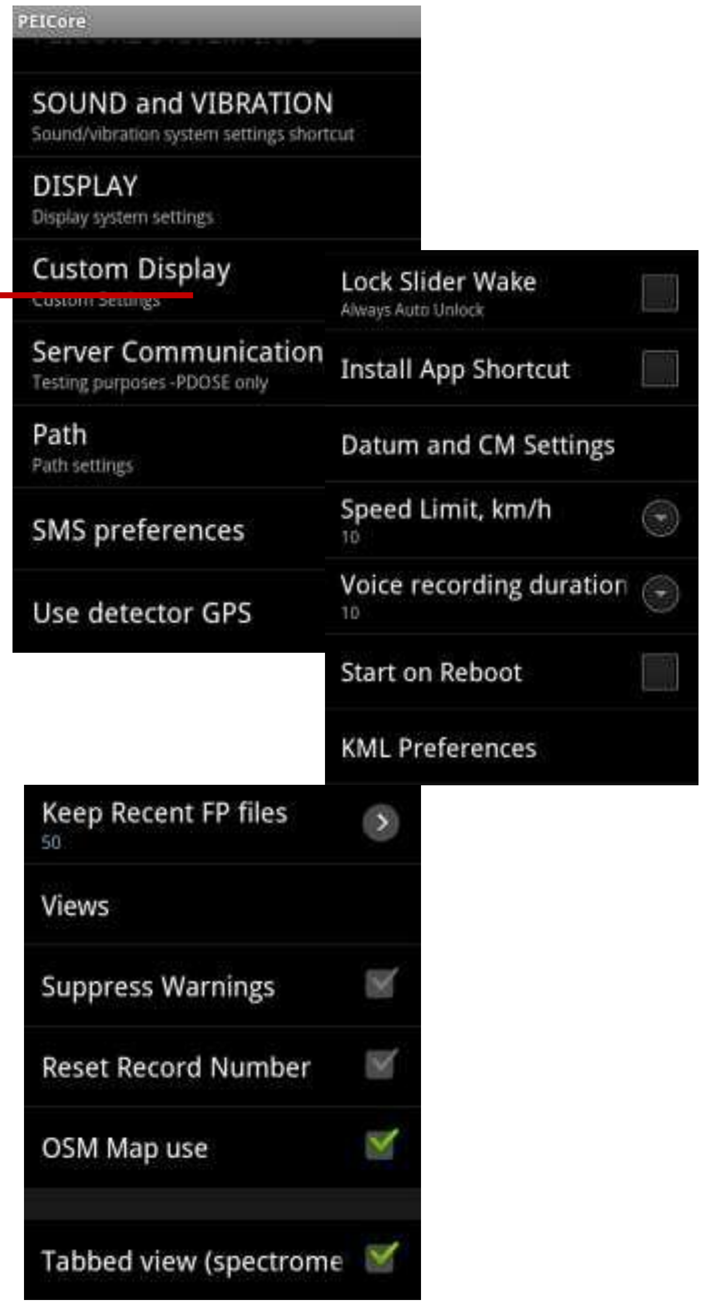
At the bottom of the Main View there is a button for Common Dialog that gives you quick access to Turn ON/OFF Sound, Vibration and Station Mode. The Common Dialog is accessible from every page of the PEICore application. Station Mode is described in the **Station Mode** section.

Notes & references to the images/audio files are stored in FP binary file (one-second fooot-path data) as well as in the exported KML. KML file and the original georeferenced photo and audio files is stored in the PEI/FP/NOTES/<*folder named after FP file*>. You can change the image resolution to reduce the size of the image and the resulting size of the KMZ file.

5.3 SHARED PREFERENCES



Select Device Settings menu Item to open Device Specific Settings

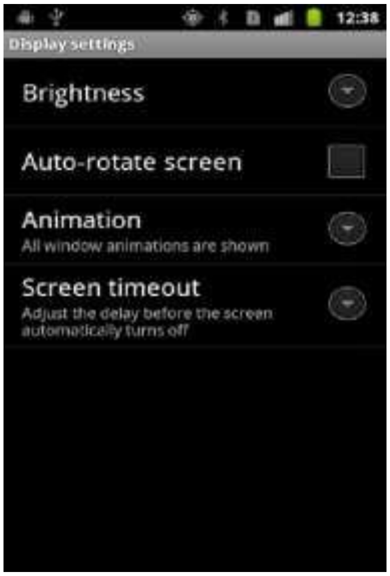


5.3.1 SOUND and VIBRATION

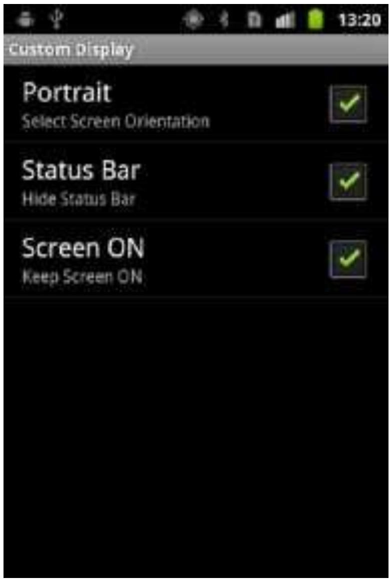
Get access to the system **Sound settings** page and adjust the volume and vibration according to your needs.

5.3.2 DISPLAY

Get access to the system **Display settings** page and adjust the screen settings according to your needs.



5.3.3 Custom Display Settings

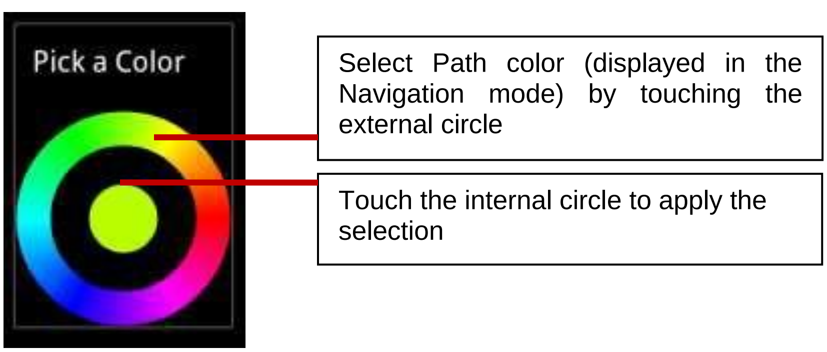


Some custom display settings are also available:

- Set Portrait or Landscape mode – application will keep the selected orientation independently of system display settings
- Show/Hide Status bar – save screen space
- Keep screen ON – uncheck this option to save battery life.

5.3.4 Path

Path Color



Drawing Path

Trajectory will not be drawn (Navigation mode) if the Drawing Path checkbox is unchecked.

Data Logging Frequency

Set 1 2, 5, 10 value for record data in PEI format (Foot-path & Dose data) once in 1, 2, 5 or 10 seconds (for example)

5.3.5 SMS Preferences

The „panic“ SMS number may be stored for sending SMS that contains current location.

5.3.6 Use Detector GPS

Use Detector GPS (NMEA strings coming from detector). If unchecked – internal Android GPS will be used.

5.3.7 Lock Slider Wake

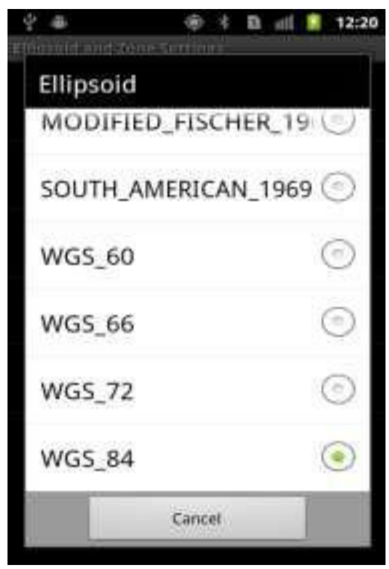
The Lock screen is shown on the slider wake – the usual lock glass screen will appear once the Android device wakes up.

Always Auto unlock – use this option to wake up the Android device by hitting the button. No glass swipe will appear.

5.3.8 Install App Shortcut

As mentioned above, select this option if the main desktop PEICore icon is missing.

5.3.9 Ellipsoid and Zone Settings



PEICore uses the following information to define the datum:

An **ellipsoid**, also called a spheroid. This is an ellipse rotated around its minor axis to form a three-dimensional surface. The ellipsoid is described by two mathematical parameters: the length, in meters, of its semi-major axis and its degree of flattening. See Appendix A for the list of available ellipsoids. By default WGS84 is selected.

Three **shift parameters** specifying the distance, in meters, to shift the ellipsoid along each of its axes. These parameters are denoted by dX, dY, and dZ.

Central Meridian (CM) can be defined in case the survey is covering two adjacent zones. In this case navigation will be persistent. Survey map and Area (*.xyz) file should be created and used for the desired zone (CM). By default the CM is defined from the first GPS string obtained. See Appendix B for the Central Meridian and Zone reference.

5.3.10 Speed Limit

Enter Speed Limit (in km/h) to get notifications about exceeding the limits.

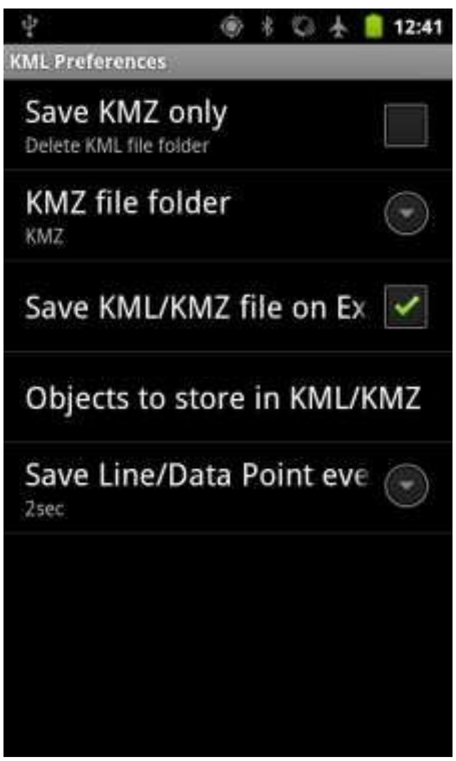
5.3.11 Voice recording duration

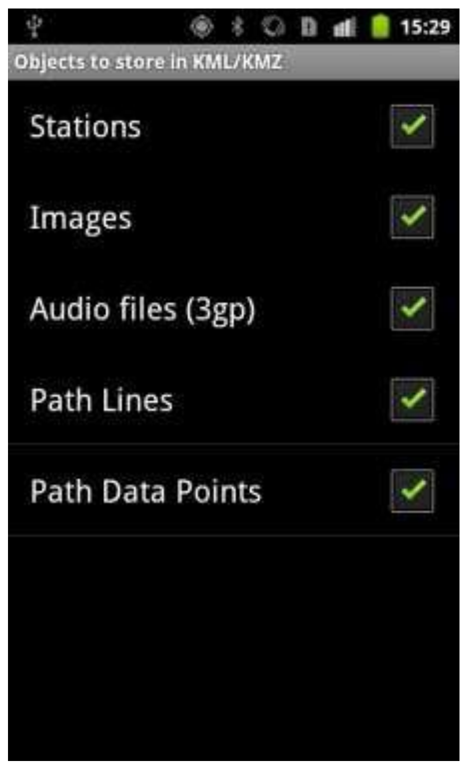
Enter duration for recording files in *.3gp data format (you always can stop it earier)

5.3.12 Start On Reboot

Check this option to start PEICore application when the phone reboots.

5.3.13 KML Preferences





KML/KMZ export support was added for quick data visualization (as a layer of Google Earth) when the survey session is finished.(see **KML data presentation** for the detailed description). Take a look at several options (on the images above) that will help to present the survey data in the best way.

KMZ (zipped KML file & georeferenced images/audio files) file format allows you to share your data with partners by sending out just one compact data file. For your convinience it is stored in the ./KMZ folder (you can change this). Check **Save KMZ only** to delete the source KML (zip) folder.

Save KML/KMZ file on Application Exit means that you may also save the KML/KMZ file using the app Exit Dialog..If checked, an additional button Save KMZ/KML will be created in the **Exit** dialog. Uncheck it if you are not going to use KML files.

Stations, Images Audio files references are saved in KML (however, you can find georeferenced images and audio files in PEI/FP/<*specific FP folder (the same name as FP binary data file*)>/ folder) if **Save KMZ only** option is unchecked. If the option is checked KML file folder will be deleted and only zipped KMZ file will be available.

Once Path Lines or/and Path Data Points are checked, you can change the frequency of saved data points.

5.3.14 Keep Recent FP Files

Every time you start PEICore your position (and additonal data such as speed, elevation etc.) is recorded in the FP (foot-path) file. It was decided to keep the last N file, no matter how old they are (you will always have the last recorded N files). Set the number of recent FP files you want to keep.

5.3.15 Views

Check the Maps &/or Charts if you want the view shortcut to be presented on the dashboard (UI simlification)

5.3.16 Supress Warnings

Check to supress all warnings

5.3.17 Reset Record Number

Every time you start/stop recording the fiducial number is saved.To set the fiducial number to 1 – check the „Reset Record Number“ checkbox

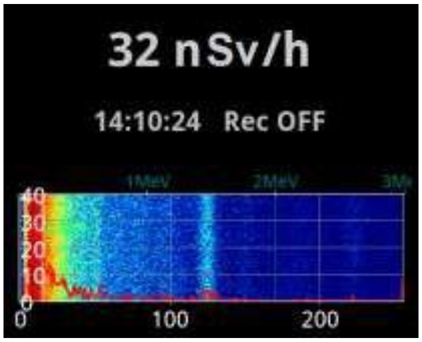
5.3.18 OSM Map use

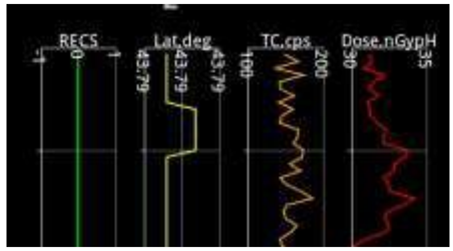
You have a choice to select between using online/offline Open Street Maps or use the georeferenced bmp created by PEIConvert. For more details on both options see Navigation.

OSM Map

Geo-referenced bmp

5.3.19 Spectrometer Mode /Tabbed view





This option allows you one-click access to the charts view from the spectrometer view without returning to the main dashboard

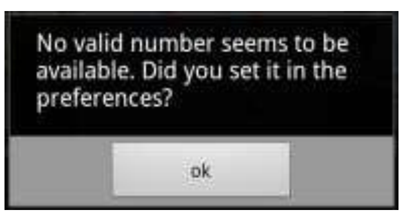
5.3.20 Spectrometer Mode : *Radiometrics/Spectrometry* or *Geophysics*

Select one of two mode to display the more appropriate information from the Spectrometer (for details see *Spectrometer View – PGIS-2*)

5.4 SEND SMS

Store valid number you want to connect via *Settings -> SMS preferences.* Once the valid number is stored you can send SMS from the main (dashboard) screen using **Menu** ->Send SMS;

If there is no valid number you will see the following message:

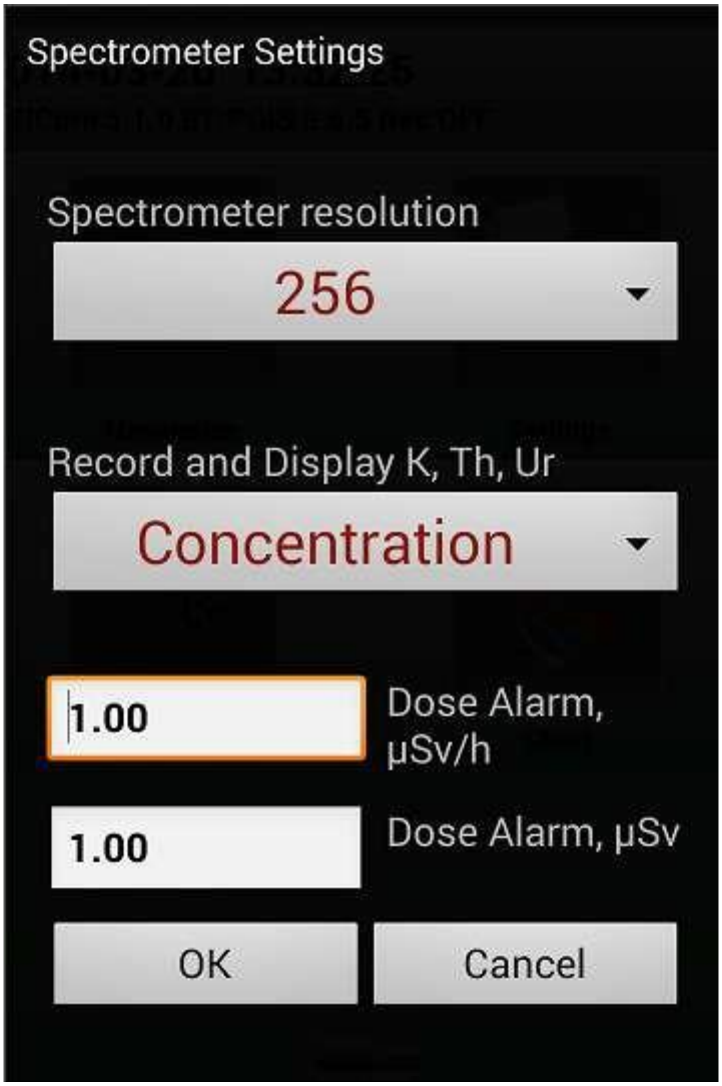


SMS message is generating automatically and contains:

lat = <current latitude>; lon = <current longitude>

5.5 DEVICE SPECIFIC SETTINGS

5.5.1 Spectrometer (PGIS-2)



Spectrometer resolution can be set for 256, 512 or 1024 channels.
K, Th Ur are recorded as Windows (cps) and either as Concentrations (pct, ppm) or Activity (Bq/kg)
3-sec filtering is used to smooth the data.

5.6 NAVIGATION VIEW

On the Main Screen touch the Navigation icon. 

5.6.1 Using Static bmp as a background

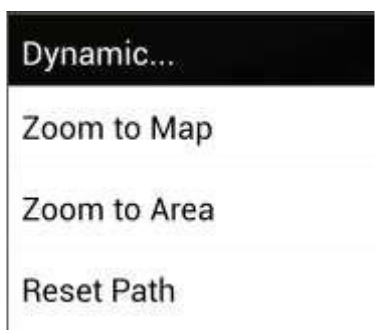
Navigation mode may be used without any connection to the device. The foot-path (path) file will be recorded while the PEICore application is running (Data is stored in PEI\FP folder). In-build navigation is intended to use maps and xyz files that were prepared by **PEIConvert**. Different maps and xyz (project) files may be loaded in runtime.

No Wi-Fi is required for this mode. You can always use your preferable third-party online and cached navigation.

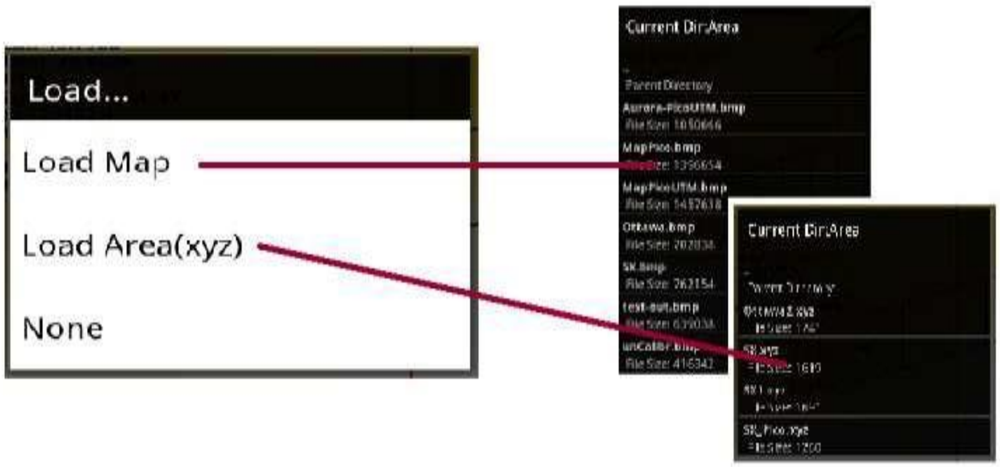
Press the **Menu** button  to see the menu below:

Lock – Switch Lock mode On/Off. In Lock Mode you can select one of the predefined Objects (Survey Line, Tie Line or Way Point). Touch the screen close to the desired object and it will be highlighted.

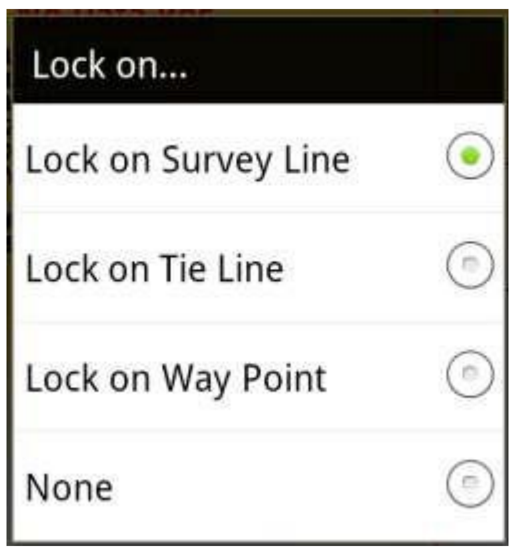
Dynamic... submenu allows you to **zoom in** to a loaded **map**, loaded **area**, and reset (clear) current path.



Load...submenu contains three items: **Load Map, Load Area** and None. You may load georeferenced *.bmp and *.xyz file that were prepared by **PEIConvert** and uploaded to the **PEI\Area** folder. In case the directory exists and is not empty you will see:



Lock on



After the object is selected in the LOCK MODE don't forget to press the < **Lock**> menu item **again** to actually lock on the object. The Object name will be saved in the regular data file.

Next Obj, Previous Obj - lock on next/previous selected object.

Once the object is locked you will be navigated and information about the locked object will be stored, both in track-path and data file.

Map and area file names will be saved after the current work session is complete. This information will be retrieved for the next session.

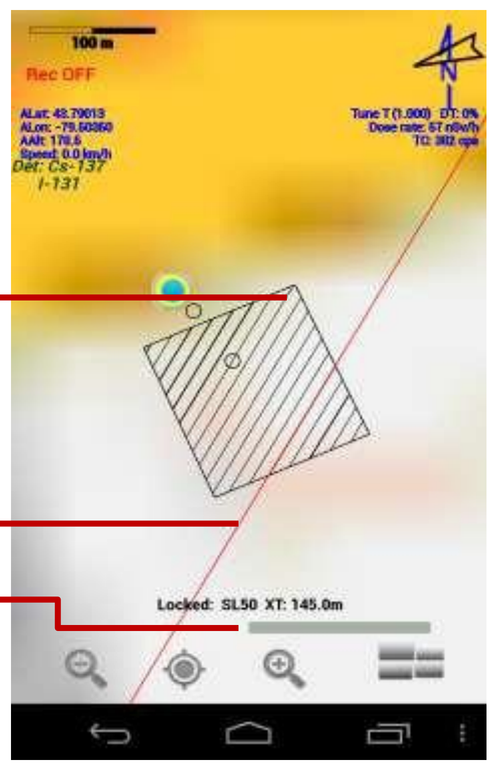
Scale

Compass

Current position info:
Tap in the position area to get Lat/Lon, **or** UTM position, Zone & Central Meridian

Current Location
Outline of the icon:
YELLOW - normal
GRAY - NO GPS Fix
RED - service is connected but no data is being received.

Open Common Dialog



Loaded Area and Survey Lines (SX_Pico.xyz)

Locked on SL90 (Survey Line). Cross Track (XT): 26.4 m. Navigation Bar (dark green) is shown below the text

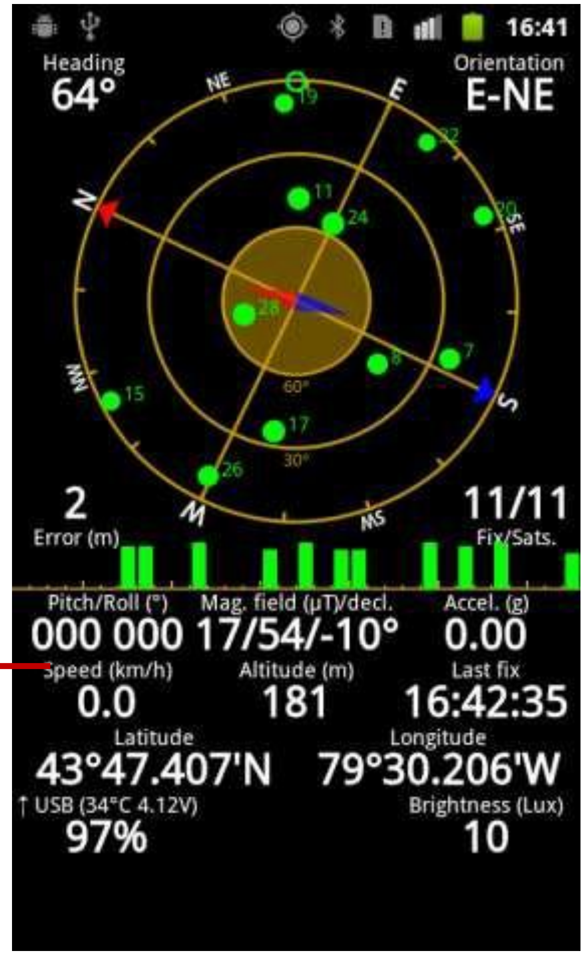
Third-party GPSStatus (free application) may be invoked.

Tap in the Compass area  to see the screen shown on right.

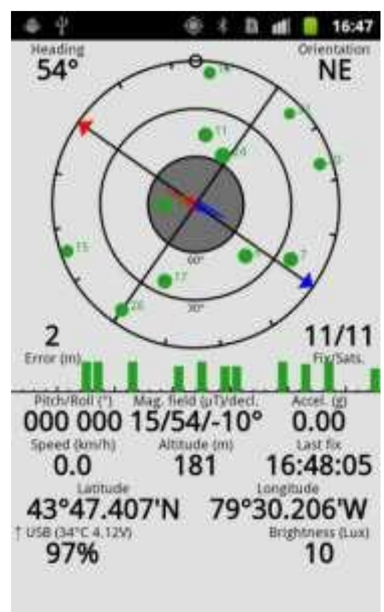
If a GPS Status application is installed on your Android HHC the GPS Status screen will appear.

If application is not installed you will be guided through the installation, if you wish to do so.

GPS Status Screen



Full information about internal GPS is graphically displayed in the convenient UI. A lot of custom settings (including daylight color theme is available).



To exit from the Navigation Screen use the **Back** button. 

5.6.2 OSMdroid support (Open Street Map)

The OpenStreetMap is a full/free replacement for Google Map class. The big advantage is that you have online/offline maps with zoom support. For offline usage you can pre-cache maps, for when you are in areas without cell /wifi coverage. Map tiles will be cached automatically if the app will be opened in the area with coverage.

Several overlays where added to OSM map – the same functionality as for the static map was implemented:

PEICore - on Tablet

Various map style could be selected: Cloudmade, Mapnik, MapQuest, Open Cycle Map etc.
Additional info about preparing maps for the offline usage see appendix D.

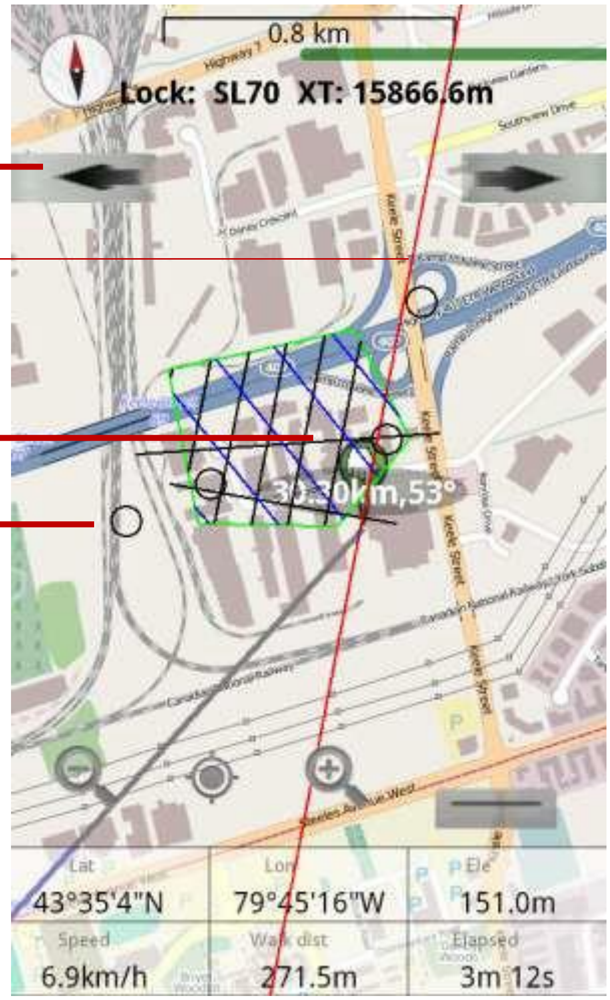
NOTE PEI XYZ file (contains Area, Survey Lines, Tie Lines, Special Lines, Way Points **must** have the coordinates in Degrees (Lat/Lon) – an option to save the *.xyz file in PEIConvert (appendix C)

Previous, Next Object (WP, TL, SL) selection

Locked on SL70 (Survey Line). Cross Track (XT): 16km.
Navigation Bar (dark green) is shown below the text

Loaded Area and Survey Lines (SX_Pico.xyz)

Way Points



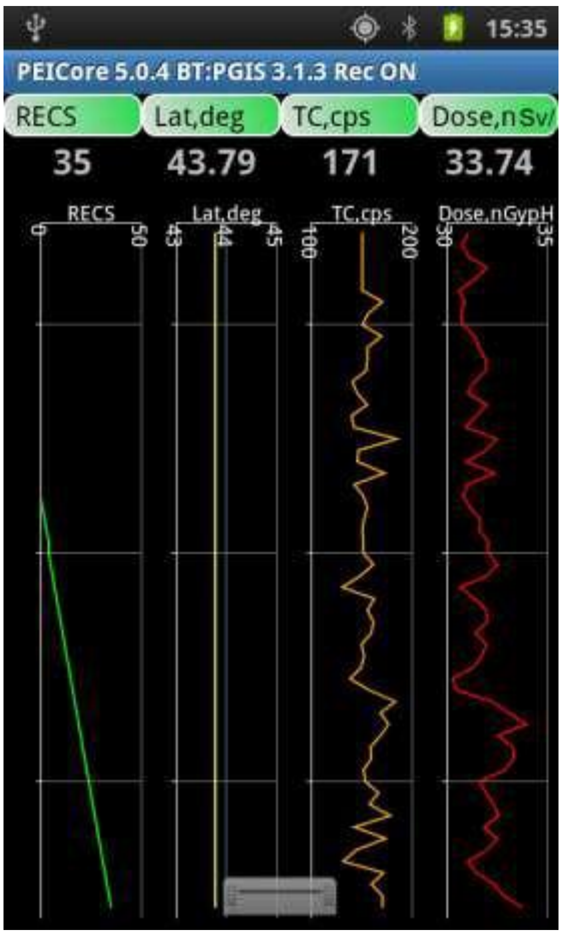
To select the point long press on the screen. After marker  appears select menu item NAVIGATE. If you have loaded PEI XYZ file and selected object to Lock On (select from SL, TL, WP) - the closest object will be selected and highlighted/ In case of no Lock object was selected or (and) no xyz file was loaded you will see just the bearing line with calculated distance.

You can choose between static georeferenced bmp (created by PEIConvert) and OpenStreetMap View by selecting the Preference **OSM Map use**. Goto Settings (main dashboard) and uncheck/heck **OSM Map use** check box.

5.6.3 Charts View

On the Main Screen touch the Charts icon. 

The Chart View includes graphical representation of the data received from the available sensors and GPS data. Data channels are chosen from the combo boxes (see the upper row). Charts channels will be saved after the current work session is complete. This information will be retrieved for the next session.



To switch between two views (multi-charts and single chart) touch the chart area.

NOTE The Charts channels sets are different for different BT devices.

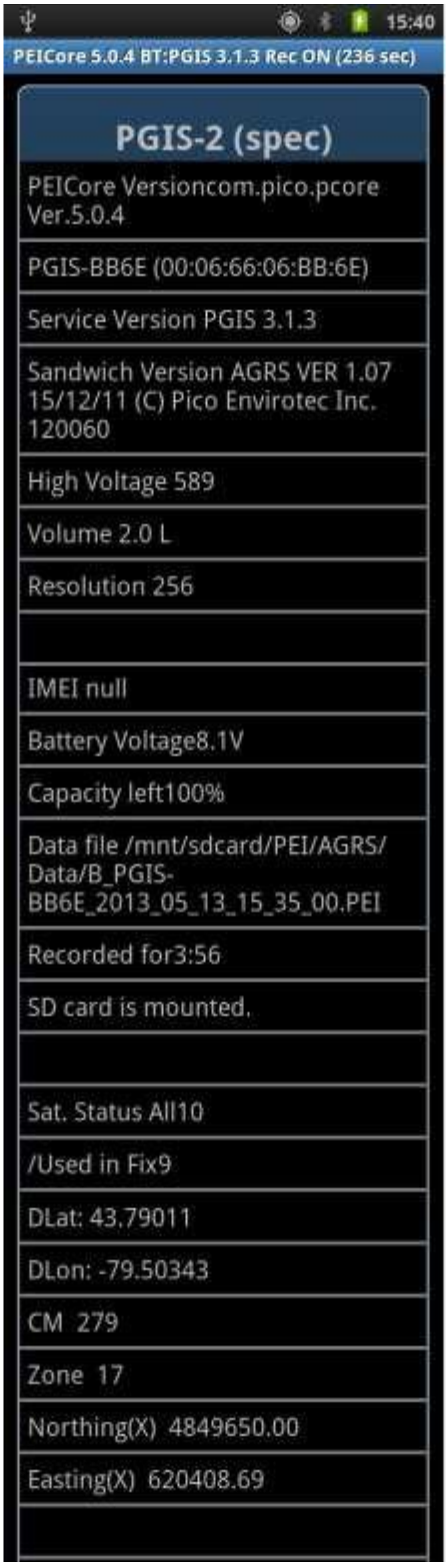
To exit from the Charts screen use the **Back** button. 

5.7 INFO VIEWS

Information is presented in the different Info Views:

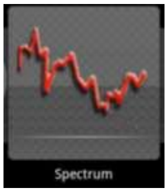
No connection screen

5.7.1 PGIS-2 Spectrometer screen

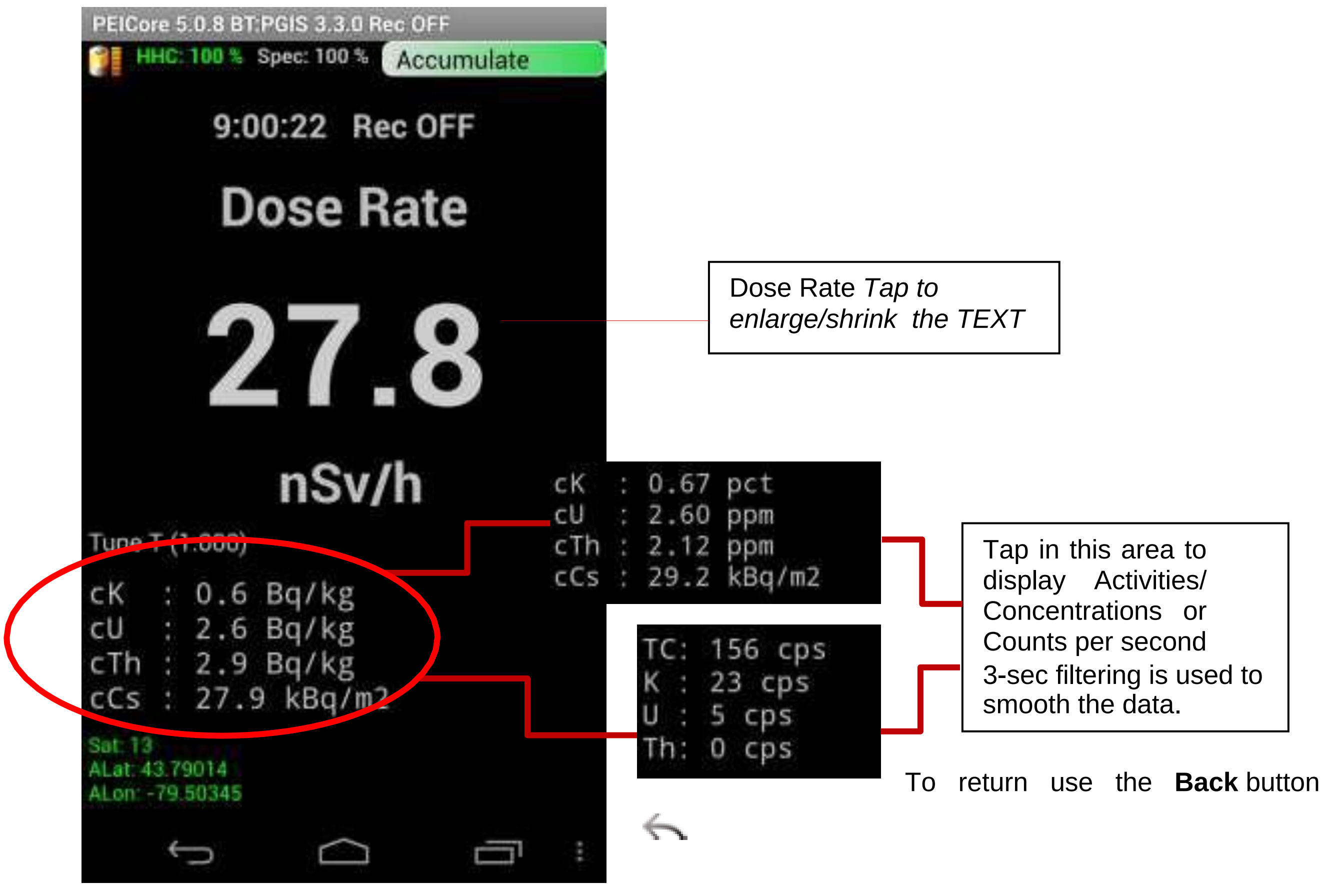


5.8 SPECTRUM VIEW (PGIS-2)

Once you have selected PGIS-2 and have connected to the Advanced Gamma Ray Spectrometer (AGRS) the Spectrum screen is available.



5.8.1 Spectrometer Mode – Geophysics



Current Positon may be displayed for Android (ALat, ALon) or Detector (DLat, DLon) GPS Go to Preferences to select the desired GPS.

Detector GPS may get the location from external or internal GPS. In case of External GPS is in use, you will see "**/Extern**." after the **Sat**. indication

5.8.2 Spectrometer Mode – Radiometrics/Spectrometry

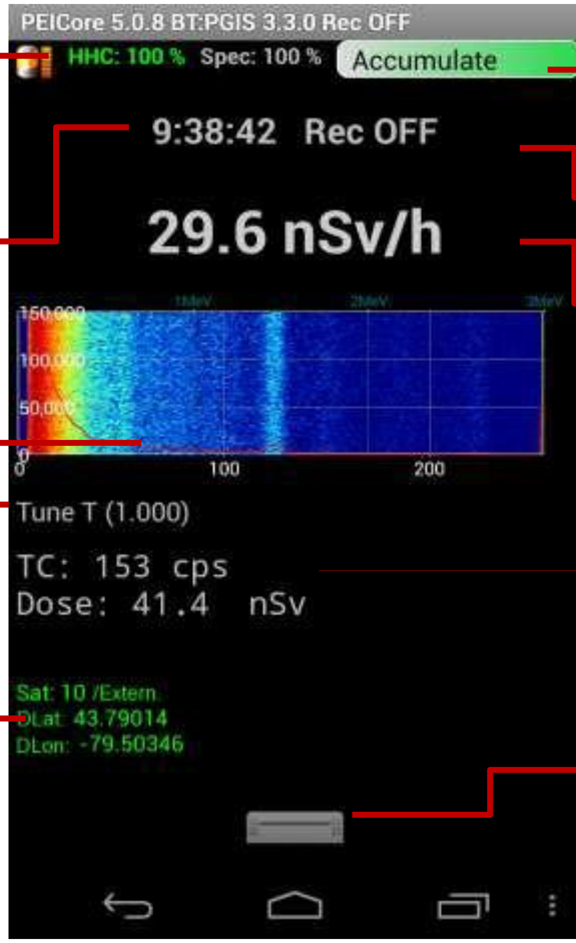
Battery Charge Monitor. Battery status expressed as a percentage for both handheld device and Spectrometer

Current Time

Incoming Spectrum: ***Tap to go to the expanded/full Spectrum view***

Tuning Status (Gain)

Current Position :



Display mode selection: Normal – 1 sec data/ Accumulation/ Average/ Compton Removed

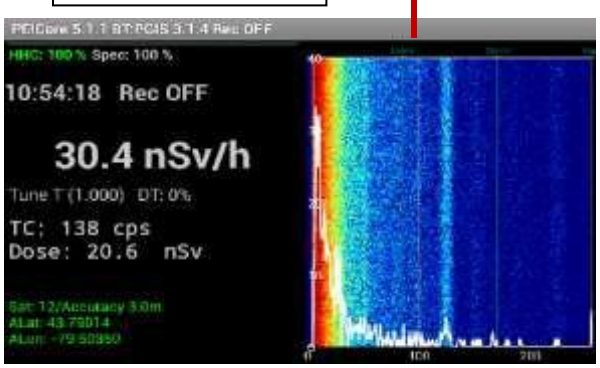
Recording Status/Record Number

Dose Rate ***Tap to enlarge the TEXT***

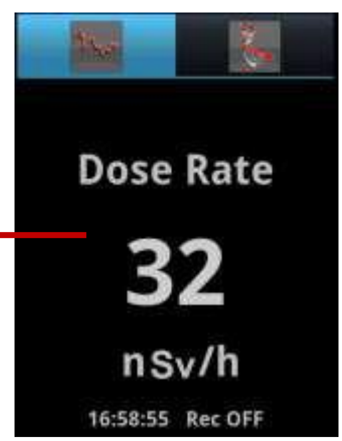
Total Count & Dose,

Common Commands (Station Mode & Recording)

Landscape device orientation



Enlarged Dose Rate (On Touch)



To return use the **Back** button.

In order to calculate Concentrations for K, U, Th, a file named “spec.cal” is used. This file should be located in PEI\AGRS\Config\spec.cal. 3-sec filtering is used to smooth the data.

IMPORTANT	If there is no file (under PEI/AGRS/Config) that contains Stripping Ratios and Sensitivities constants, the concentrations values (K, pct; U, ppm; Th, ppm) will not be calculated (you will see NaN).

The spectrometer tuning is fully automated. The tuning algorithm provides the spectrum stabilization on natural radio nuclides (Th208 or K). The spectrometer tuning status gets recorded as the ASCII channel called ISPS.

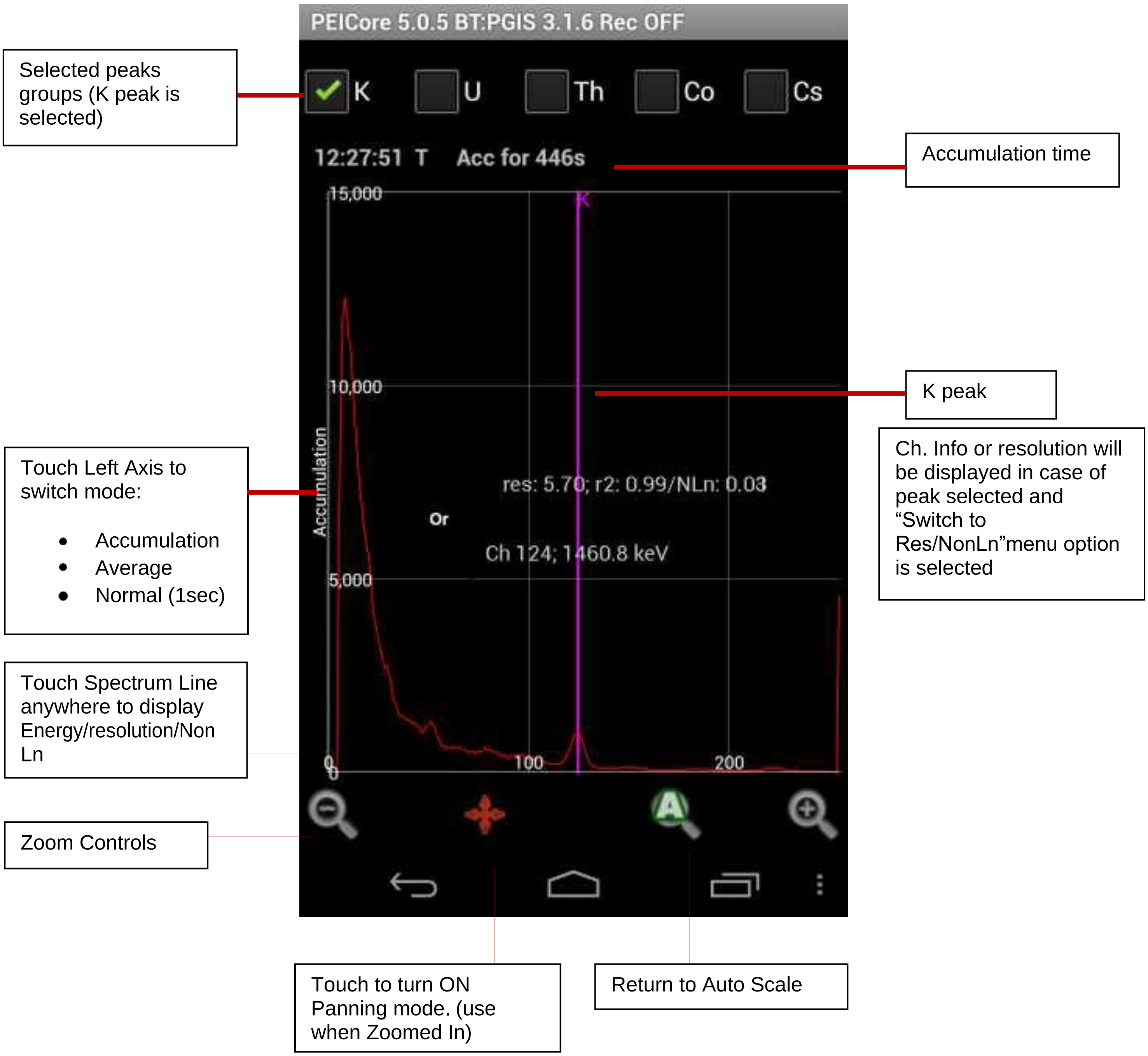
Tuning statuses are:

T = Thorium
K = Potassium
U = Uranium
A = almanach
N = not tuned.

The almanach file is updated on program termination.

Full Spectrum View, landscape device orientation, Th peaks group selected

To return use the **Back** button. 



To return use the **Back** button.

When Accumulation mode is selected FWHM resolution/fit quality (R2) /nonlinerity is displayed along the the peak energy.

For the convienience purposes (one-click view) the Charts view is now also available from the Spectrum View.(you may use the view without tabs to save the screen space: uncheck „Tabbed View“ in Settings)

Spectrometer View menu :

Reset Dose - reset absorbed dose

Graph Color/Width - change graph color & width (red, white, cyan, **blue**)

Draw Waterfall **-** turn drawing waterfall on the graph on/off

Switch to Ch/Energy/ or Res/NonLn

Calculate Resolution or show Ch/Energy on the selected peak **–** if you want to calculate the resolution on the selected peak turn on **Accumulation/Avearaging mode,** select the peak (checkbox) and select menu Item **„Switch to Res/NonLn“.** Otherwise the channel & energy for the selected peak will be displayed

DATA RECORDING

SD Card Mounting check

If SD Card is not mounted you will receive a notification message:

In this case you should exit the application.

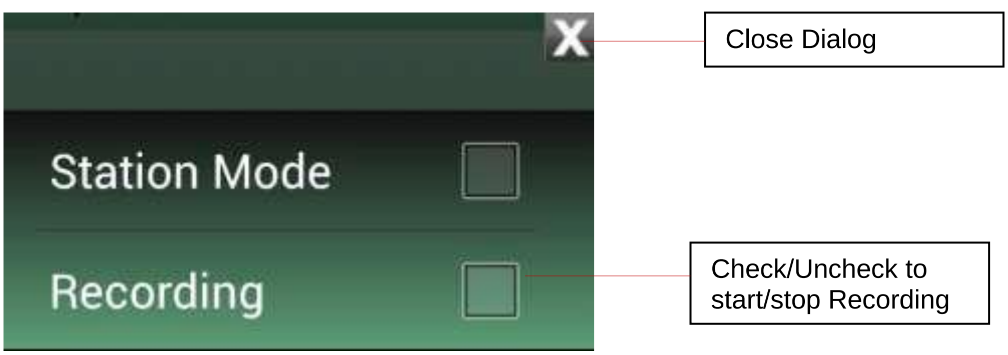
Press the **Menu** button ->Notifications->Turn off USB storage, touch **Turn off USB storage** button.

Press the **Back** button to return to the main screen.

Start/Stop Recording

To start/stop Recording Data, touch the **Common Settings** button (available at the bottom of every screen) and check/uncheck the **Recording** item.

To close the current dialog, use the **Back** button or touch the **X** button at the right –top corner

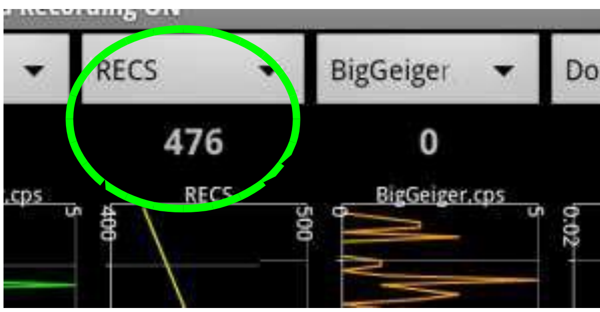


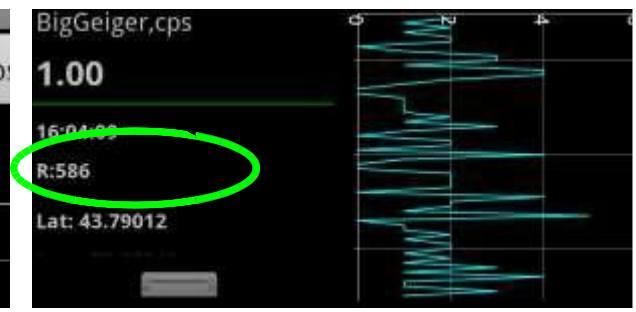
Recording Information

- Navigation View:

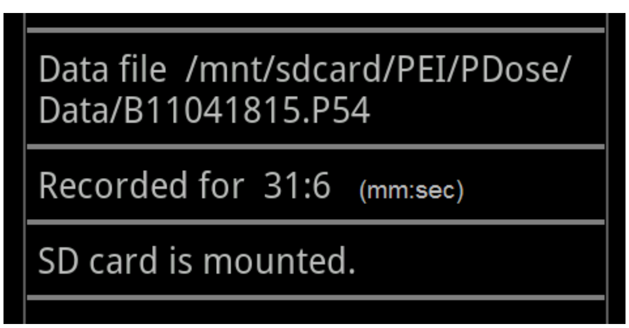
- Spectrum View:

- Charts View:





- Info View:

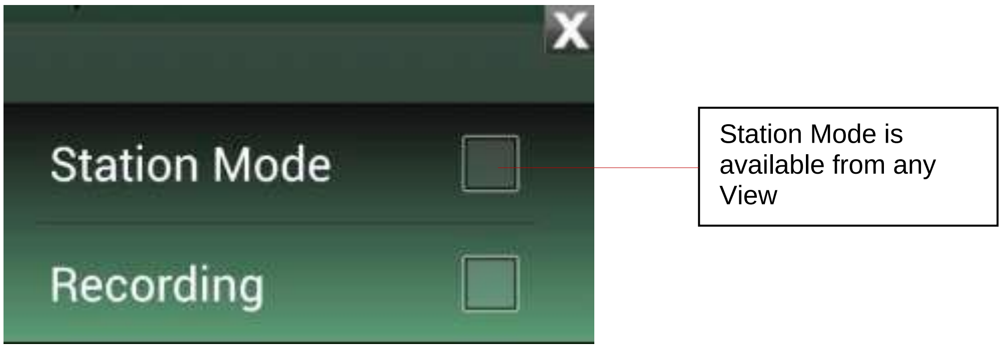


- Status Bar:

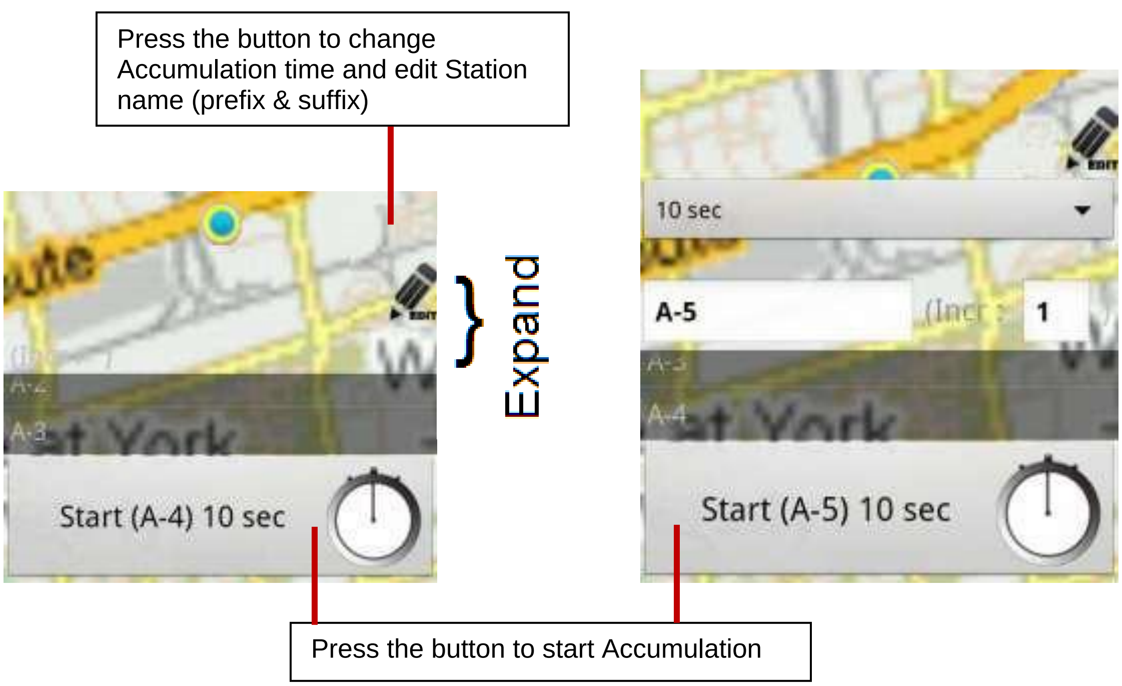
6 STATION MODE

Station mode allows you to collect data for certain observation points. The Station Name will be recorded and may be retrieved using the **PEIView** functionality. A Station Points file will be created and accumulation data may be used independently.

The Station Mode allows user to select the data accumulation time (1sec, 2 sec, 5sec, 10sec, 15sec, 20sec, 25sec, 0.5min, 1min, 2min, 5min, or 10min). It is recommended not to change the data accumulation time during the survey once it is being set.



Once Station Mode is selected the Common Dialog will be closed and the following overlay will appear:



To change the Station Point name you can edit the prefix (before "**-**") and the suffix (after "**-**"). The next station will show the new prefix and the increased (by increment value) suffix which will make things easier for the field operator.

If you enter just the new prefix, the suffix will be created automatically and added to the next station.

NOTE Station Point **Suffix** will change automatically (increased by **incremental** value).

After pressing the **Start** button, wait while the countdown has finished and then you may start collecting Station data again.

NOTE Station Data will be marked with **Station** and **AccMark (**see **PEI Data Channel Description)** and may be retrieved from the PEI Data file via **PEIView.**

Media Bar is available in Station Mode, so you can take a picture and record audio files simultaneously. Station Data will be added as a geo-referenced NOTE (with Station Point name and averaged Data) in the KML file for further analysis, and there is no need to add note manually for this point.

Press the **Back** button to return to the previous screen.

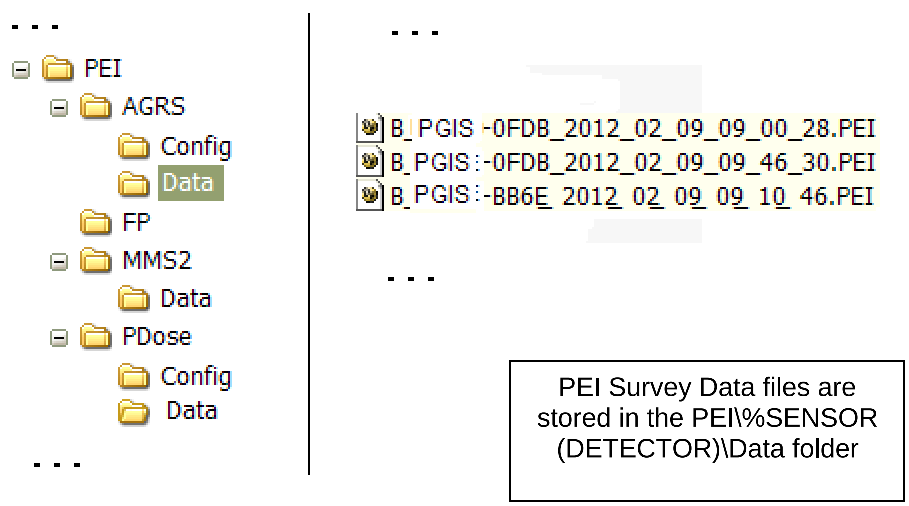
7 DATA RETRIEVING

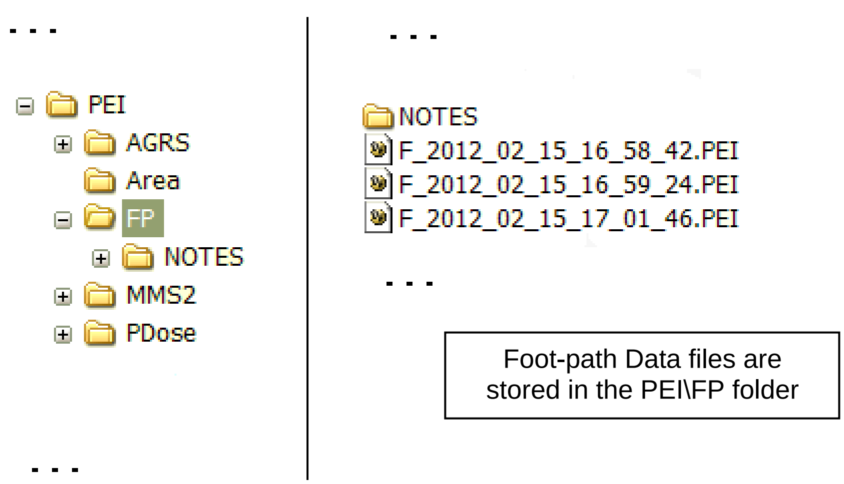
The Survey Data file name is automatically generated as:

B_<*device name*> _YYYY_MM_DD_hh_mm_ss.PEI

In this example the name is***: B_PGIS_0FDB_2012_09_12_34_00.PEI***

Connect the Android device to the computer (see **Connection to the computer**). Once the content of SD Card is opened in Windows Explorer, and you expand the folders, you will see something like the following:





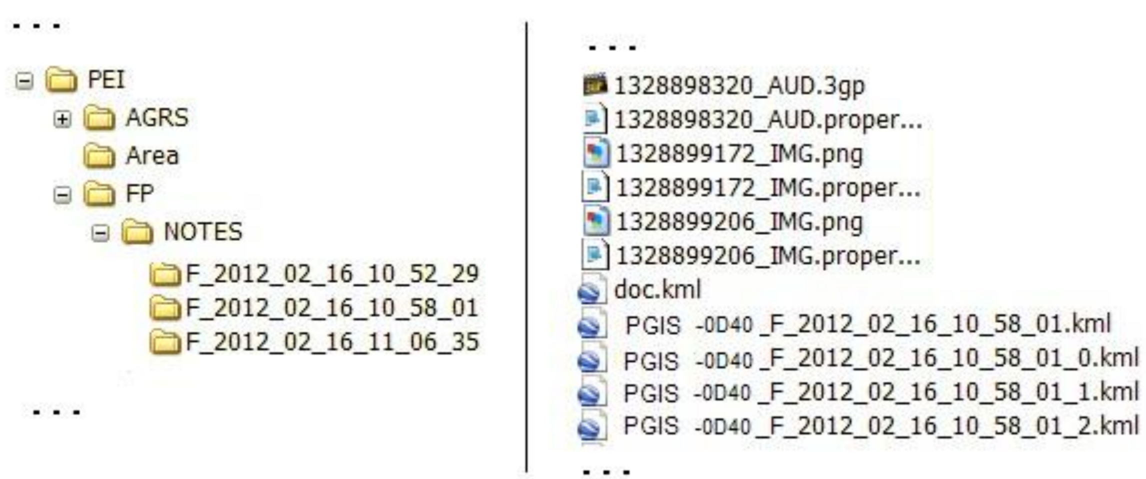
Foot-path data files name used the same data/time presentation as a data file (F_YYYY-MM-DD-hh-mm-ss) (it doesn't include the device name because foot path data is recorded always when the application starts and have no connection.

KML data file(s).are stored along the Images/Audio files and summary doc.kml in case there is more than one KML file. Amount of data points is 3600 (5 hours if data are stored once per 5 sec for example). If the amount of waypoints exceeds 3600 another kml file will be created when "Save KML/KMZ" command will be executed. The summary list in this case will be created in a doc.kml.

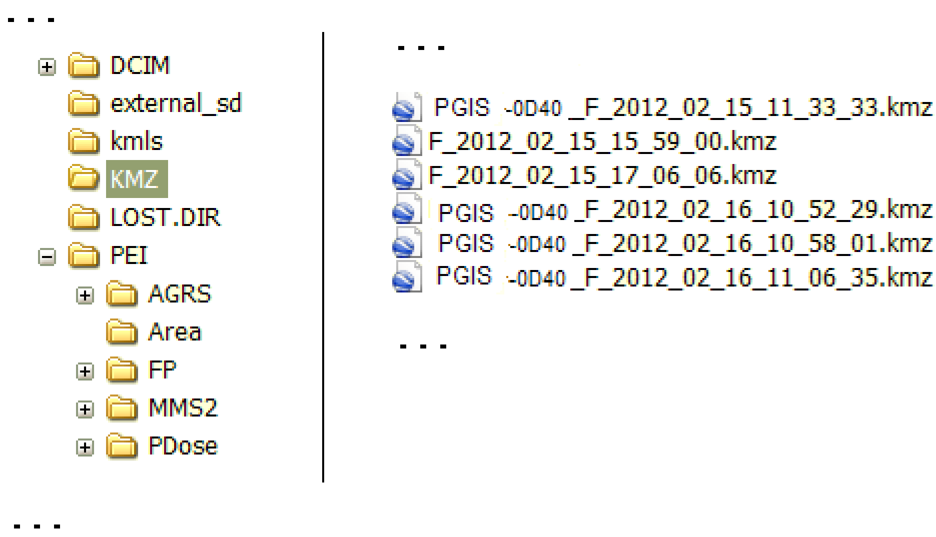
doc.kml example

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://www.opengis.net/kml/2.2" xmlns:gx="http://www.google.com/kml/ext/2.2"
xmlns:kml="http://www.opengis.net/kml/2.2" xmlns:atom="http://www.w3.org/2005/Atom">
<Document>
<name>Summary</name>
<NetworkLink><name>PGIS_0D40_F_2012_02_16_11_06_35.kml</name>
<Link><href> PGIS_0D40_F_2012_02_16_11_06_35.kml</href></Link>
</NetworkLink>
<NetworkLink><name> PGIS_0D40_F_2012_02_16_11_06_35_0.kml</name>
<Link><href> PGIS_0D40_F_2012_02_16_11_06_35_0.kml</href></Link>
</NetworkLink>
</Document>
</kml>
```

Images/Audio have unique name :<*epoch*>_IMG.png and are saved in the NOTES folder.



KML file name is combined from FP file name and device name.File is stored under NOTES in the according folder



KMZ is a zipped PEI/FP/NOTES/< cur FP file name> folder. It contains all images, audio files, kmls and doc.kml file and is saved in <root>/KMZ folder. The original PEI/FP/NOTES/< cur FP file name> folder will be deleted in case a KML option **Save KMZ only** will be checked

Copy and/or delete data files to your computer. Don't forget to close the Explorer Window and turn off the USB storage on your Android device.

The structure of the file is defined by the file header written in the ASCII code and separated from data by the hex “1A” character.

The “channel description line” describes each recorded data channel. Channel description lines are placed between two key words (lines) **BEGIN … END**.

A channel description line contains the following parameters, placed on one line separated by commas:

Name, Number of elements, Data type, Coefficient, Offset, Unit, Comment

Normally ***Number of elements*** displays the time sequence (…”2, wd” for example.. means 2 times a second and word format).

If the ***Data type*** is followed by “*” than it represents the number of elements of the spectrum information (…256, wd*,… 256 elements of a spectrum collected once a second in word format).

The Internal file description is self-explanatory.

Foot-path Data

This file has position data stored to it as long as the data acquisition system is running. This file cannot be turned off by the operator. It contains position, date, and timing information. If no equipment is connected only the Foot-path Data will be recorded.
Foot-path Data files are stored in the **PEI\FP** folder.

Survey Data

Data file contains geophysical data from enabled sources and all reference information (GPS position and time). Operator controls when data is recorded. PEI Survey Data files are stored in specific to the sensor/detector **Data** folder.

7.1 PEI SURVEY DATA FILE CHANNEL DESCRIPTION

7.1.1 Spectrometer (PGIS-2) Data structure

Name	Meaning	Unit	Source
RECS	*Fiducial number*		
AnrLat	*Android Internal GPS Latitude*	*deg*	*Android GPS*
AnrLon	*Android Internal GPS Longitude*	*deg*	*Android GPS*
AnrGalt	*Android Internal GPS Altitude*	*m*	*Android GPS*
AnrEpoch	*Android Internal Epoch: number sec since 12:00AM 1-Jan-1970*	*sec*	*Android GPS*
Lat	*Detector GPS Latitude*	*deg*	*Detector GPS*
Lon	*Detector GPS Longitude*	*deg*	*Detector.GPS*
Gtm	*Detector GPS second of the day**	*sec*	*Detector.GPS*
GPSFix	*Detector GPS fix quality***	*0,1,2 (intenal) 100, 101,102 (external)`*	*Detector.GPS*
Stl	*Detector GPS number of satellites*		*Detector.GPS*
Geos	*Geoidal separation (Diff. between WGS-84 earth ellipsoid and mean sea level)*		*Detector.GPS*
Galt	*Detector GPS Altitude*	*m*	*Detector.GPS*
Epoch	*Number of sec since 12:00AM 1-Jan-1970*	*sec*	*Detector.GPS*
Locked	*Name of the Locked Object*		
AccMark	*Accumulation Mark*		
Station	*Station Name*		
Status	*Internal use*		
AccumTime	*Internal use*		
LiveTime	*Internal use*		
SampleN	*Data Integrity check*		
Cosmic	*Cosmic channel*		
CurrentHV	*Internal use only*	*step*	
CurrentADCRef	*Internal use only*	*step*	
TC	*Window from 0.41 to 2.81 MEv*	*cps*	*AGRS1*
K	*Window from 1.37 to 1.57 MEv*	*cps*	*AGRS1*
Ur	*Window from 1.66 to 1.86 MEv*	*cps*	*AGRS1*
Th	*Window from 2.41 to 2.81 MEv*	*cps*	*AGRS1*

Cs	*Window from 0.574 to 0.762 MEv*	*cps*	*AGRS1*
Dose	*Dose rate*	*nSv/h*	*AGRS1*
cK	*Concentration/Activity K*	*Pct/Bqpkg*	*AGRS1*
cUr	*Concentration/Activity U*	*Ppm/Bqpkg*	*AGRS1*
cTh	*Concentration/Activity Th*	*Ppm/Bqpkg*	*AGRS1*
cCs	*Surface Activity Cs*	*Bqpm2*	*AGRS1*
ISP	*Spectrum (256, 512 or 1024 res)*		*AGRS1*
ISPS	*Tuning status (T,K, U, A)*		*AGRS1*
Gain	*coefficient*		*AGRS1*
Battery	*Battery voltage*	*V*	*AGRS1*

*Time may be converted to the MM-DD-YY:hh:mm:ss format in PEIView
** Example： GPS fix internal GPS -2
. GPS fix external GPS –102 (fix value +100)
Fix: char from GGA string 0 = Invalid (NO fix), 1 = Regular (GPS) fix, 2 = Differential (DGPS) fix

For GM extension few more data channels are added:

RawSGCt	*Raw Small Geiger counts*	*cps*	*AGRS1*
RawBGCt	*Raw Big (Medium) Geiger counts*	*cps*	*AGRS1*
DoseGM	*Dose rate (GM)*	*uSv/h*	*AGRS1*
DoseAGRS	*Dose rate(Spectrum)*	*nSv/h*	*AGRS1*
DoseGMFlag	*Dose from GM flag****	*Flag*	*AGRS1*

7.2 PEI FOOT-PATH DATA FILE CHANNEL DESCRIPTION

Name	Meaning	Unit	Source
RECS	*Fiducial number*		
Locked	*Name of the Locked Object*		
AccMark	*Accumulation Mark*		
Station	*Station Name*		
Time	*Android Internal Time (Number of sec since 12:00AM 1-Jan-1970)***		
Lat	*Latitude*	*deg*	*Android GPS*
Lon	*Longitude*	*deg*	*Android GPS*
Alt	*Altitude*	*m*	*Android GPS*
Epoch	*Number of the sec since 12:00AM 1-Jan-1970***	*sec*	*Android GPS*
Bearing		*deg*	*Android GPS*
Accuracy		*m*	*Android GPS*
Speed		*m/s*	*Android GPS*
Xco	*UTM: X coordinate*	*m*	
Yco	*UTM: Y coordinate*	*m*	
Data	*Current Data channel****		
Image	*Image Name**		
Audio	*Audio file Name**		
titleNote	*Note (title)*		
Note	*Note (body)*		

* Images and Audio Files Names are references to the actual files (and geo-references) stored in FP\NOTES<*current FP filename*> folder **and/or** in the zipped KMZ file.
** Time may be converted to the MM-DD-YY:hh:mm:ss format in PEIView
*** Data Channel depends on the connected device/detector

NOTE The **Survey Data file** can be synchronized with the **Foot-path Data file** using the Epoch channel.

8 ESSENTIALS

There is no need to edit the common PEI\PEIcore.config or specific configuration files for each module. Default configuration files will be created for the new installation.

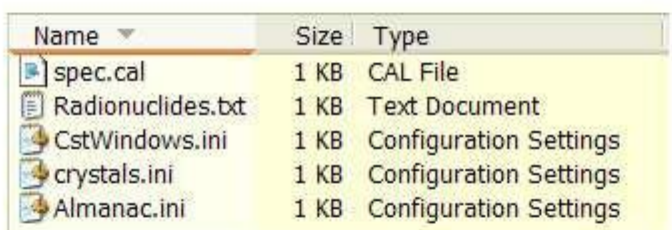
ATTENTION! Manually editing any of the configuration files may have a huge impact on the system behaviour and performance.

The PEI\PEIcore.config file contains various settings that are stored for future use. For internal use only.

8.1 SPECTROMETER (PGIS-2) ESSENTIALS

AGRS1.apk and PEICore.apk should be installed on the Android device. AGRS1 is a program that operates the Pico Envirotec Inc. Intelligent Gamma Spectrometer (AGRS) supporting one detector. The AGRS1 is intended to be used with Android controlled devices (handheld computer).

8.1.1 Configuration Files



Almanac.ini - for internal use only

```
GainSlope=0.0
HighVoltage=400
AlmanacCRC=3874738886
K_NonLinearity=0.0
Volume=0.347
gain=1.0
```

crystals.ini - for internal use only

Example:

```
[Config]
Debug=False
Ports=zzzz
Record_To_file=False
```

```
TcpPort=22222
Data_Latency_ms=0
Spectrum_Sample_Collection_Period_ms=1000
LogErrosOnly=False
Spectrum_Linearize=True
Spectrum_Resolution_Requested=1024
Spectrum_Threshold=6
Tune_Buffer_Threshold=50
```

CstWindows.ini - Custom Windows file. File can be created using **PEIView** (see PEIView manual). You can add up to 50 custom windows that you can monitor and record.

Name	*Meaning*	*Unit*
WName	*Channel name*	
WFrom	*Window low energy*	*keV*
WTo	*Window high energy*	*keV*
WUnits	*Units*	
WType	*Window type*	

Example:

```
[Default]
WName1=Cs
WFrom1=550
WTo1=850
WUnits1=cps
WType1=Window, cps
WName2=Co
WFrom2=1200
WTo2=1600
WUnits2=cps
WType2=Window, cps
```

For the given example two windows Cs and Co will be added to standard energy window channels list (Th, U, K, TC/Total count) and recorded to data file.

spec.cal - calibration file: Stripping Ratios and Sensitivities constants that are based on the data collected on the calibration pads (background, Thorium, Potassium, Uranium) Constants are specific to the crystal type (volume & shape). For internal use only.

Example (volume: 0.3-0.4L & 3.9-4.4L):

```
[Param]
VFrom1=0.3
VTo1=0.4
Alpha1=0.5267
Beta1=0.6791
Gamma1=0.9904
Delta1=1
Epsilon1=1
Tau1=1
A1=0.0314
B1=0.0017
D1=0
```

```
G1=0.0013
Ksens1=3.24
Usens1=0.27
Tsens1=0.13
Csens1=3.6
….
VFrom5=3.9
VTo5=4.4
Alpha5=0.305
Beta5=0.435
Gamma5=0.801
Delta5=1
Epsilon5=1
Tau5=1
A5=0.044
B5=0
D5=0.0002
G5=0
Ksens5=32.71
Usens5=2.81
Tsens5=1.47
Csens5=36.5
```

RadioNuclides.txt – list of radionuclides to be detected in real time

Radinuclide Name – Energy Peak1, Energy Peak2… Energy PeakN

Na-22;511;1274.5
Cs-134;604.7;795.7;569.3;801.8;563.3
Cs-137;661.6
Mn-54;834.8
Co-60;1332.5;1173.2
Zn-65;1115.5
I-131;364.5
Ce-144;133.5
Eu-152;121.8;344.3;1408.1;964;778.9;1085.8;244.6
Ra-226;186

DoseCalib.txt (GM Extension)

In order to convert the tube(s) counts to dosage, a Calibration table (DoseCalib.txt) is used. This file should be located in PEI\AGRS\Config.

DoseCalib.txt file format is simple comma separated values of Small tube, Big tube and corresponding Dose. In case the tube is turned off the value is -1.

Example:

```
//UnitID=S/N:161009
//SmallGM  MediumGM    Dose
//  cnts    cnts       µSv/h
   0.00,     0.00,      0.00
   0.00,     0.13,      0.03
    0.25,    3.73,      1.4
    1.38,   22.74,      9.7
    2.01,   30.42,      13.0
    2.62,   42.31,      18.0
    4.12,   64.74,      27.4
    6.56,  110.05,      45.6
    8.96,  155.02,      62.7
   13.76   238.1        91.7
   27.00,  468.85,     200.00
   68.70,  1198.0      500.00
  139.20,   -1.00,    1000.00
  273.00,   -1.00,    2000.00
  655.00,   -1.00,    5000.00
 1202.00,   -1.00,   10000.00
 2041.20,   -1.00,   20000.00
 3675.30,   -1.00,   50000.00
 4625.00,   -1.00,   80000.00
 5071.00,   -1.00,  100000.00
 5776.40,   -1.00,  145000.00
 6328.80,   -1.00,  200000.00
 6960.30,   -1.00,  300000.00
 7084.00,   -1.00,  389800.00
 7130.00,   -1.00,  450000.00
```

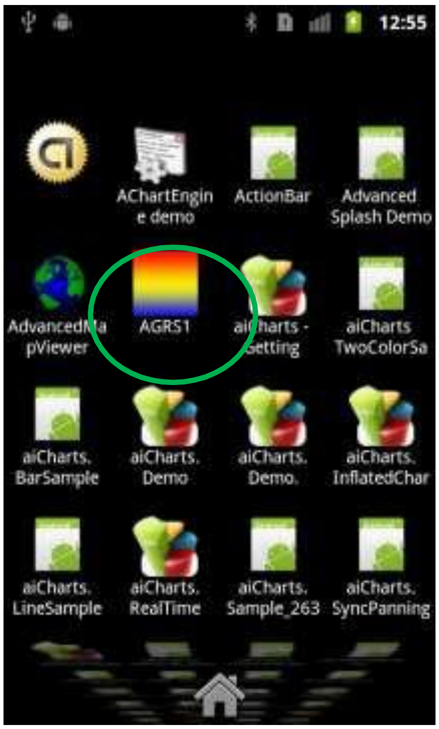
DoseCalib.txt file is stored on the Android device SD Card in the **PEI\PDOSE\Config** folder.
Some points may be added

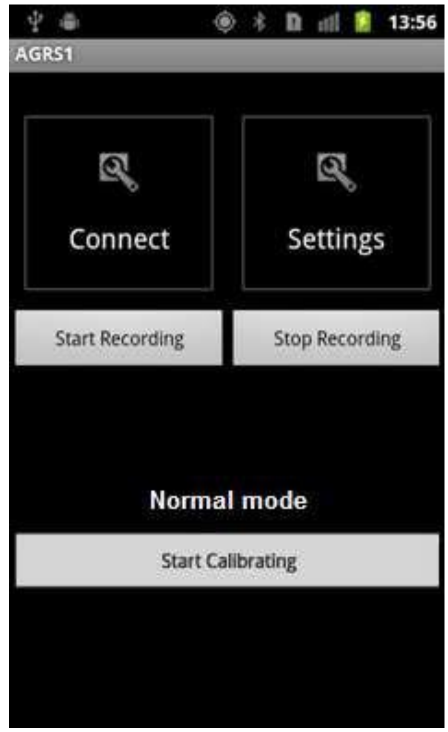
8.1.2 Calibration

The calibration routine is based on defining the natural radiation background peaks (K, U, Th) and adjusting the High Voltage (HV) value.

PGIS-2 calibration can be performed using the AGRS1 service (for more details see AGRS1.doc).

Start AGRS1 service (AGRS1.apk). Find AGRS1.apk in the Application List and start standalone AGRS1service

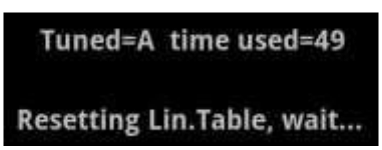


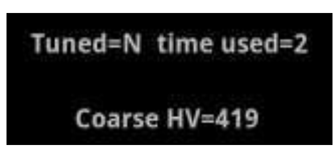


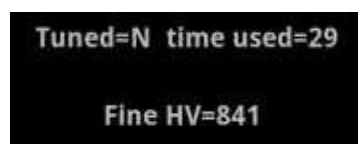
Connect the Bluetooth. Connect to the paired BT PGIS-2 device (Connect->BluetoothPGIS....)

Start Calibration. After BT is connected press the <Start Calibrating> button.

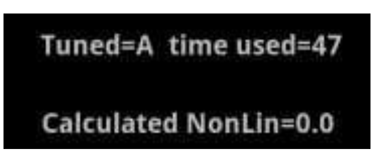
You will see the following messages (corresponding to the calibration steps):

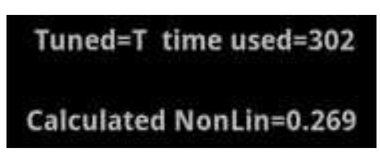


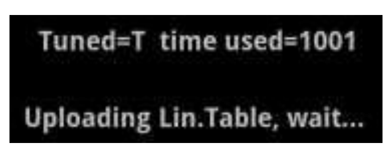




HV (High Voltage) value will keep changing until the best fit is found. After that the system continues tuning. Don’t interrupt it, wait until the Linear Table is updated and the calibration has finished.







The whole process may take up to 45 minutes, depending on the background radiation and crystal volume. No user’s impact is required.

8.2 LOG FILES

Up to 5 log files are written for the debug purposes. In the PEI/Logs folder you can see:

AGRS1_log1.txt… AGRS1_log5.txt
PEICore_log1.txt… PEICore_log5.txt

The content of the above files are for the debugging/internal use only and may vary.

9 QUICK START

See **Setting & Installation** if you don't have an application installed and set up.

9.1 NO DETECTOR CONNECTION

For "NO Detector" mode and in case "Light Connection" prompt appears. If you press Connection button previous BT address will be cleared and you will be able to select the different BT device from the device list . If you are not going to use any BT device – press Connection button to clear the address, and then restart the application

Troubleshooting

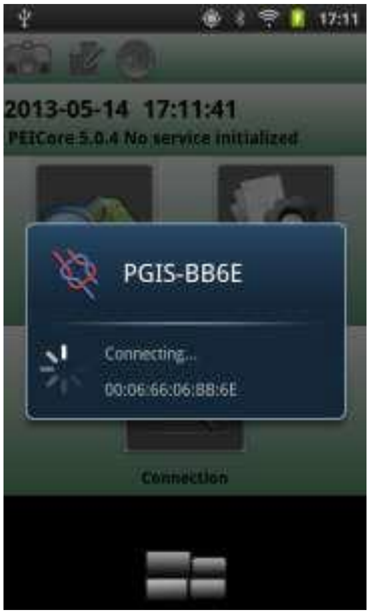
Check the detector LED sequence – before communication starts you should see only green (and red – depends on battery level) . If you see blue light detector is connected and it's better to restart it.

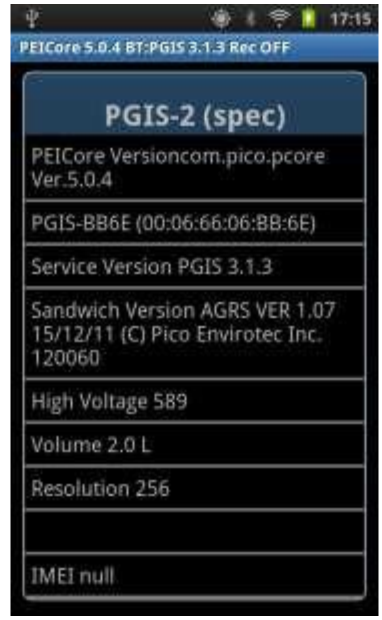
Try to Unpair- Pair back the detector unit.

Check if services : AGRS1.apk (PGIS-2) apk is running. Force the applications close.

Restart PEICore.

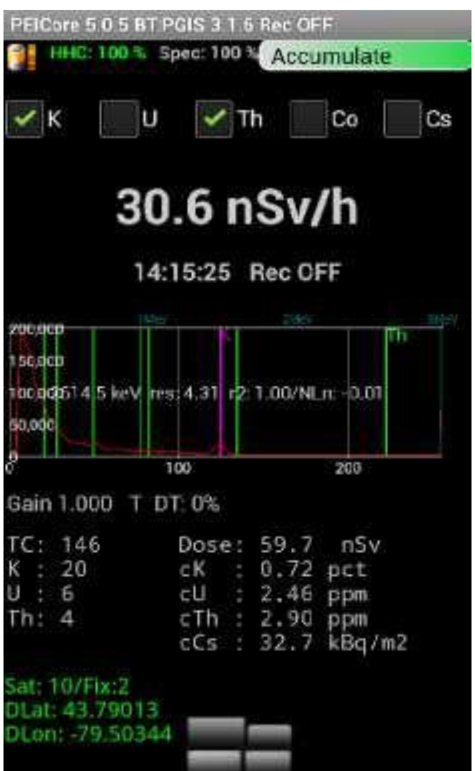
9.2 LIGHT CONNECTION





After connection with the detector is established specific detector service will be initialized and two buttons (Specific for the Detector & Charts) will appear instead of the button "Connection"

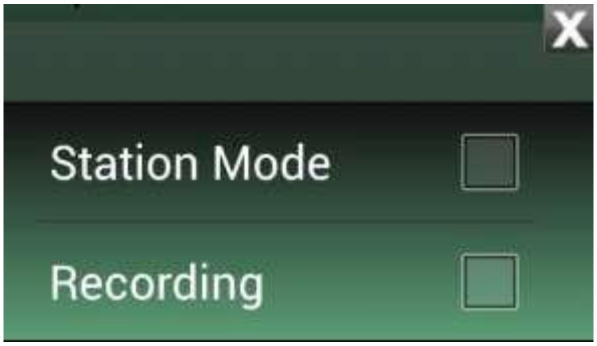
9.3 SPECTROMETER VIEW



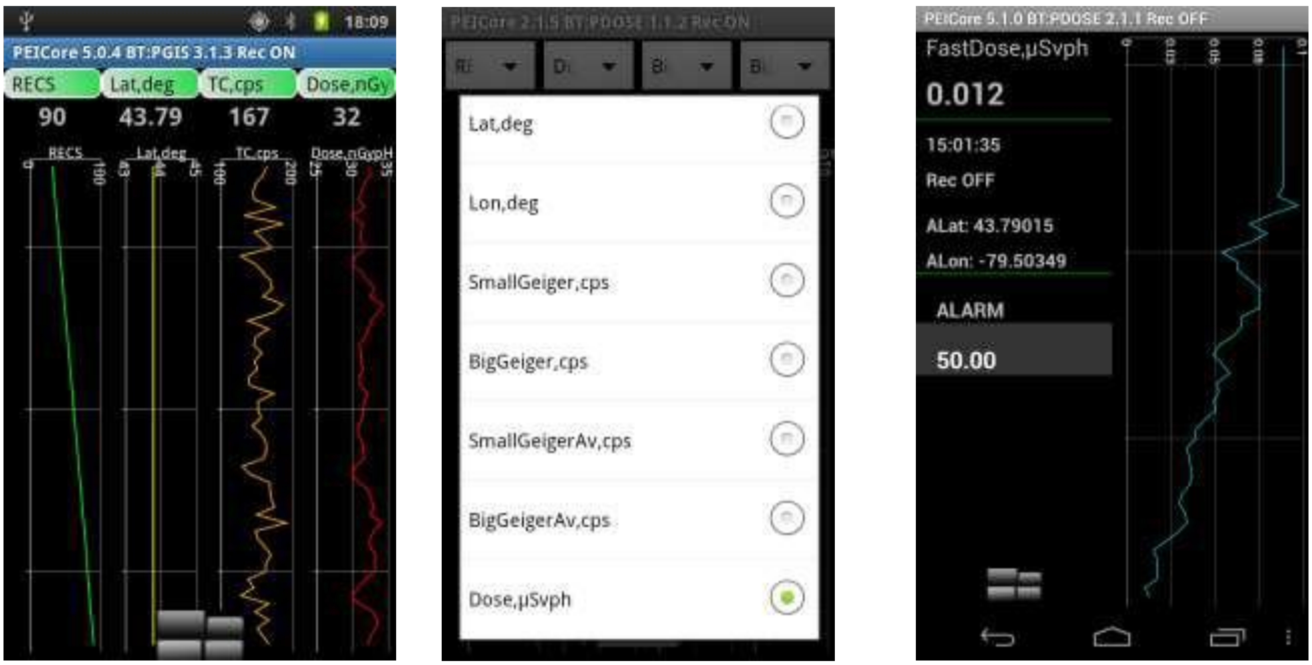
Press the corresponding button on the dashborad to get the Spectrometer specific View. Don't forget to start Data Recording!

9.4 DATA RECORDING

To start recording, press the button on the bottom of the each page to call up the common dialog:



9.5 CHARTS VIEW



You can select the required set of channels and watch a particular one by tapping on the chart area.

9.6 NAVIGATION VIEW

You have a choice to select between using online/offline Open Street Maps or use the georeferenced bmp created by PEIConvert. For more details on both options see Navigation.

Maps and xyz files for use in the Navigation Mode should be stored on the SD Card in **PEI\Area** folder.

OSM Map

Geo-referenced bmp

10 SCREEN ORIENTATION

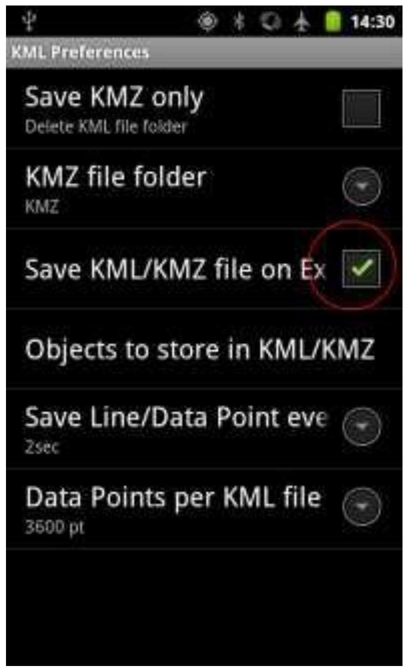
It is not always convenient to have the screen orientation change when the position changes. Therefore, you can change the screen orientation from the main dashboard screen. Press the **Menu** button and select "SETTINGS“. Select **Custom Display** Preference screen and check/uncheck the **Portrait** option.

Select orientation and use the **Back** button to return.

11 APPLICATION TERMINATION

From the main dashboard screen press the **Menu** button and select "EXIT“.

Exit Dialog will contain an additional button **Save KML/KMZ** in case *Save KML/KMZ file on Exit* option is checked (*KML Preferences*). Otherwise the Image button Save KML/KMZ will appear in the upper corner of the Media Bar (see images below), and **Exit Dialog** will not contain the **Save KML/KMZ** button



Android OS does not support the concept of "*closing a running Android application*". Some additional work was done to force the PEICore application and the corresponding Service to be closed and close the BT connections.

In case an application is closed incorrectly you can check if it is still running:

Menu->Applications->Manage applications->select the **All** or **Running** tab and check to see if one of the following applications is running:

PEICore - Managing Application
AGRS1 - Service

If the Managing Application, or service, is still running it may keep the BT device connection alive and you will not be able to connect to it again. Force the application to stop if it is still running.

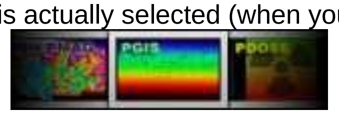
You can also reboot the Android device.

12 TROUBLESHOOTING

If the application **crashed for whatever reason** please check if the applications PEICore (main) and AGRS1 (service) are still running.

Menu->Settings->Applications->Manage Applications- tab ALL or Running.

If the application is still running, force it to close. You can also reboot the android device.

When you try to connect to the detector/sensor make sure that the desired service mode (**PGIS-2)** is actually selected (when you touch the icon in detector/sensor gallery)*Connection View ->*  will be enlarged and you can see the **PGIS-2 (spec)** strings fading in accordingly before you touch the **Connect** button.

If the device is undetectable you will receive the following message:

Ensure that the BT device has power. Restart both the detector and the Android device. Try to connect again.

If the BT device is connected but no data can be delivered you will receive the following message:

This can be caused if the application:

- Is trying to connect to a BT detector/sensor different from the one selected
- Was not closed correctly in the previous session
- Lost communication with the BT detector/sensor

Reduce the distance between the BT detector/sensor and the Android device.
Make sure the BT detector/sensor has power.
Check that the BT connection and settings are on.
Try to unpair the BT detector/sensor and pair it back.
Restart both the detector/sensor and the Android device.
Try to connect again.

Sometimes this message will appear just once at the beginning of communication – that may be caused by a start delay.

13 APPENDICES

13.1 APPENDIX A: LED DESCRIPTION

13.1.1 Charging

Green and red flashes describe the capacity of battery during charging
5 green flashes = battery capacity more than 90%
4 green flashes + 1 red = battery capacity between 70% and 90%
3 green flashes + 2 red = battery capacity between 50% and 70%
2 green flashes + 3 red = battery capacity between 30% and 50%
1 green flashes + 4 red = battery capacity between 10% and 30%
5 red flashes = battery capacity less than 10%

13.1.2 Stauts LED PGIS

Green and red flashes describe the capacity of battery during discharging the same way as the charging LED as described bellow. Blue flashes might follow, see description bellow green and red flashes.

5 green flashes = battery capacity more than 90%
4 green flashes + 1 red = battery capacity between 70% and 90%
3 green flashes + 2 red = battery capacity between 50% and 70%
2 green flashes + 3 red = battery capacity between 30% and 50%
1 green flashes + 4 red = battery capacity between 10% and 30%
5 red flashes = battery capacity less than 10%

one blue flash is added when Bluetooth interface is connected to a host. One host can be connect at the time so if blue flash is shown no new connection is allowed. Bluetooth time-out when connection is lost is about 30 seconds.

13.2 APPENDIX B: REFERENCE ELLIPSOIDS

Ellipsoid	Semi-major axis (meters)	1/flattening
Airy	6377563.396	299.3249646
Australian National	6378160.0	298.25
Bessel 1841	6377397.155	299.1528128
Bessel 1841 (Nambia)	6377483.865	299.1528128
Clarke 1866	6378206.4	294.9786982
Clarke 1880	6378249.145	293.465
Everest	6377276.345	300.8017
Fischer 1960 (Mercury)	6378166.0	298.3
Fischer 1968	6378150.0	298.3
GRS1967	6378160.0	298.247167427
GRS 1980	6378137.0	298.257222101
Helmert 1906	6378200.0	298.3
Hough	6378270.0	297.0
International	6378388.0	297.0
Krassovsky	6378245.0	298.3
Modified Airy	6377340.189	299.3249646
Modified Everest	6377304.063	300.8017
Modified Fischer	6378155.0	298.3
South American 1969	6378160.0	298.25
WGS 60	6378165.0	298.3
WGS 66	6378145.0	298.25
WGS-72	6378135.0	298.26
WGS-84	6378137.0	298.257223563

13.3 APPENDIX C: CENTRAL MERIDIAN AND ZONE NUMBERS

LONG(-)	LONG(+)	CM	Zone	LONG(+)	CM	Zone
-180..-174	180..186	183	1	000..006	003	31
-174..-168	186..192	189	2	006..012	009	32
-168..-162	192..198	195	3	012..018	015	33
-162..-156	198..204	201	4	018..024	021	34
-156..-150	204..210	207	5	024..030	027	35
-150..-144	210..216	213	6	030..036	033	36
-144..-138	216..222	219	7	036..042	039	37
-138..-132	222..228	225	8	042..048	045	38
-132..-126	228..234	231	9	048..054	051	39
-126..-120	234..240	237	10	054..060	057	40
-120..-114	240..246	243	11	060..066	063	41
-114..-108	246..252	249	12	066..072	069	42
-108..-102	252..258	255	13	072..078	075	43
-102..-096	258..264	261	14	078..084	081	44
-096..-090	264..270	267	15	084..090	087	45
-090..-084	270..276	273	16	090..096	093	46
-084..-078	276..282	279	17	096..102	099	47
-078..-072	282..288	285	18	102..108	105	48
-072..-066	288..294	291	19	108..114	111	49
066..-060	294..300	297	20	114..120	117	50
-060..-054	300..306	303	21	120..126	123	51
-054..-048	306..312	309	22	126..132	129	52
-048..-042	312..318	315	23	132..138	135	53
-042..-036	318..324	321	24	138..144	141	54
-036..-030	324..330	327	25	144..150	147	55
-030..-024	330..336	333	26	150..156	153	56
-024..-018	336..342	339	27	156..162	159	57
-018..-012	342..348	345	28	162..168	165	58
-012..-006	348..354	351	29	168..172	171	59
-006..-000	354..360	357	30	174..180	177	60

13.4 APPENDIX D: DEFINITION OF THE AREA.XYZ FILE

The example below shows the composition of the **area .xyz** file for a simple survey area containing only 4 corners. More complex survey areas having more corners would be identical to this file with the exception of the additional corner point information. The structure of this file must be rigidly adhered to or errors will be generated in other parameter files when the area.xyz file data is imported during project set up.

```
UTM,        L1 coordinate system "UTM"
m,          L2 "deg" = lat/lon, "d:m"=lat/lon "m" =meters (for UTM any)
metric,     L3 for speed and distance "metric" [m, km, km/h], "US" [ft,nm,knot]
ft,         L4 for altitude "m" meters, "ft" feet
Name,       L5 client name
-79.502 Lat
43.789 Lon
279 CM
0 dsx
0 dsy
0 dsz
620937 xSL
4849543 ySL
0 HSL
100 spacing SL
620937 xTl
4849543 yTl
90 HTL
200 spacing TL
c 620304 4852829 c1
c 622313 4853466 c2
c 622946 4850171 c3
c 620937 4849543 c4 up to 96
w wp1 620937 4849543 w1 way points
w wp2 622313 4853466 w2b up to 16
l li1 680000 477900 680000 477000 l1 up to 16 special lines
l li2 680200 477900 680200 477000 l2_
```

The first item in each line is the defined value followed by a comma. The remainder of each line is a comment only that gives a brief description of the line.
The lines in the file are defined as follows:

UTM, L1 coordinate system "UTM"

defines the type of coordinate system the user will employ to define the survey area. As of this revision only UTM coordinate systems are supported.

L, L2 "deg" = lat/lon, "d:m"=lat/lon "m" =meters (for UTM any, for ADRG deg or d:m only)

defines the type of geodetic system used for the survey. The user can choose between specifying positions in degrees and decimal degrees, **(deg),** degrees minutes and decimal minutes **(d:m)** and in meters for UTM **(m).**

metric, L3 for speed and distance "metric" [m, km, km/h], "US" [ft,nm,knot]
defines the units for speeds and distances displayed on the pilot reference indicators and navigations screens of the PEICore system. Information is sourced from the GPS system only.

ft, L4 for altitude "m" meters, "ft" feet
defines the units used for altitude data derived from the GPS system

Name, L5 user name
provides a user name reference for the project

-79.502 Lat
43.789 Lon
in the two lines shown above the user should enter the approximate latitude and longitude of the center of the survey area expressed as degrees –decimal degrees. This allows the survey program to properly determine line parameters.

279 CM
the Central Meridian is used in the determination of the UTM co-ordinates. The Central Meridian value is determined by the longitude of the survey area. Refer to the table in Appendix G to determine the CM for your survey area. The span of a UTM boundary area is 6 degrees of longitude.

NOTE If your survey area lies across a UTM boundary line choose the next Central Meridian to the west as the desired CM for the survey

0 dsx
0 dsy
0 dsz
the values of **dsx, dsy, and dsz** should always be set to a value of **zero (0)** unless the coordinate system used in the survey is different from WGS-84. Since GPS is now the primary method of navigation on geophysical surveys and is based on the WGS-84 reference ellipsoid there should be no requirement for datum shifts to be entered. These numbers should only be changed by knowledgeable personnel.

620937 xSL
4849543 ySL
the values of xSL and ySL serve as the master point from which line spacing and orientation will be derived. This point does not have to be inside the survey area. It is recommended that the point be selected such that it lies south of the most southern extent of the survey area and west of the most western point of the survey area. The southwest corner of the area will usually make a good default master point. As PEICore navigation lines are defined by the start and the end points this parameter is obsolete.

0 HSL
the heading of the survey. For navigational purposes and simplicity heading selection should be restricted to be between the range of 270 to 359.9 degrees and from 0 to 89.9 degrees. Headings entered outside this range will be automatically converted. As PEICore navigation lines are defined by the start and the end points this parameter is obsolete.

100 spacing SL

determines the space between surveys lines for the survey area.

620937 xTl
4849543 yTl
90 HTL
200 spacing TL

same functionality as described above for Tie lines (also called control lines) as the previous 4 lines do for survey lines. Typically the Tie lines are flown at 90 degrees to the survey lines and usually have much wider spacing. The same master point should be used for the tie lines as the survey lines as a general rule. If desired a different master point MAY be used.

c 620304 4852829 c1
c 622313 4853466 c2
c 622946 4850171 c3
c 620937 4849543 c4 up to 96

This series of lines defines the corner points of the survey polygon. Each line should be prefaced by the letter c followed by the x and y UTM values for each point. Each point should be assigned a corner number as shown in the example. The survey program supports a polygon with up to 96 points.

The points should be entered in order around the perimeter of the polygon. Convention and good navigation practices dictate that the user should start point entry in either the south western most point or the north western most point in the polygon and proceed to enter the remaining points moving around the polygon in a clockwise manner.

w wp1 620937 4849543 w1 way points
w wp2 622313 4853466 w2 up to 16

the user is allowed to enter up to sixteen (16) waypoints. These points can be locations of emergency landing strips, home base, test areas etc.

The waypoint line should be started with the letter w, followed by the waypoint number wp1, wp2, wp3, etc. The waypoint x and y UTM values should then be entered followed by a short descriptive name for the waypoint.

l li1 680000 477900 680000 477000 l1 up to 16 special lines
l li2 680200 477900 680200 477000 l2_

the user may add up to 16 special lines that are not included in the survey area. These are typically test or calibration lines that must be repeated on a regular basis in the same location each time. These would include altimeter, spectrometer repeatability and background tests, navigation tests, heading effect, and compensation.

The lines are prefaced with the letter l. This is followed by a line number designation as shown in the example above, li1, li2, li3 etc up to a maximum of 16 lines. The start and end points of each line would then be entered followed by a short name description.

Example of **area.xyz** (coordinates for area corners, survey lines, tie lines as **Lat/Lon**) – *for using with OSM maps.*

```
………..
620203; xSL
4849329; ySL
5; HSL
100; spacing SL
620203; xTL
4849329; yTL
70; HTL
50; spacing TL
c;-79.504253;   43.789467;  c1
c;-79.501700;   43.789163;  c2
c;-79.501996;   43.787295;  c3
c;-79.506086;   43.787258;  c4
l sl10; -79.506061;  43.787258; -79.506047;  43.787303; sl10
l sl20; -79.504805;  43.787268; -79.504535;  43.789129; sl20
l sl30; -79.503250;  43.789346; -79.503550;  43.787279; sl30
l sl40; -79.502023;  43.789204; -79.502307;  43.787290; sl40
l sl10010; -79.501995;  43.787322; -79.502095;  43.787296; tl10010
l sl10020; -79.501908;  43.787816; -79.504072;  43.787277; tl10020
l sl10030; -79.501834;  43.788310; -79.506061;  43.787258; tl10030
l sl10040; -79.501759;  43.788804; -79.505599;  43.787846; tl10040
l sl10050; -79.502060;  43.789204; -79.505099;  43.788452; tl10050
l sl10060; -79.503349;  43.789356; -79.504599;  43.789048; tl10060
ver; PEIConvert Version 5.4.28 // xyz for ground survey
```

13.5 APPENDIX E: GPS STATUS – FAQ

http://m.eclipsim.com/gpsstatus/

Why do you need permission XXX?

coarse and fine location: obviously we need this to display your location :)
full internet access: used by the advertisement component. Donated version does not use the internet connection at all.
access extra location provider commands: allows the program to re-download AGPS data or reset the GPS.
view network state: allows checking if there is an active internet connection. If there is no net connection, advertisement and AGPS download is disabled to save memory and battery.

It is eating all my battery according to the battery status screen. It is even running in the background.

Fortunately no. There is a bug in the battery status screen and it calculates the percentages incorrectly. If you click on the GPS Status item on the battery info screen, you will get details about how long the application was running total/in foreground. You can verify that it is not running in the background.

Yes, but it still eats a lot of battery if it is running in the foreground.
Well, that is true. Please keep in mind that GPS Status turns on all the sensors of your phone constantly runs and updates the screen. It just needs the power to do all these things. You should not run it all days long (unless you are on charger). It was just meant to quickly start when you need it, check the data and then close it.

Can I still save some battery?

Sure, the biggest power draw in the application is the CPU. You can reduce the screen refresh rate in the settings menu. This will save a lot of power.

The application is using only half of the screen on my Nexus One, Droid etc. phone.

You have turned off the "Compatibility Mode" in the Spare Parts application. Enable it and reboot your phone. To support users who are still using older android versions (Hero, G1, several Motorola handsets) GPS Status is compiled for android 1.5. To display correctly on 2.1 systems, compatibility mode must be turned on. Also it is not a good idea to turn it off as other programs may have also issues.

The GPS time is 15 seconds ahead compared to the official UTC time. Why? I thought GPS clocks must be extremely accurate.

The rotation period of the Earth is not constant and additionally it is 2ms longer than 86400 sec. This causes some drift over time between the atomic clocks (used by the GPS system) and the UTC time. To avoid confusion, every now and then leap seconds are inserted into the UTC time. (Yes, there are sometimes 61s long minutes!). GPS and UTC was in sync in 1980. Since then 15 leap seconds were inserted into the UTC time. The GPS satellites broadcast this information, but only in every 12minutes. Your receiver may not hear the broadcast, so it does not know how much it should subtract from the GPS time. In this case it simply displays the GPS time and does not correct it to get UTC. You should wait at least 15 minutes with the GPS on to receive the correction data.

The location/altitude or other data is inaccurate.

GPS Status simply displays the data received directly from the phone hardware. In fact this is the main purpose of the software (that's why it's called status). Inaccurate data is not the fault of the software, but shows that you may not have optimal reception of GPS satellites or there is a magnetic anomaly nearby affecting your compass. Find a different location and try again. If you feel that the data is inaccurate, it may indicate a hardware issue. Please note that the sensors in your phone (including the GPS receiver) are very prone to environmental disturbances.

My compass is very "jumpy"...

Try to set the sensor filtering in preferences. It can filter out the measurement noise, but at the same time the compass will react slower to changes.

I am standing at the sea shore, but the altitude is always minus 80 feet... Why?

GPS (in android phones) does not report the height above the mean sea level; rather the GPS system compares the height to the WGS84 reference ellipsoid which may be above or below the actual sea level. In different parts of the earth it can be off by more than 200 meters (depending on the mass distribution of Earth). For example the geoid's surface around Florida is above the mean sea level by a good 30-40 meters, which means that standing on the shore would show you -30m as altitude. This is normal, and not an error, and caused by the fact that the altitude is relative to an artificial reference surface and not to the sea level. If you are interested in this topic, I recommend reading this. Over the long term I will add some options to the program to allow for the correction of this value.

Is it showing magnetic or true north? How to set the magnetic declination?

Magnetic declination is the difference between the true and magnetic north at your location. The value is calculated automatically by the program using the current geo-magnetic earth model. The algorithm uses your current location and time. To answer the question: The needle in the middle is always showing the magnetic north while the grid itself (small blue arrow) points always towards true north. The angle between these two corresponds to the magnetic declination. The last number in the "Magnetic field" instrument is the magnetic declination in degrees.

My compass points to the wrong direction or I'm asked to calibrate my compass. What should I do?

Your phone contains a digital compass which measures the magnetic field's strength in three directions with three separate sensors. The orientation of your phone is calculated from these values. Unfortunately the sensitivity of the sensors are a little different. To correctly calculate your orientation your phone must measure first these differences. This is done during the calibration process. To calibrate your phone, simply find a space where no external magnetic field is present (preferable outside of buildings) and rotate your phone 1-2 times on EACH of its three axes (Swinging your phone in big 8s in all direction will also do, but it' less scientifically correct :)). If you feel that your compass has become inaccurate you can repeat this procedure.

What does the Magnetic field reading mean?

Aside from your orientation, your phone can measure the absolute strength of the magnetic field which is displayed as the first number in the reading. The second number is calculated from your GPS position and current time using the earth geo-magnetic model. It is the theoretical strength you should measure in an open space. If the two values are sufficiently different, then you are standing in a magnetic anomaly. This is pretty funny because this allows you to detect big nearby metal objects. Go and try hunting for treasures.

The compass needle changes its size...

The size of the needle indicates the relative magnitude of measured magnetic field to the calculated value. If the measured and calculated value is the same, the needle should be the same size as the inner circle on the grid. If the magnetic field is bigger/smaller than it should be, the needle will be also bigger/smaller. This way you can see at a glance whether you are standing in a magnetic anomaly. If the needle is too small or too big chances are that an external magnetic field is present and the compass points to the wrong direction.

Velocity cuts out above 400 km/h.

Civilian GPS systems are guaranteed to work only under certain conditions. They cannot measure reliably if your speed is above 4-500 km/h or your height is above 15km. So this is a limitation of the GPS system itself.

13.6 APPENDIX F: KML/KMZ OVERVIIEW

Google Earth is a powerful tool for viewing, creating and sharing GIS data. The latest improvements in the KML format allow storing attributes as structured data.

KML/KMZ are Google Earth's file format for storing placemarks, network link information, and much more. KML stands for Keyhole Markup.KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. Since a KML file is a text file, its size might become quite large. Google Earth also takes a lot of RAM when large KML files are loaded. For this reason we tried to split your datasets to subsets before converting them to KML.

KMZ stands for KML-Zipped. It is the default format for KML because it is a compressed version of the file. One of the more powerful features of KMZ is that it allows any images and additional files you use - say images in your descriptions for ex. - to be zipped up within the KMZ file. That way you can share these details without having to reference the files through some link to the Internet. For KMZ files without images, the file size will be much smaller than the equivalent KML file. Depending on the content of the KML file, this process typically results in 10:1 compression.

Tip: You may need to change the file extension from .kmz to .zip to have the file be recognized by a zip tool. Remember to change back to .kmz before using the file again.

Use Google Earth (http://www.google.com/earth/index.html) to open KML and KMZ files.

13.6.1 Viewing KML/KMZ in Google Earth

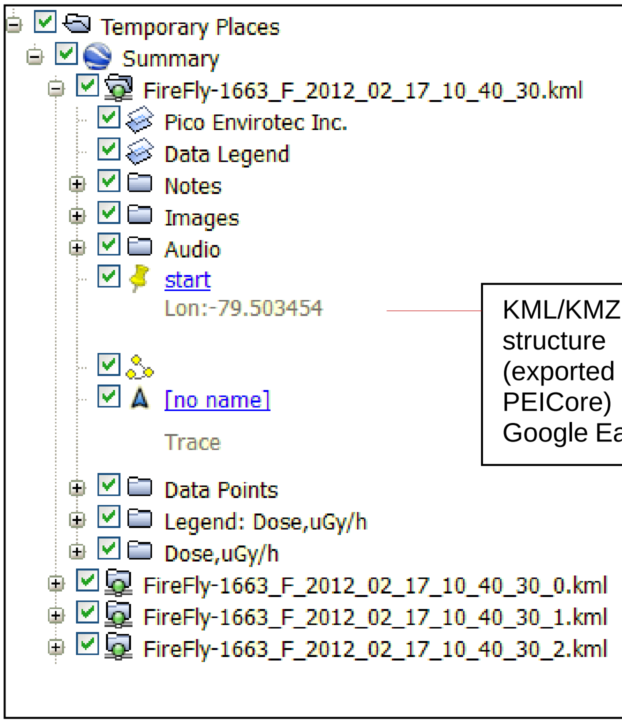
Open KMZ file (right-click on the file – Open With Google Earth or start Google Earth and FILe->Open)

On the left side (Places) you will see:the structured data that was created by PEICore

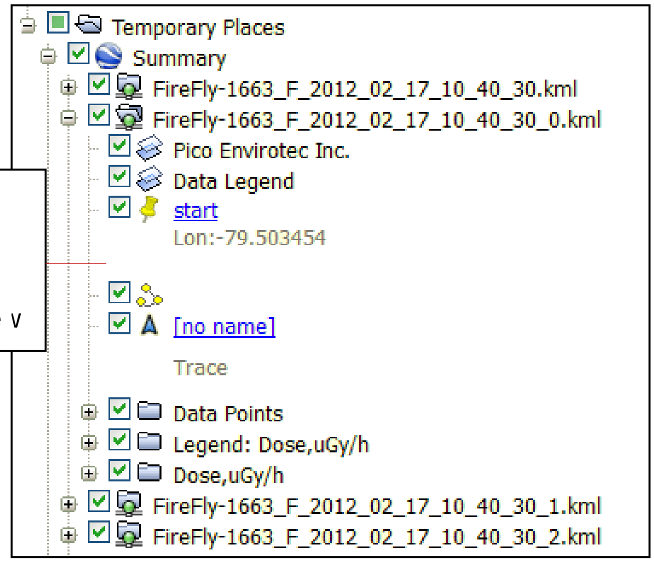
If there are more then one KML file created (kml files contains 3600 data points) the summay *doc.kml* will keep the list of all of the KML files. Note, that only the one of them will contain the references to your additional files and stations.

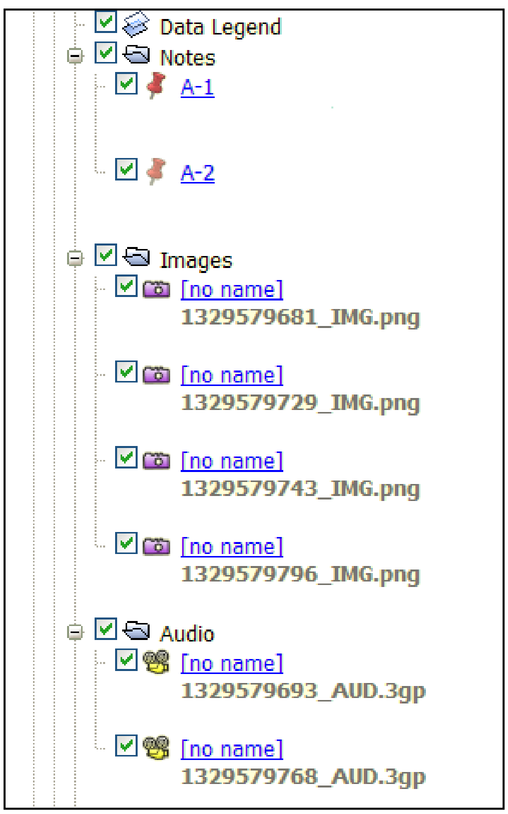
Data points are shown as path/route (colored line): in two ways : consequtive points and grouped by value range. You can select a group folder to see the data in a particular range.

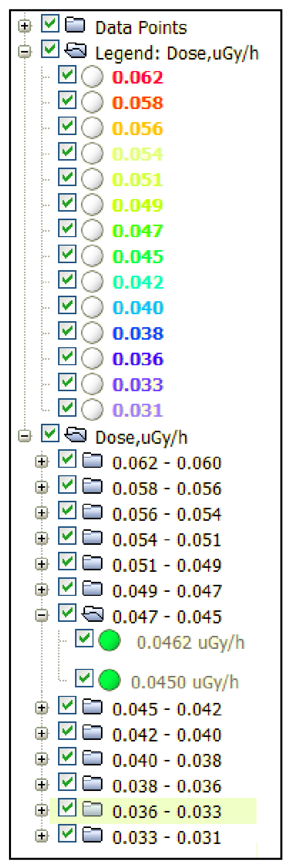
The below images displayed the folder structure of the exported KMZ/KML files.



KML/KMZ file structure (exported by PEICore) – Google Earth view







Notes, Images, Audio files are stored in the searate folders and the details will be displayed when you select it (click)

Audio files are stored in the .3gp format and played via 3gp player

13.7 APPENDIX G: PREPARING THE MAP FOR USING OFFLINE

To download the map tiles you may use Mobile Atlas Creator.

The steps were as follows, most settings are done in the options pane to the left of the map:

1. Set atlas format to Osmdroid ZIP [Atlas - Convert Atlas Format].
2. Set your map area coordinates, either by clicking and dragging on the map, or by setting min and max coordinates in the coordinate selection pane to the left.
3. Set map source to OpenStreetMap Mapnik. **Note**: I originally set my source to something else, and the map wouldn't appear on my phone. I'm sure there's a simple fix for this, but haven't looked into it yet.
4. Select the zoom levels you want to include. This will impact the storage space required. As you select more levels, the number of tiles needed are displayed. Each pane takes about 20kilobytes. I included all levels because my area of interest is so small that I'm not to concerned about that yet, I might make small versions available when I publish the app. For my area, 178 tiles + 20kB = 3.48MB.
5. In the Atlas Content pane, set the name of your map first, then click "add selection" (the name really isn't important, though).
6. Then select "Create atlas" and your map is stored in the atlas folder under Mobile Atlas Creator.
7. Move the resulting zip-file to /mnt/sdcard/osmdroid/ on your device. (For a slight improvement in performance, you can unzip the file and move the resulting Mapnik-folder to /mnt/sdcard/osmdroid/tiles/ instead. The difference in size isn't that big, but the zip-file might be a good way to organize different maps if you have several areas, but I digress).

Also works with other maps if they have the same directory structure and png format for images (exported as osmdroid zip). / sdcard / osmdroid / theosmdroid.zipInside the zip file:

Mapnik /
NN / (zoom levels)
NNNN / (folder area)
xxxx.png (png images)

GAMMA REMOTE SENSING

GAMMA Portable Radar Interferometer
Model: GPRI-II

User Manual

12-Aug-2014

GAMMA Remote Sensing AG
Worbstrasse 225
CH-3073 Gümligen, Switzerland
www.gamma-rs.ch

Table of Contents

1. Read First

This is the user manual for the GPRI-II hardware that uses the Gamma developed azimuthal scanner, and Instrument Computer running Ubuntu Linux 14.04 LTS. If you have feedback please do not hesitate to contact us gamma@gamma-rs.ch.

1.1 Regulatory Notices

NOTICE (FCC 15.19/RSS-GEN):

This device complies with Part 15 of the FCC Rules [and with Industry Canada license-exempt RSS standard(s)].

Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and

(2) this device must accept any interference received, including interference that may cause undesired operation.

Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio
exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

(1) l'appareil ne doit pas produire de brouillage, et

(2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

NOTICE (FCC 15.21):

Changes or modifications made to this equipment not expressly approved by Gamma Remote Sensing AG may void the FCC authorization to operate this equipment.

NOTICE (FCC 15.105):

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

Notice (FCC 2.1091 / 2.1093 / KDB 447498 / RSS-102)
Radio frequency radiation exposure Information:
This equipment complies with FCC and IC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance of 100 cm between the radiator and your body. This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

Cet équipement est conforme aux limites d'exposition aux rayonnements IC établies pour un environnement non contrôlé. Cet équipement doit être installé et utilisé avec un minimum de 100 cm de distance entre la source de rayonnement et votre corps.

Notice (IC RSS-Gen 7.1.2):
This device has been designed to operate with the antennas listed below, and having a maximum gain of 32 dB. Antennas not included in this list or having a gain greater than 32dB are strictly prohibited for use with this device. The required antenna impedance is 50 ohms. The 3 identical antennas used with the instrument are custom manufactured for Gamma Remote Sensing AG and only available from Gamma:

GPRI-II-2 Antennas:

Model:	*ANT0235-0100*
Type:	*Slotted Waveguide*
Frequency:	*17.1 to 17.3 GHz*
Polarization:	*Vertical*
Maximum Gain:	*32 dB*

To reduce potential radio interference to other users, the antenna type and its gain should be so chosen that the equivalent isotropically radiated power (e.i.r.p.) is not more than that permitted for successful communication.

Cet appareil a été conçu pour fonctionner avec les antennes énumérées ci-dessous, et ayant un gain maximal de 32 dB. Antennes pas inclus dans cette liste ou présentant un gain supérieur à 32 dB sont strictement interdits pour une utilisation avec cet appareil. L'impédance requise de l'antenne est 50 ohms. Les 3 antennes identiques utilisés avec l'instrument sont fabriqués sur mesure pour Gamma Remote Sensing AG et uniquement disponible à partir de Gamma

GPRI-II-2 Antennes:

Modèle:	*ANT0235-0100*
Type:	*Slotted Waveguide*
Fréquence:	*17.1 to 17.3 GHz*
Polarisation:	*Vertical*
Gain Maximum:	*32 dB*

Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante.

1.2 Electrical Safety

There are no user serviceable parts in the RF Assembly, Instrument Controller Enclosure, or Azimuthal Scanner

1. The mains socket outlet must be close to the equipment and easily accessible. It must be provided with a protective earth. Depending on national safety regulations, a double pole circuit breaker is required.
2. The auxiliary output provides a voltage of 22 to 30 VDC. The maximum current is 4A.
3. Disconnect all power by turning off the power and unplugging the power cable before installing or removing a chassis or working near power supplies.

1.3 General Safety

- Keep the working area clear during installation and instrument operation.
- Wear safety glasses if you are working under any conditions that might be hazardous to your eyes.
- Do not perform any action that creates a potential hazard to people or makes the equipment unsafe.
- Do not work alone if potentially hazardous conditions exist.
- Never assume that power is disconnected from a circuit; always check the circuit.
- Electrical equipment generates heat. Ambient air temperature may not be adequate to cool equipment to acceptable operating temperatures without additional measures.
- Ensure that the Tripod, Tower, Antennas, RF assembly and Instrument Controller are mechanically secure, especially in high wind situations. All components should be securely fixed to prevent them from falling over.

1.4 Introduction

The Gamma Portable Radar Interferometer (GPRI) development at Gamma is based on the benefits of in-situ measurement of deformation using differential radar interferometry. Our extensive experience with satellite differential interferometry has demonstrated successful application of this technique for measuring deformation due landslides, subsidence due to pumping of oil and water, slope failures in open-pit mining, and glacier and tectonic motion.

However, when the deformation between repeat observations exceeds wavelength/4 the usefulness and interpretation of the data rapidly become difficult. A ground-based instrument can be rapidly deployed and obtain data with both high spatial and temporal resolutions that are particularly well suited to measuring rapid deformation.

Unlike orbital SAR systems, in-situ measurement permit flexibility in the selection of the observation geometry. The geometry can be selected to give maximum sensitivity to deformation along the line of sight. Observations from multiple aspect angles can be combined to resolve the deformation into components along different look vectors.

Path delay variation due to tropospheric water vapor is the most significant cause of error in deformation using differential interferometry. A stationary instrument has the ability to acquire multiple observations for mitigation of path delay variations. Note that ground measurements have a shorter path through the atmosphere than orbital observations also leading to reduced error from this source.

Multiple observations acquired over short time intervals have the advantage that decorrelation is minimized by the shorter time intervals. Successive measurements can be processed to track non-linear deformation within the scene.

This manual shall help the user to setup and use the instrument but also provides background information on the instrument. Section 2 describes how to setup the instrument in the Field. Section 3 describes the software interface to the system and how to operate the instrument using secure shell (ssh). Section 4 gives more detailed information on the instrument hardware and operation. Section 6 describes the instrument software for data acquisition and processing as well as lower-level utility programs for instrument control. Section 7 describes some of the programs in the GAMMA software that are used for processing the GPRI data to obtain deformation maps. Section 8 has the instrument specifications and the Appendix (section 9) contains a sample form used for recording system parameters during a field campaign.

2. Mechanical Setup for Measurement

The installation needs to be stable and reproducible (if repeat measurements from a given position are foreseen). The GPRI can be installed either on a heavy duty tripod or on a concrete or metal pier. In either case there must be sufficient free room for the instrument to rotate (about 2.5 meters). There should not be any obstacles in the direct path of the antennas such as trees, bushes, fences, or buildings. Large structures such as buildings or towers should not be in the line of sight in the region of interest.

Figure 1: GPRI-II installed on a pedestal with adapter plate and spacer

2.1 Tripod Mounting

Installation of the tripod is the first step in setting up the GPRI-II. The tripod legs should be initially fully retracted. Make sure that you have a clear view of the region of interest in the scene and that there are no large obstacles in front of the radar such as walls or power towers. Radar backscatter from near targets can saturate the radar receiver. Nothing should get in the way of the antenna rotation and any objects such as bushes should be at least a few meters away from the antennas.

Take the tripod out of the canvas transport bag and take out the 3 stainless steel rods.

1. Install the stainless steel support rods to the tripod to maintain the legs at a fixed 60 degree angle. These rods fit into the attachments at the bottom of each leg. The end of the rod is shaped to fit into the slots on the attachment points. A small locking arm on each attachment point must be rotated to permit insertion of the rod. Once the rod is attached, rotate the arm back over the rod ends and it will lock into place.
2. The tripod legs are numbered 1,2, and 3 with label. Make sure that you note the location of each leg so that when you return to the site, the orientation of the tripod is identical. One leg of the tripod should remain fully retracted and this should not change. In sloping terrain, this leg should be the leg with the highest elevation. The zero degree look direction of the radar is in the direction of leg 2 and should point to the center of the region of interest.
3. Using the bubble level on top of the tripod, extend the other 2 feet of the tripod until the tripod top surface is horizontal as seen in the small bubble level. Remember to keep one leg of the tripod fully retracted and only extend the other 2 legs.
4. Screw the feet through the hole in the tip to the ground using anchor screws (6mm anchors).
5. Measure and note the extension of the legs for future repositioning if you intend to return to the same position for repeat pass observations.

Figure 2: Stabilization rods for the tripod. These snap into the rod brackets mounted on the tripod legs.

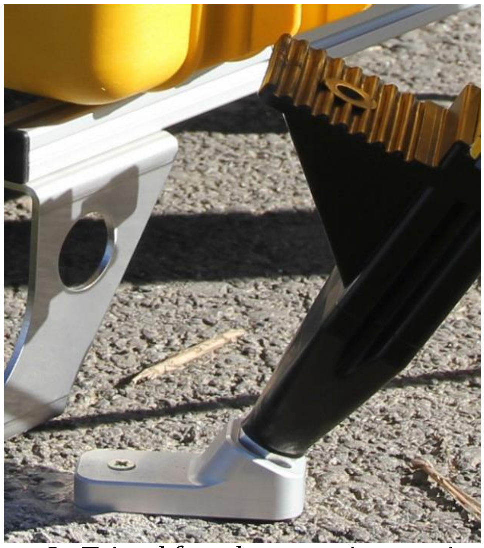


Figure 3: Tripod feet that permit screwing down the legs at fixed positions

Figure 4: Tripod leg extent measurement. Only required for repeat measurements.

Figure 5: Interface Plate of the Tripod with level and 5/8" hollow screw. The small level is used to ensure that the tripod is level after the feet are locked.

2.2 Mounting of the GPRI-II on a Pedestal or Mounting Plate

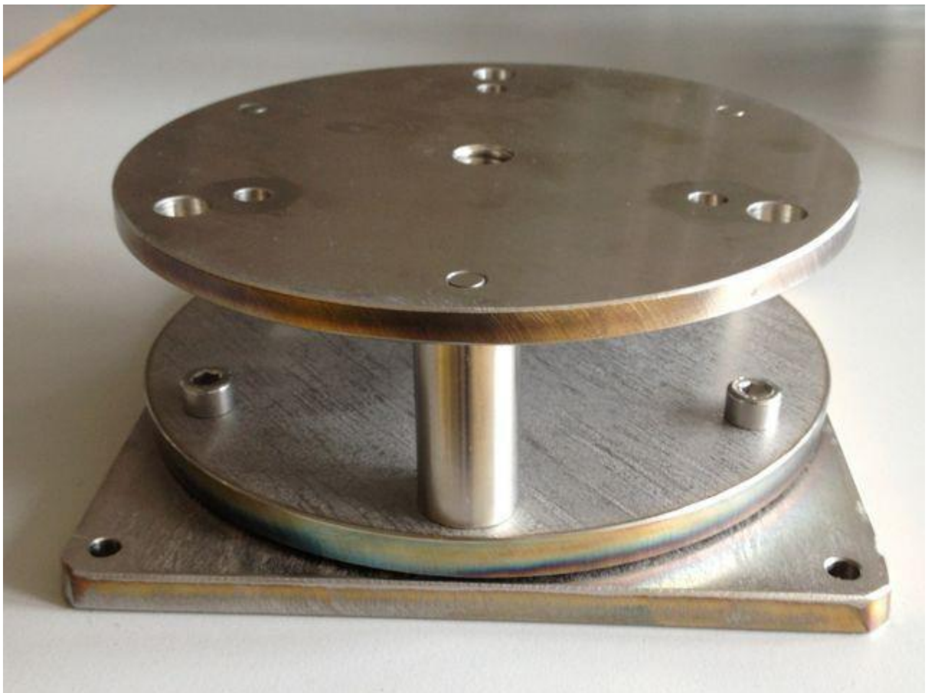


Figure 6: Mounting Plate and Tribrach Spacer

The GPRI can also be mounted on a pier using a stainless steel plate and spacer included with the GPRI. The plate should screwed down to the pier using anchor screws. The tribrach spacer (shown in Figure 6) is attached to the plate and to the tribrach using four M8 x 20 mm socket screws. The mounting plate can also be used on rock surfaces using anchors for attachment. The tribrach is attached to the spacer using 4 M8 x 20 mm socket screws. Stainless steel hardware should be used throughout. Additional plates are available from Gamma.

2.3 Azimuthal Scanner, Tribrach and Tower

1. Mount the rotary positioner and leveling assembly on the tripod using the black 5/8” screw interface of the tripod. The positioner has labels with the numbers 1 and 3. Position this edge of the positioner +leveler between tripod legs 1 and 3. Rotate the positioner and leveler assembly such that the edge of the positioner plate is parallel with the tripod stainless-steel rod between legs 1 and 3.
2. Make the antenna tower interface perfectly level using the tribrach level adjustment screws. Note, the screw on side 1 is fixed and should never be loosened. The large bubble level on the positioner should be used to determine if the tower mounting plate is level. Be sure to look down from directly above the level to make sure the bubble is centered. Alternately you can look from 2 sides and make sure that the bubble is in the center of the black ring.
3. If you intend to perform repeat observations from the same point, then power on the laser plummet using the battery pack. If this is the first measurement, mark the position of the laser on the ground for future repositioning. This point is precisely on the rotation axis of the tower. If you are returning to the site, adjust the positioner and leveler so that the laser beam hits the previously marked rotation center
4. Remove the 4 wing screws on the tower mounting plate, and mount the tower on the plate. There is an alignment pin on the plate that makes sure that there is only one way to position the tower. Screw the tower to the mounting plate. When you remove the tower, be sure to screw the 4 screws back on to the plate for future use and storage.
5. Define the antenna elevation angle and set all six antenna holders accordingly. The antenna illuminates about 60 degrees in elevation, Set the elevation angle so that the beam center aims at the area of interest. If there are areas that are significantly farther away, adjust the beam to be centered on these areas.

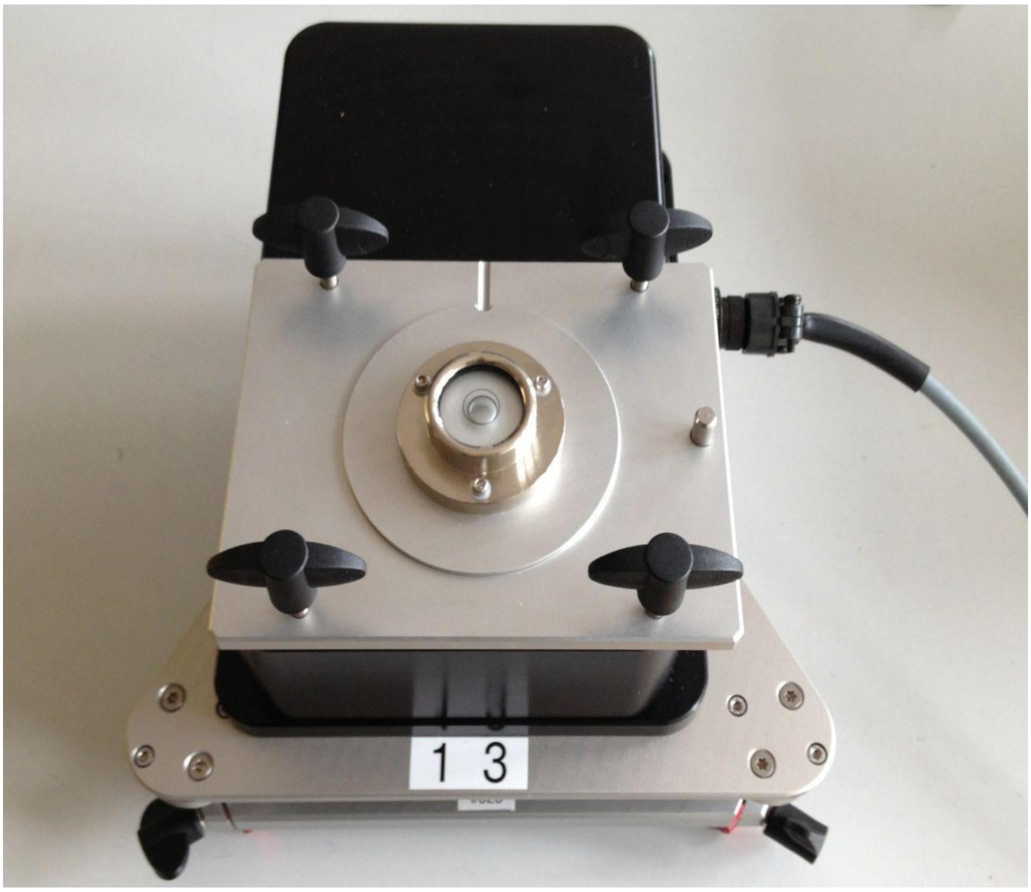


Figure 7: Azimuth Positioner with Tribrach. The 4 wing screws are used to secure the tower to the positioner. The bubble level is used to level the tower. Note the pin on the right side of the positioner plate for accurate repositioning of the tower. The front of the positioner (top of image) should point towards the center of the region that is azimuthally scanned.

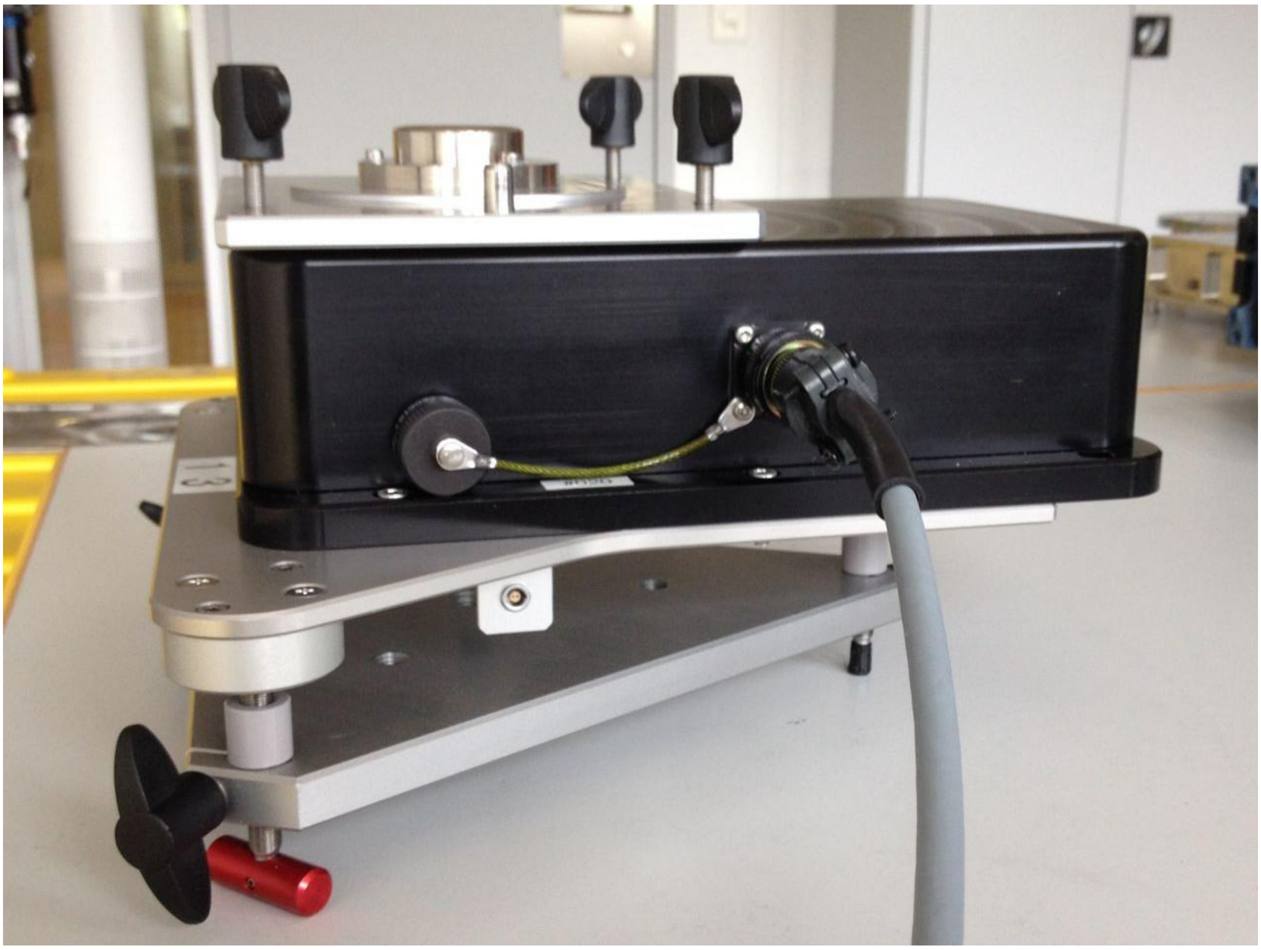


Figure 8: Side view of the tribrach and azimuth positioner. The tribrach is leveled by rotating the two red knobs that are locked by the black wing screws. The power connector for the laser plummet is below the azimuth positioner.

2.4 Mounting the RF Assembly (RFA) on the Tower

1. Mount the RF Unit on mounting brackets at the back of the Antenna Tower. Use the 2 wing screws on the back to secure the RF unit to the tower.
2. Attach the GPS Antenna cable to the BNC connector on the side of the RFA. The GPS antenna is located on top of the tower centered on the tower rotation axis.

Figure 9: RF Assembly antenna connectors. The three antennas connect to the SMA coaxial connectors using the 8mm torque wrench.

Figure 10 : RF Assembly mounted on the antenna tower. On the left side is the BNC GPS antenna connector.

2.5 Antenna Mounting

These have been precisely positioned on the tower to insure that the antennas are parallel. The elevation angles must be set to the same value on both sides of the tower. **The antenna can be severely damaged if the elevation angles of the bracket are are not the same angle for both sides of the antenna!** There are 5 degree detents where you can insert the pins so that the elevation angle can be set in 5 degree increments. The antenna has a half-power elevation beamwidth of about 30 degrees and a null-to null beamwidth of about 60 degrees. The elevation angle is usually selected so that the center of the antenna beam points towards the far range of the region of interest. Since the gain of the antenna is maximum at the center of the beam, the beam center should point near to the farthest area in the region of interest to get a stronger radar echo. For example if you are looking at a mine pit from the edge, the antenna is pointed in elevation slightly down, perhaps -5 or -10 degrees from horizontal. As an other example, if looking at a mountain slope, where the crest is at +35 degrees elevation, select the antenna elevation to a value near +25 degrees.

The antenna elevation (Tilt Angle) must be set BEFORE mounting the antennas on the brackets. To adjust the brackets to a specific elevation angle loosen the center butterfly screw 1 turn and pull out both locking pins. The bracket should then be able to rotate about the screw axis. Select the elevation angle such that you are pointing approximately at the farthest point in the region of interest near the center of the beam and insert the locking pin at that angle. The antenna elevation beamwidth is about 30 degrees, so make sure that the region of interest lies within the beam. The elevation angle can be set in steps of 5 degrees. The positions alternate between the two pins in 5 degree steps, such that only one of the pins can be inserted at a time. After the appropriate pin is inserted at the desired tilt angle, tighten the wing screw (do not over-tighten!).

1. Take each antenna out of the tube by loosening the thumb screw at the end of the tube. NOTE it is important that you slide out the antenna with getting the antenna cable caught between the tube and the antenna. For that reason pull out the end of the antenna with the desiccator. The clear plastic end-plates have a hole that you can grasp to pull out the antenna.
2. Mount the antennas one by one on the corresponding antenna brackets. Make sure you use a fixed order for the antennas (TX, RX1, RX2) to avoid phase effects due to slightly different antenna characteristics. The antennas are marked TX, RX1 and RX2. Typically the TX antenna is on top and RX1 and RX2 are above one another. But in the case of the radome, the TX antenna is at the tower center and RX1 and RX2 are at the top and bottom respectively.

   NOTE: When using a radome, the transmit antenna should be the center antenna on the tower to reduce reflections.
3. Connect the 3 antennas to the appropriate SMA connect jacks on the side of the RF assembly using the 8 mm torque wrench. **Do not over-tighten the SMA coaxial connectors**! Rotate the torque wrench until it clicks. Inspect the connector before each use to make sure the pin is straight and not damaged and that connector is clean.
4. **Never move or adjust location of the antenna brackets on the tower.** These have been carefully positioned on the tower. The spacing between the top brackets and the center bracket is 35 cm. The distance between the center and lower brackets is 25 cm. Hence if you are using the center antenna for the transmitter, the interferometric baseline between the receive antennas is 60 cm.

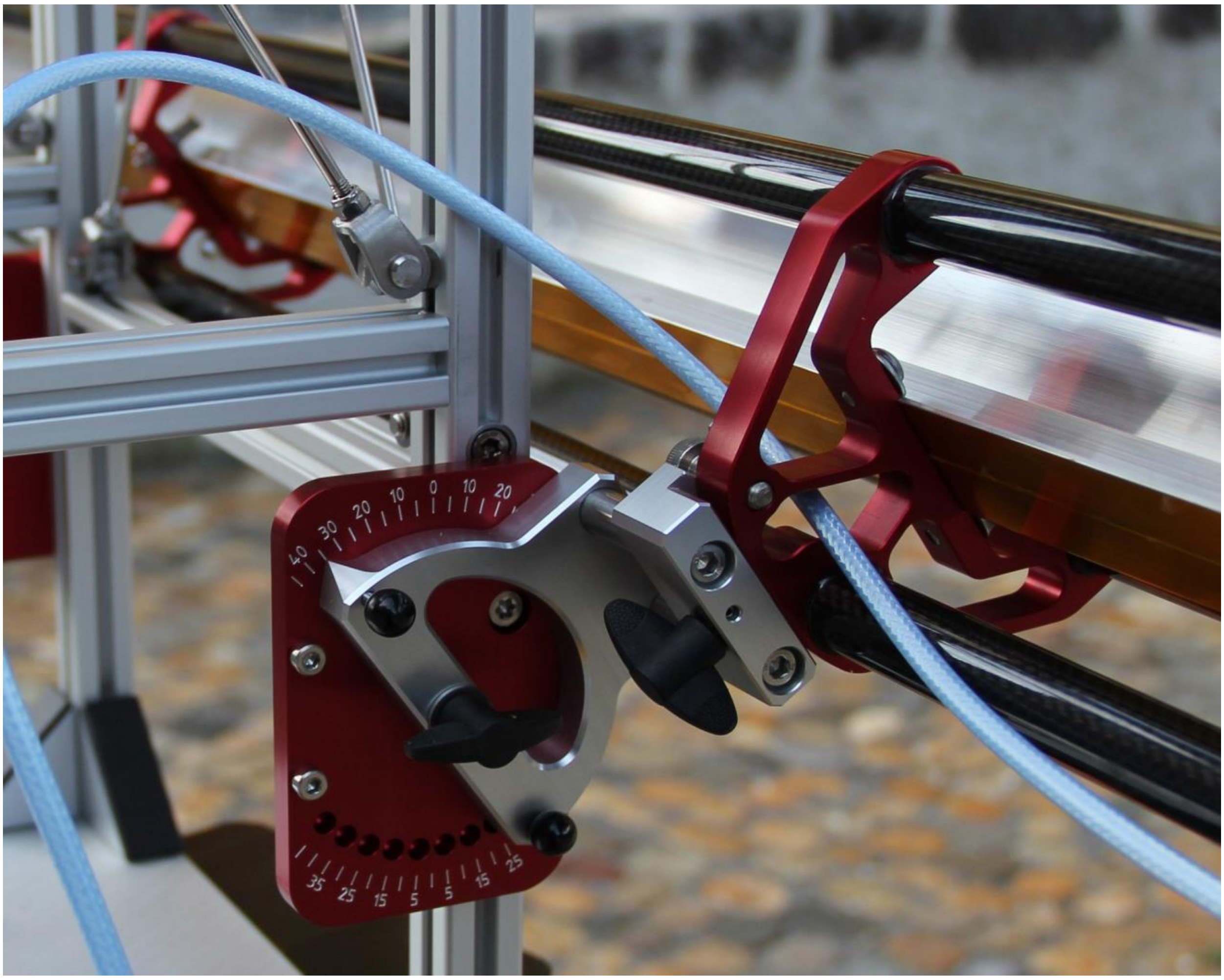


Figure 11: Closeup of the antenna bracket with elevation setting. Here an elevation angle of 35 degrees has been selected. Note that the angles in 10 degree steps are for the upper pin, and the angles offset by 5 degrees are on the lower circle.

2.6 Power Requirements

The GPRI-II can be powered either using AC in the range of 100 to 240 VAC 50-60 Hz at 2.0 Amperes, or DC power at 22-30 VDC at 7.5 Amperes. The instrument is supplied with a power cable for AC. The DC power cable uses different wiring at the Instrument Computer power plug to differentiate between AC and DC. A power cable configured for DC is provided with an available Lithium-Ion Battery pack. A DC power cable is available from Gamma if this is required for DC operation without the battery pack.

Connect the GPRI power cable to the AC or DC power source only after the RFA has been connected to the Instrument Computer with the RFA Multi-Function cable.

2.7 Instrument Controller Installation

The instrument controller inclosure contains the instrument computer, power supplies, and software defined radio (SDR) used for digitization of the radar signals.

1. Place the Instrument Computer case close to the tripod in a dry location. The usual location

is close to the tripod so that there is sufficient slack for the cable to wrap ¾ turn around the tripod.

2. Make sure the Instrument Controller is switched off before connecting any cables
3. **The RFA can be damaged if the RFA Multi-Function cable is connected or disconnected when the Instrument Controller is powered ON!**
4. Connect the Instrument Controller with the RF Unit (orange cable).
5. Connect the Instrument Controller with the azimuthal scanner using the grey cable.
6. Connect the Instrument Controller to the computer network using an Ethernet cable at the LAN port.
7. Switch on the power to the Instrument Controller.

Figure 12: GPRI Connector Plate: Ethernet LAN, RFA, Power, USB, Scanner, Auxiliary Power for the radome fan connection

3. Instrument Operation

Communication with the instrument in the field is through TCP/IP over Ethernet. The easiest solution is to connect the instrument to a laptop computer. Modern laptops automatically check on the direction of the signal and crossed Ethernet cable is not required. For maintenance it is also possible to connect screen and keyboard directly to the video port and USB ports. This would be a way to change the IP address of the instrument or to set the instrument to obtain an IP address via DHCP.

The GPRI-II supports two communication layers, SSH (Secure Shell) and HTTPS (Secure Web). It is good policy to have also a logbook for the instrument and take pictures for documentation. A list of items to record is given in Appendix A.

3.1 Field Measurement Setup Procedure

When setting up the instrument at a new site the following parameters must be set up to ensure a successful measurement campaign after the instrument has been installed. The parameters for a measurement are stored in a GPRI-II profile described in Section 5.7.1. An example of a measurement profile is shown below for a 2 ms FM-CW chirp:

```
RF_center_freq:     1.720000e+10
IMA_atten_dB:   48
CHP_freq_min:   100.0e6
CHP_freq_max:   300.0e6
CHP_num_samp:   12500
STP_antenna_start:  -80
STP_antenna_end:    70.0
STP_gear_ratio:       72
STP_rotation_speed:  10.0
TX_power: on
TX_mode: None
ADC_capture_time: 0.0
ADC_sample_rate:   6.25000e+06
antenna_elevation: 10
```

Table 1: Measurement Profile for a 2ms chirp. The azimuth scan starts at -80 degrees and ends at +70 degrees. The nominal rotation rate is 10 deg./second. The chirp lasts 2ms, equivalent to 12500 samples as specified by the CHP_num_samp keyword.

The usual procedure is to copy one of the default profiles from the $GPRI2_HOME/profiles into the directory where you will be storing the data on the disk and edit this profile using a text editor such as *gedit or pico.* You can also use a previous created profile and adapt it.

mkdir /data/RoboNorth
cd /data/RoboNorth
cp /home/gpri2/GPRI2-2/profiles/gpri_2ms.prf robonorth_2ms.prf

#edit the profile using a text editor
gedit robonorth_2ms.prf

The parameters in the profile in keyword:value format determine the azimuth sweep starting and ending angle (degrees), sweep speed in degrees/second, the FM-CW chirp length (samples), and the radar attenuation.

The FM-CW chirp length is the number of samples the radar acquires during the transmission time of the chirp. The radar samples the data at 6.25 MHz or equivalently 6250 samples/millisecond. A 1 ms chirp has 6250 samples, 2ms 12500, and a 4ms chirp 25000 samples.

The radar attenuation is the opposite of gain and is specified in decibels (dB). The higher the attenuation, the lower the gain. The nominal default value of the attenuation is 44 dB. Generally when looking at targets close to the radar, the attenuation can be higher. It has valid values that are even, ie 40,42,44... in the range of 0 to 60 dB. When operating in a radome, the default value is +48 dB due to the additional reflections within the radome.

The radar image will cover a slightly smaller span than the actual scan due to the time required to accelerate the radar to the constant scan speed. The raw data collected by the radar is processed to produce 2 SLC images, one image from each of the receiving antennas. The Single-Look complex image metadata (SLC_par) generated from the raw data contains the actual start and end azimuth angles and the angular spacing between image lines.

The RAW_par metadata file for the raw data is similar to the measurement profile but includes additional information such as the GPS coordinates, exact start time of the data acquisition, and the exact frequencies and FM-CW chirp rate. An example RAW_par file is shown below and described in detail in Section 5.7.2:

```
time_start: 2010-11-05 10:57:06.025627+00:00   #UTC time at s tart of data
geographic_coordinates:    46.6809900000, 7.6398266667 613.00 47.3
RF_center_freq: 1.72000000000e+10
RF_freq_min:     1.71000578460e+10
RF_freq_max:     1.72999421541e+10
RF_chirp_rate:   9.99425537884e+10
CHP_num_samp:   12500
TX_mode:        None
IMA_atten_dB:   48
ADC_capture_time:    9.50679
ADC_sample_rate:     6.25000e+06
STP_antenna_start:   -80.0
STP_antenna_end:     70.000
STP_rotation_speed: 10.00000
STP_gear_ratio:      72
antenna_elevation:  10.00000
CHP_temperature:  23.500
TSC_temperature:  28.400
```

Table 2: RAW_par meta-data file is generated for each raw data file

3.1.1 Determine the Field of View for the Azimuth Scan

When you turn on the radar and have made a connection using SSH, the first thing that must happen is that you calibrate the azimuthal scanner by entering the *home_run.py* command:

home_run.py

When this command is completed, the antenna will be in the home position that corresponds to an azimuth angle of 0.0. The antenna can rotate from -270 degrees to + 270 degrees. Positive rotation is to the right when looking at the antenna tower, standing behind the antennas. It is good practice to orient the antenna mount so that azimuth angle 0.0 is close to the center of the azimuthal scan, such that for a scan of 120 degrees, you would set the azimuth scan angles from -60.0 to +60.0 degrees.

You can move the azimuth position from the command line using the move_abs.py command

move_abs.py -30

will move the azimuth antenna position to -30 degrees. You can then determine the azimuth scan starting and ending azimuth angles.

3.1.2 Selection of the FM-CW Chirp

Select the FM CW chirp duration based on the maximum distance that will be recorded in the image and background. See Section 5.7.1.

Acquire the initial radar image and adjust the radar gain to avoid saturation. Check and possibly modify the azimuth field of view to ensure that the radar. View a plot of the radar echoes using the *-g* option when acquiring data with *gpri2_capture_utc.py*. Alternately call the program *gpri2_raw_plot.py* to examine the raw data that have been written to disk.

3.2 Operating the GPRI-II through SSH

To control the instrument through SSH a SSH client program is necessary. Preferred is to access from a Linux system that also permits using the X-Windows graphics supported by the Linux OS running on the instrument. There are X-Windows servers that run on Windows (e.g. Cygwin). See the Cygwin web page for an open-source X-server and SSH client that can be installed. It is easiest to have a laptop running Linux for communication but not essential. Under Linux, be sure to install the Linux SSH client *openssh.*

Please refer to Section 5 for the detailed instrument software reference. Program parameters are provided for easier reading but need to be adjusted for each case.

1. Login to instrument:
   ssh -X gpri2@192.168.1.xx *where xx = 70+GPRI-II Serial Number*

2. Check available disk space for data. The data are stored in the */data directory*. This directory is in its own partition on the disk.
   df /data

   and then set your current directory to be /data:
   cd /data

3. Initiate home run of the positioner (make a visual check that instrument can move freely and the RFA cable has enough room when it rotates!):
   home_run.py

4. The instrument is now looking at 0 degrees local instrument azimuth angle. Angles increase clockwise. Negative to the left, positive to the right when standing behind the instrument looking in the illumination direction of the antennas. This would be a good time to measure the azimuth heading of the instrument using a compass (there is one in your iPhone or other smart phone). The azimuth heading of the radar is the angle relative to true North when at the home position. If the radar is facing East the heading is +90 degrees, West is -90 degrees, and south is 180 degrees from North. Furthermore you may want to check system and GPS status to make sure these components are working properly:
   chupa_status.py
   tscc_status.py
   gps_message.py
   The CHUPA and Instrument Computer interior temperatures should be below 65° C. The program *tscc_status.py* prints the interior temperature of the instrument computer to the screen. *gps_message.py* will print several lines of the GPS NEMA messages to the screen.

5. Create a directory for your site, e.g. the location name, and move into:

```
mkdir -p /data/mysite/20140625
cd /data/mysite
```

6. Define the measurement parameters and setup the corresponding measurement profile. The profile contains information on the transmitter chirp, angular scan, speed, and receiver attenuation. See Table 3 for a description.

   You can copy a template preference file from ~/GPRI2-2/profiles for several different chirps. Its a good idea to give it a descriptive name (site, name), especially if you do repeat measurements.

   ```
   cp /home/gpri2/GPRI2-2/profiles/gpri_2ms.prf mysite_2ms.prf
   ```

7. Determine the start and stop azimuth angles for the scan. Be aware that approximately 2 degrees are needed on both sides of the scan for acceleration and deceleration. To determine the starting and stoping azimuth angle use the *move_abs.py* command to move to the angle desired.

   ```
   move_abs.py -30
   ```

8. Edit the profile to reflect your settings for *IMA_atten_dB, STP_antenna_start*, *STP_antenna_end* and *antenna_elevation*. The setting *TX_power* must be "on" for measurements, or "off" for listen only. The -g option generates a screen plot that can be examined for saturation. Description of the profile parameters is given in Section 5.7.1.

   ```
   gpri2_capture_utc.py mysite_2ms.prf 20140625\
   1 now 60 -p 20140625 -m 20140625 -g -d 5 -R 2000 -s .35 -e .35
   ```

9. Then display the processed data:

   ```
   eog 20140625/*.bmp
   ```

   Check signal levels by plotting the raw data signals with *gpri2_raw_plot.py* to make sure there is no saturation. If there is saturation (signal above 0.75 volts) then increase the attenuation value in the profile by 6 dB and repeat until there is no saturation in any echo. Nominal values for attenuation are between 44 and 50 dB. If the signal is below 0.1 volt you might consider decreasing the attenuation level by 6 dB.

10. A long series of SLC images can be acquired using the *gpri2_capture_utc.py* script by specifying the number of scenes and the time interval parameters (see documentation on *gpri2_capture_utc.py*). If a long series of differential interferograms for deformaton analysis is required then use the script *gpri2_capture_ts6.py*.

11. **Backup** data. e.g. with *rsync* to a network attached disk. Use *ionice* to avoid disk timeouts while acquiring data at the same time that a backup is being performed:

    ```
    ionice -c2 n7 rsync -av mysite 192.168.1.1:/backup
    ```

    Alternately use an external USB disk and mount it. To find out the device id of the disk, most likely */dev/sdb1*:

    ```
    dmesg | tail -n 50
    ```

    and look out for lines such as

    ```
    [1295858.275037] sd 16:0:0:0: [sdb] Assuming drive cache:
    [1295858.275046] sdb: sdb1
    ```

    Mount the device on /mnt for user GPRI-II with:

    ```
    sudo mount -o gid=1000,uid=1000,user /dev/sdb1 /mnt
    ```

The data can now be copied to and from /mnt.
ionice -c2 -n7 rsync -av mysite /mnt
Make sure you unmount the device when finished:
sudo umount /mnt

12. **Always** do a positioner home-run before you switch off the instrument:
home_run.py

13. Shut down the GPRI instrument computer properly:
sudo poweroff
and press the power switch into the off position. Next unplug the radar at the power source.

4. Instrument Description

4.1 Instrument Components / Package List

The instrument consists of the following components:

- 3 Ku-band slotted waveguide antennas
- 1 RF Assembly RFA (Radio Frequency electronics that are mounted on the rotating tower)
- 1 Instrument Computer (Yellow Instrument Computer Case)
- 1 Power Cable
- 1 Instrument cable (thicker 2m orange cable with military connectors)
- 1 Antenna Tower with GPS antenna on top
- 1 Tripod with 3 stainless rods (orange bag)
- 1 Azimuth Positioner with Tribrach (Leveler)
- 1 Laser Plummet Battery Pack
- Tool kit
  - socket screw key (socket screw key provided in toolkit)
  - 8mm SMA torque wrench

Additional items necessary for field work

- Power generator with spare fuel or Lithium-Ion battery pack
- Laptop computer with SSH and X-Server software
- USB backup disk
- Power Drill fo and screws, washers, anchors to fix the tripod to the ground (4 mm screws in 6mm anchors should be fine)

4.2 GPRI-II Electronic Description

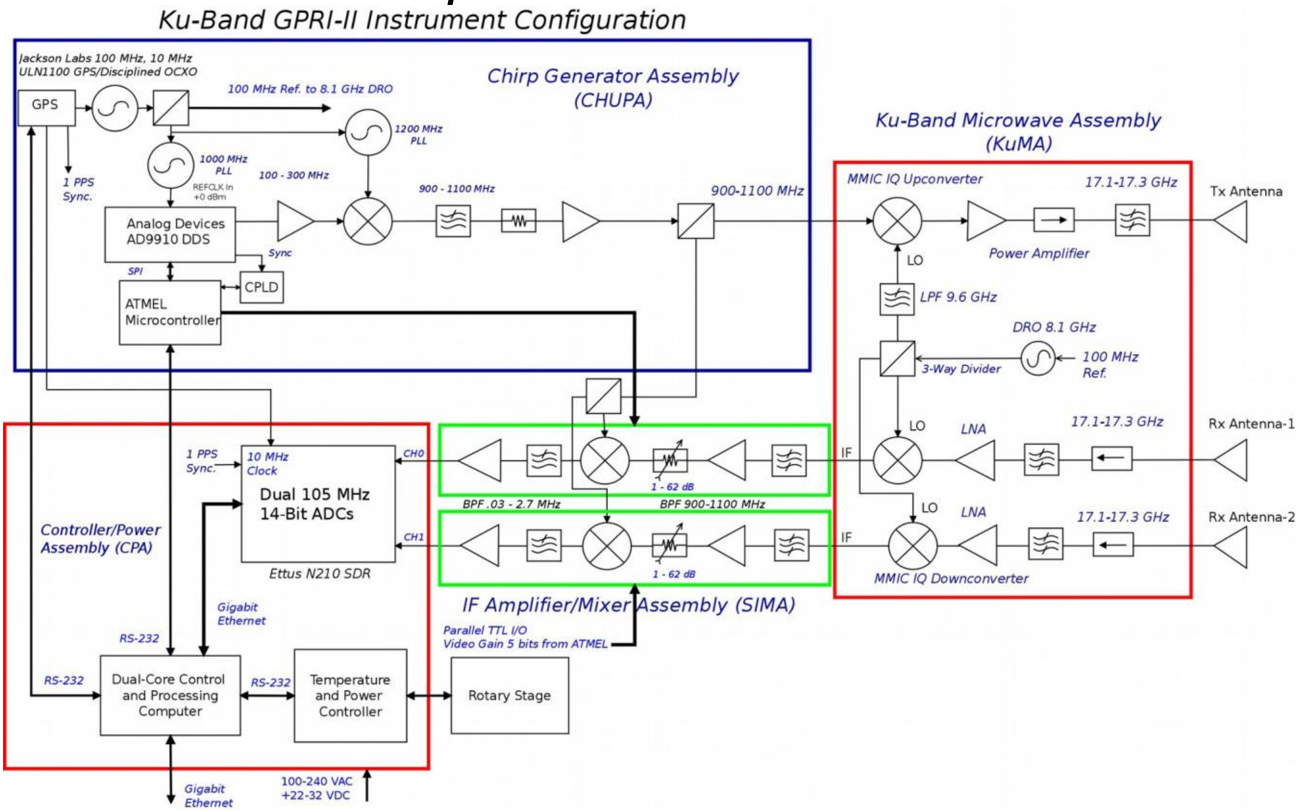


Figure 13: GPRI-II System Level Design

The high-level block design of the GPRI-II is shown above. The main elements in the electronics are the Chirp Generator Assembly (CHUPA), Single Channel IF Amplifier/Mixer Assembly (SIMA), Ku-Band Microwave Assembly (KuMA), and the Instrument Computer (IC). The GPRI acquires data within a the duration of the chirp minimizing the effects of temporal decorrelation on image focus.

The use of a built-in computer permits autonomous operation and recording of data with the need for an external lap-top. Data acquisition speed is increased substantially because data acquired during continuous rotation of the motor avoiding stop/start motion and the associated mechanical settling time.

The computer, power-supply, and dual ADC digitizer are all within the controller/power assembly enclosure. Temperature and power regulation are steered by a controller on the TSCI (Temperature and Power Controller) board. It is responsible for ensuring that the temperature within the enclosure is within operational limits and can provide functionality for implementation of a low-power sleep mode.

The RF electronics assembly is connected to the Computer/Power enclosure using a single multi-conductor cable with 19-pin MIL-C26582 connectors. These connectors are weather resistant (IP-65) and rugged. The receiver output goes directly to the input of the ADCs of the SDR

4.3 Antenna Characteristics

The GPRI-II antenna is an end-fed slotted-waveguide antenna. The azimuth antenna sidelobes remain constant over the entire operational bandwidth from 17.1 to 17.3 GHz at an acceptable level (-20 dB). The slotted waveguide antenna is designed with an aluminum flare that determines the elevation beam-width of approximately 32 deg. The elevation pattern is shown in Figure 14.

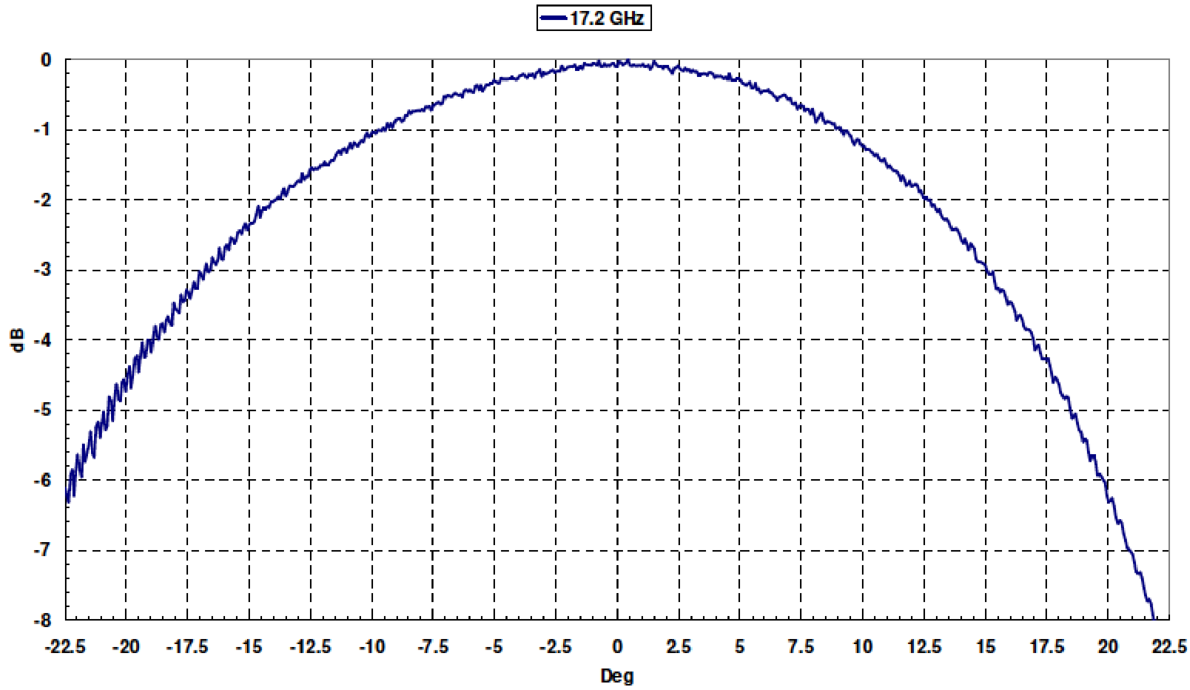


Figure 14: Antenna elevation pattern at 17.2 GHz, The half-power beam width varies between 31.4 and 33.8 degrees depending on the particular antenna unit

A thin plastic radome over the flare opening to seal the antenna against moisture. The GPRI-II antennas support is designed to fit in a 125 mm PVC tube for protection. These tubes fit in a custom shipping case for shipping by a commercial shipping company.

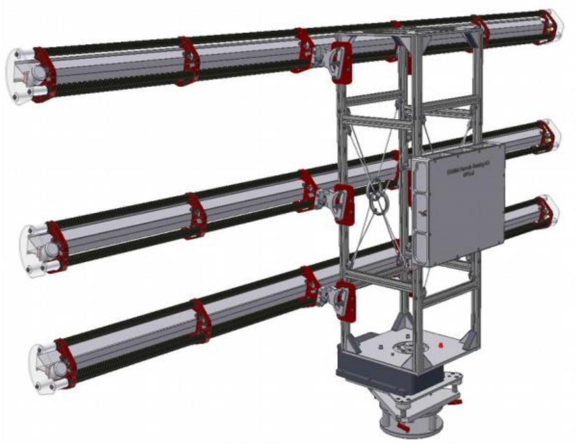
4.4 GPRI-II Mechanical Description

4.4.1 GPRI-II Antenna Tower

The antenna support tower has a height of 80 cm and a square cross-section of 28 x 28 cm and is constructed using ITEM aluminum extrusion. The tower is further stiffened on each face through the use of stainless-steel rods under tension connected to a central stainless-steel ring as shown in Figure 15. These cross-struts stiffen the tower to reduce torsional deformation.

4.4.2 Tripod, Positioner and Tribrach Leveler

The tripod supporting the scanner and antenna tower is a heavy duty fiberglass tripod. It comes with a 5/8” threaded screw that is standard and is adjustable to permit repeatable positioning. A small bubble level embedded in the tripod mounting plate has been added to allow initial leveling of the tripod.. The tripod can be leveled approximately by moving out the legs. An aluminum foot has been added to the end of each tripod leg that permits fixed mounting of the legs using screws and anchors. This arrangement facilitates accurate repositioning of the GPRI-II for later data acquisitions. A laser plummet on the scanner rotational axis projects the rotational axis on the ground. Additional metal struts have been added at the tripod base to improve the rigidity and to permit precise repositioning of the tripod on preexisting anchors.



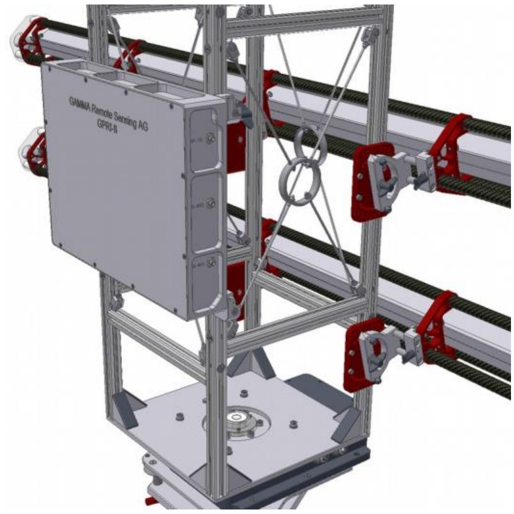


Figure 15: GPRI-II Tower with RF electronics Assembly (RFA).

A rugged custom tribrach supports the tower and is used to adjust the axis of rotation to be vertical. A stainless steel spacer is also provided to mount the tribrach and azimuthal scanner on a pier or rock outcrop or other structure.

Figure 16: Tripod mounting adapter for screw anchor mounting.

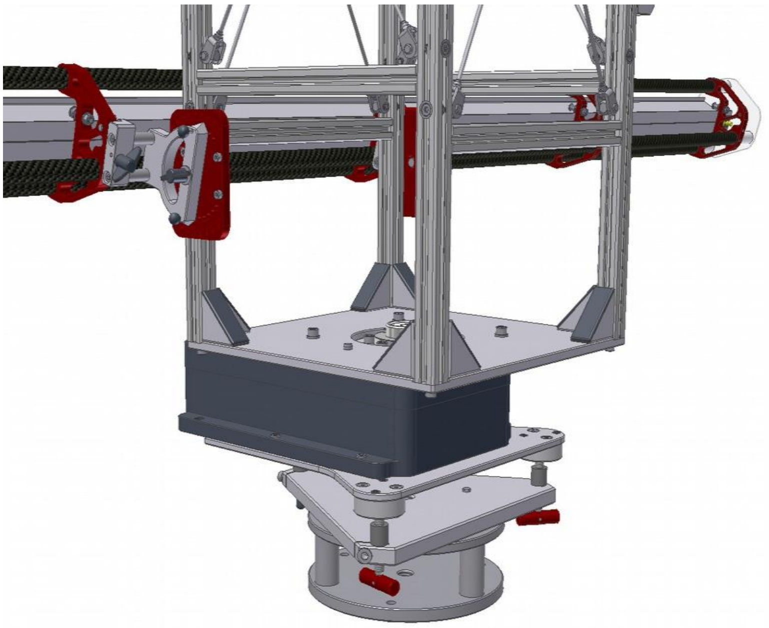


Figure 17: Tribrach with azimuthal scanner and tower. Adapter for pier mounting is shown attached to the tribrach. Red knobs adjust the tilt of the azimuthal scanner mounting plate.

4.4.3 Azimuthal Scanner

The GPRI-II uses a custom designed intelligent azimuthal scanner. This positioner has a repeatability of 5 arc-sec, and a resolution of 0.36 arc-seconds. The scanner has dual thrust bearings eliminating any measurable wobble in the axis and permits a load up to 100 kg. The internal scanner micro-controller supports smooth ramp-up and ramp-down of the rotational velocity It also remembers the current position even if power is lost suddenly and this prevents subsequent wrapping of the RFA cable. The scanner memory has a duration of up to 10 days. It is essential whenever powering up the GPRI to perform a home-run of the azimuthal positioner using the *home_run.py* program.

The range of angles that the tower can rotate is +/- 270 degrees relative to the home position after running *home_run.py*. The home position azimuthal angle is 0.0 degrees. The rotation velocity can be set in steps of approximately 0.1 degree/sec from 0 to 15 degrees/sec. The controller can be queried to determine the time and angle required for acceleration to a constant velocity or to stop rotation.

4.5 Radio Frequency Assembly (RFA)

The radar RF electronics are mounted in an aluminum enclosure made of single aluminum slab 56mm thick with a 6 mm central plate dividing the enclosure into two 22 mm deep cavities. . A gasket for the top and bottom plates makes the RF enclosure watertight. A gas-permeable membrane prevents accumulation of condensate in the enclosure. A single 19-pin MIL C26582 connector is used for baseband radar signals and power to the Radio Frequency Assembly (RFA). The cable connecting the RFA and Instrument Controller carries power, serial communication, and the analog receiver output. SMA microwave connectors for the TX output and 2 RX inputs are mounted on the side of the RFA.

The RFA is powered by +22-28 volt DC that is then converted to the various voltages used by the

RFA modules in the power distribution module inside the RFA enclosure. The 24 VDC used to power the RFA comes from the Instrument controller enclosure.

The RFA contains the linear FM chirp generator and up-converter assembly (CHUPA) that generates a programmable chirp in the 900-1100 MHz frequency range. This FM chirp signal is used both to drive the transmitter up-converter and to deramp the received radar echo in the dual receivers.

The receiver IF amplifier assemblies (SIMA) amplify the output of the Ku-Band (KuMA) RX down-converters and deramp the echo to obtain a range compressed radar echo in slant range geometry. Communication and control of the RFA is via a microprocessor located in the CHUPA. The CHUPA configures the chirp parameters, receiver gain, and controls the power to the different modules. Each of the different modules in the CHUPA can be powered up or down by software command. The entire RFA can be powered on or off by command of the TSCI in the Instrument controller enclosure.

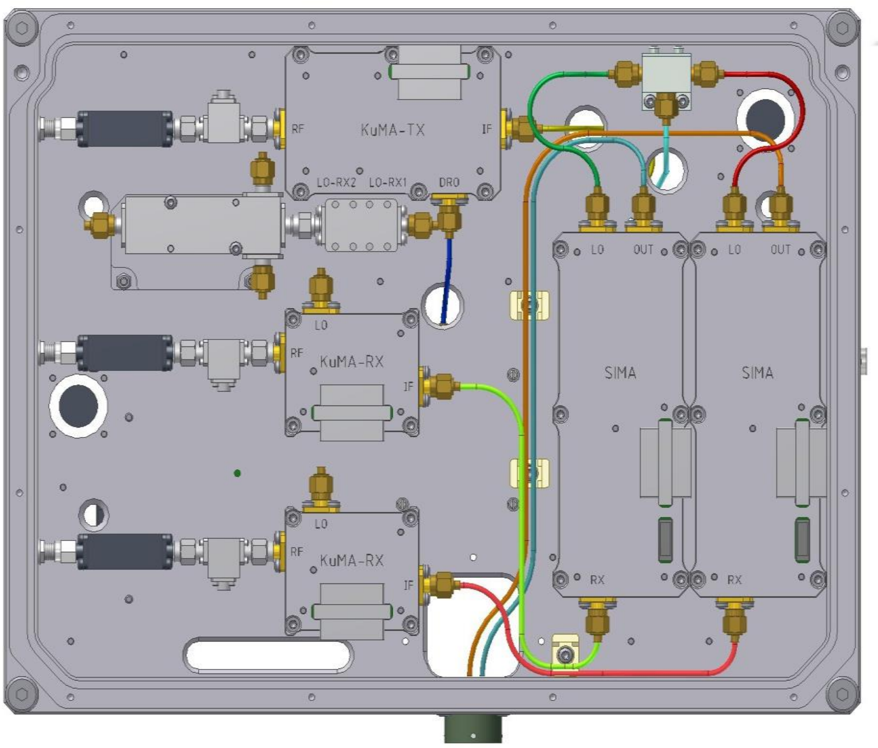


Figure 18f: RF Electronics Assembly Interior showing KuMA-TX and KuMA-RX modules along with the dual SIMA modules. The compartment on the other side of the RFA contains the CHUPA, GPS and DISTRI modules

The microwave up- and down converters and SIMA are located on one side and the GPS receiver, CHUPA and DISTRI on the opposite side of the enclosure.

4.6 Instrument Controller and Power Unit

The instrument computer is located in the Instrument Controller and Power Unit. The computer is a

Mini-ITX board and uses a 3rd generation Core I5 processor with 8 GB RAM. A solid-state disk (SSD) with 1 TB capacity is used for the operating system and data buffer.

The Instrument Controller and Power Unit also contains the power supplies that convert 100-240 VAC or 22-28 V DC to the voltages required by the radar. The power input connector can either have AC or DC input power. An internal switch can be used to select the input power source. Output connectors are provided for the RF electronics and the azimuthal scanner. Additional ports for Ethernet and USB interfaces are also available.

An internal fan circulates air to transfer heat to the baseplate in the case. The internal fan speed is regulated to provide control of the internal temperature. An external fan cools the external heat sink. An external fan draws air over the external heat sink to allow operation at high ambient temperatures. There is also built in heater for operation at temperatures below 0 C. The GPRI can operate over the temperature range of at least -20 to +50 C.

5. Instrument Software

The instrument has different levels of software. The instrument controller is running Ubuntu Linux as the operating system. On top of that different system services such as *openssh* and *lighttpd* and tools that are provided through the Ubuntu software repository. User Interface

The GPRI-II instrument can be accessed through TCP/IP over the Ethernet connection provided at the Instrument Controller, or by opening the Instrument Computer case and connecting a computer display and keyboard/mouse. The latter allows access in case the IP address of the instrument is unknown or any other communication problem occurs.

5.1 Local Terminal Access

To have local access to the Instrument computer requires opening the Pelican case to attach a video terminal (DVI interface) and a keyboard and mouse using USB. These interfaces are on the connector panel of the instrument computer. After booting up the instrument computer, the Ubuntu login screen appears and the user can login as user **gpri2** with password **gpri2**.

A Ubuntu desktop is is then presented on the video screen. In this configuration, there is access to all system settings, most importantly the network configuration. Right-clicking on the network configuration icon on the top taskbar reveals a menu with various options including “Settings” at the bottom. Selecting this option brings up the configuration window for network interfaces. One of the system Ethernet interfaces (eth0) is the system external connection. The other interface (eth1) is connected to the Ettus N210 Software Defined Radio using a fixed IP of 192.168.10.2. **Do not change the configuration of this interface**. The other interface has a fixed IP set to 192.168.1.xx where xx is determined from the serial number of the radar+70. As an example, the IP of GPRI-II-20 is 192.168.1.90. This IP can be changed if required to your desired network configuration.

5.2 Terminal Access via SSH

The instrument computer terminal can be accessed through secure shell (ssh). The export of the X11 windows is supported through the ssh -X option:

```
ssh -X gpri2@192.168.1.x
```

In this section the command line tools are described grouped by functionality. Furthermore at the end of the section the parameter and data file formats are given. Section 6.5 shows the list of auxiliary tools that are not needed for every day use but can be helpful in case of instrument problems.

5.3 Radar Data Acquisition

The basic program to acquire data is gpri2_capture_uhd.py. However, usually it is much more convenient to use gpri2_capture_utc.py or gpri2_capture_ts4.py. gpri2_capture_utc.py can acquire a time-series of SLC images and MLI images derived from them. gpri2_capture_ts4.py goes several steps further and can optionally generate a series of interferograms, correlation maps, unwrapped interferograms, filtered interferograms, and the time-series from adding the sequential unwrapped and filtered interferograms.

5.3.1 gpri2_capture_ts8.py

This script acquires a series of radar images and generates the interferogram time series from sequential series of acquisitions AB, BC, CD.. This sequence of interferograms can be optionally unwrapped and integrated to create the time series. The user can specify the start time, number of acquisitions, and time interval between acquisitions. The image region can be specified in terms of the starting and ending slant range. The user can also specify the channel (RX1, or RX2) data that will be used for generating a series of differential interferograms.

```
usage: gpri2_capture_ts.py  <profile> <nraw> <start_T> <delta_T> <DATA_dir> [-d decim] [-
j channel] [-r rmin] [-R rmax] [-h heading] [-u] [-z "x y"] [-c cthres] [-p pthres] [-m
mask] [-f radius] [-t] [-x] [-k] [-w days] [-s scale] [-e exp]
  profile      GPRI2 profile for raw data acquisition
  ndata        number of raw data acquisitions to perform
  start_T      starting time in UTC of the first acquisition in ISO-8601 format,
               enter "now" for immediately
               (YYYY-MM-DDTHH:MM:SS, example: 2011-06-25T13:00:00)
  delta_T      time in seconds between start of each acquisition, interval includes
                acquisition time
  DATA_dir     main data directory, data will be stored in subdirectories organized
               by date and time
  -d decim     raw data decimation factor (default: 5)
  -j channel   channel specification for creation of differential interferograms
               (1:lower-RX1  2:upper-RX2 (default))
  -r rmin      starting slant range (default: 50 meters)
  -R rmax      maximum slant range enter, default is maximum determined from chirp
                duration (meters)
  -h heading   radar heading at the center of the azimuth sweep (deg., default = 0.0)
  -u           unwrap interferogram phase and generate 2 column list of unwrapped
               interferograms and delta_T values in decimal days
  -z "x y"     reference point for phase unwrapping and phase reference for stacking,
               x and y arguments must be in quotes (default: image center)
  -c cthres    interferometric correlation coefficient threshold used for selection
               of points for phase unwrapping (default: 0.7)
  -p pthres    relative radar image intensity threshold used for selection of points
               for phase unwrapping, (default: .01)
  -m mask      mask to apply to interferometric phase after phase unwrapping (BMP or
               Sun raster format)
  -f radius    apply fast GPRI spatial filter to the unwrapped phase for atmospheric
               phase suppression (nominal: 160 samples)
  -t           generate time-series of interferograms in the TS_dir directory,
               files are named ts_nnnn, -u option is required
  -x           delete raw data after processing to generate SLC images
  -k           do not generate raster format images
  -w days      delete output directories older than the specified number of days,
               value must be 1 or greater
  -s scale     display scale factor (default = .4)
  -e exp       display exponent (default = 0.35)

   Note: All data are stored in sub-directories in DATA_dir.
         Subdirectory names are organized by date with suffix YYYYMMDD
         SLC data files are listed in SLC_tab1_YYYYMMDD and SLC_tab2_YYYYMMDD
         MLI data files are listed in MLI_tab1_YYYYMMDD and MLI_tab2_YYYYMMDD
         unwrapped phase data files are listed in DIFF_tab_YYYYMMDD
         time-series data files are listed in TS_tab_YYYYMMDD

        -u option is specified then the differential interferograms are unwrapped
           and DIFF_tab and when time series are generated
        -z option is used to specify the required phase reference point coordinates
           for unwrapping and integrating the phase
```

Interferograms and correlation maps are generated by default. To specify that the interferograms should be unwrapped, enter the -u option on the command line with the name of the file that will contain a list of differential interferograms.

The GPRI data products are stored in subdirectories created by the script in the DATA_dir directory. Each subdirectory is named with the current date in the form YYYYMMDD. When a new day begins, a new subdirectory is created and the interferometric time-series continues.
Data products stored in the subdirectory include raw data files and raw data parameter files (raw, raw_par), SLC images and their parameter files (slc, slc.par), multi-look intensity images and associated parameter files(mli, mli.par), interferograms (diff), adf filtered interferograms (adf.diff), interferometric coherence (cc), unwrapped phase (unw), and integrated time series (ts).

It is important to specify the phase reference point in the interferogram for unwrapping and stacking using the -z option. The argument of the -z option are the x and y coordinates of the center of the reference region contained within double quotes: **-z "x y"**.

Other options relate to unwrapping the phase of the differential interferogram. These options are thresholds for the interferometric correlation and intensity that must be exceeded for a point to be unwrapped:

```
-c cthres     interferometric correlation coefficient threshold used
              for selection of points for phase unwrapping (default: 0.7)
-p pthres     relative radar image intensity threshold used for selection of\
              points for phase unwrapping, (default: .01)
-m mask       mask to apply to interferometric phase after unwrapping
```

Points with low interferometric correlation will have noisier phase values. Similarly, dark regions or regions in shadow will also have noisy phase values. Typically, the value of *cthres* is set to be 0.7 or greater, while the intensity threshold parameter *pthres* is usually set to values < 0.05. The **-m** option lets you specify a mask file that is applied to the image after unwrapping the phase. The -f option is used to switch on or off the fast spatial filter used for atmosphere suppression. This script requires the Gamma software to generate the interferometric and multi-look intensity products.

Options that are related to data management are -x, -k, and -w. The -x option specifies that the raw data files be deleted after SLC images have been produced. These raw data files are up to 1 Gb in size and deleting them is a good idea to delete these if you are sure that you have the right area covered in the processed images. The -k option specifies that most of the raster images (BMP or Sun Raster format) will not be created, also saving space. The most important parameter for data management is the -w option.

5.3.2 gpri2_capture_utc.py

This is a script to capture a series of raw data sets and process these data to form SLC images at fixed time intervals starting at a specific UTC time-stamp. A time-stamp of "now" can also be specified to begin acquisition immediately. This script requires the Gamma software for generation of MLI images:

```
*** GPRI ground-based radar data capture and processing UTC time reference ***
*** Copyright 2011, Gamma Remote Sensing, v1.5 8-Aug-2011 clw ***

usage: gpri2_capture_utc.py  <profile> <RAW_dir> <nraw> <start_T> <delta_T> [-p slc_dir]
[-m mli_dir] [-x] [-d] [-r rmin] [-R rmax] [-h heading] [-a] [-s scale] [-e exp]

  profile      GPRI-II profile for raw data acquisition
  RAW_dir      directory to store raw data acquisitions and raw data parameter files
  ndata        number of raw data acquisitions to perform
  start_T      starting time in UTC of the first acqusition in ISO-8601 format, enter
```

```
"now"
               for immediately
               (YYYY-MM-DDTHH:MM:SS, example: 2011-06-25T13:00:00)
  delta_T      time in seconds between start of each acquisition, interval includes
               acquisition time
  -p slc_dir   process data to SLC and store in directory slc_dir
  -m mli_dir   generate MLI images and store in directory mli_dir
  -x           delete raw data after processing
  -d decim     raw data decimation factor (default = 5)
  -r rmin      starting slant range, default: 50 meters
  -R rmax      maximum slant range enter, default is maximum determined from
               chirp duration
  -h heading   radar heading at the center of the azimuth sweep (deg., default = 0.0)
  -a           process using ati option for gpri2_proc.py, turn off
               azimuth interpolation
  -s scale     display scale factor (default = .4)
  -e exp       display exponent (default = 0.35)
```

This program is the general purpose data acquisition program for the GPRI-II instrument. It has the option to process the data to SLC and MLI image products immediately after acquisition using the -p and -m options. If the user desires, the raw data can then be deleted (-x option) in order to save disk space. The SLC images are typically about 10% the size of the raw data due to data decimation performed by the processor.

The raw data files include the UTC time in the file name in the format YYYYMMDD_HHMMSS.raw For each RAW data file there is also a RAW_PAR file with the same root name and the extension “raw_par”. The time-stamp for data acquisition in the command line must be provided in ISO-8601 format as THH:MM:SS (example T10:11:58) where the letter T precedes the time in HH:MM:SS. Alternately there is the option to type “now” to specify that the scan should start immediately.

Important to note is the -a option. Nominally the processor performs a frequency dependent azimuth interpolation to compensate for the antenna frequency dependent squint angle. This option turns off this interpolation step for data acquired with a constant azimuth angle.

5.3.3 gpri2_capture_uhd.py

This program acquires a single GPRI-II raw data set and is called by both *gpri2_capture_utc.py* and *gpri2_capture_ts6.py*. Input used to specify the operating parameters of the acquisition are stored in a parameter file called a “profile”. This profile is organized as keyword value pairs and described in Section 5.7.1. There are template profiles (*.prf) for different duration chirps (250us, 500us, 1ms, 2ms, 4ms, and 8ms) in the /home/gpri2/GPRI2-2/profiles directory:

```
$ gpri2_capture_uhd.py
linux; GNU C++ version 4.8.1; Boost_105300; UHD_003.006.002-rc2

*** GPRI data capture program with UHD v2.5 30-Jan-2014 ***
Usage: gpri2_capture_uhd.py: [options] -p profile -o output_filename

Options:
  -h, --help            show this help message and exit
  -a DEVICE_ADDR, --device-addr=DEVICE_ADDR
                   se USRP at specified device-address which can be IP
                        address (-a addr=192.168.10.2), serial (-a
                        serial=1234567) or name (-a name=name). There is no
                        mac-address support. [default=None]
  -f FREQ, --freq=FREQ  set frequency to FREQ
  -d DECIM, --decim=DECIM
                        set fgpa decimation rate to DECIM [default=16]
```

```
-g GAIN, --gain=GAIN  set USRP gain in dB (default is midpoint)
-K SCALE, --scale=SCALE
                      set rx input scaling of usrp2, scale_iq  (default is
                      1024)
-S SHIFT, --shift=SHIFT
                      set rx output shifting of usrp2, shift_iq  (default is
                      0). Allowed values 0, 1, 2 and 3
--lo-offset=LO_OFFSET
                      set daughterboard LO offset to OFFSET [default=hw
                      default]
-N NSAMPLES, --nsamples=NSAMPLES
                      number of samples to capture [default=+inf]
-T CAPTURE_DURATION, --capture-duration=CAPTURE_DURATION
                      number of seconds to capture [default=+inf]
-o OUTPUT_FILENAME, --output-filename=OUTPUT_FILENAME
                      output filename for captured samples [default=None]
-s, --output-shorts   output interleaved shorts instead of complex floats
-M, --lock-masterclock-to-SMA
                      lock usrp2 100 Mhz master clock to external 10 Mhz
                      reference clock on SMA input
-P, --sync-to-first-1PPS
                      reset the usrp2 samplecounter on the first PPS
                      received on the PPS SMA input
-j RX_START_TIMESTAMP, --rx-start-timestamp=RX_START_TIMESTAMP
                      set start_at time of first RX packet in usrp2 100 Mhz
                      clockpulses (long) [default=-1 start immediately]
-k RX_START_TIME_SECONDS, --rx-start-time-seconds=RX_START_TIME_SECONDS
                      set start_at time of first RX packet in seconds
                      (float) [default=-1.0 start immediately]
-C EXTERNAL_PROGRAM, --external-program=EXTERNAL_PROGRAM
                      give a programname to start this as external program
                      just before streaming starts (string) [default=None do
                      not start an external program]
-v, --verbose         verbose output
-p GPRI_PROFILE, --gpri-profile=GPRI_PROFILE
                      GPRI acquisition profile [default=None]
--nosemaphore         Dont check and set measurement semaphore (used if
                      called from a master measurement script that sets the
                      flag)
```

5.4 Quality Control of Raw Data

The *gpri2_raw_plot.py* program plots the raw data records and plots the range compressed radar echoes. When first setting up the radar at a new location. This program is required to see if the gain has been set correctly to avoid saturation of the radar.

It is recommended that that the initial acquisitions of data when using the command line interface be preformed using *gpri2_capture_utc.py (see below).* This program can optionally generate SLC and MLI images that are required to determine if the region of interest in the scene has been adequately covered.

5.4.1 gpri2_raw_plot.py

```
Usage: gpri2_raw_plot.py v1.6 30-Sep-2011: [options] raw_par raw_data

Takes a GPRI raw data set and raw data acquisition parameters and displays the
two channels and the slant range echo.  The start position in the file can be
set by specifying -o or --offset and defaults to 0 (the start of the file). A
specified number of points can be set to zero using the -z option

Options:
  -h, --help            show this help message and exit
  -d DATA_TYPE, --data-type=DATA_TYPE
                        Specify the data type (float32, int16 [default=int16])
  -o OFFSET, --offset=OFFSET
                        Specify record offset to begin display [default=10]
  -z ZERO, --zero=ZERO  number of samples to set to 0 at the start of the
                        echo: [default=0]
  -s STRIDE, --stride=STRIDE
                        spacing between successive display records:
                        [default=100]
  -y YMAX, --ymax=YMAX  maximum value for range-profile magnitude:
                        [default=20.0]
  -r RMAX, --rmax=RMAX  maximum slant range for plot: [default=0.0]
  -n, --no_range_wgt    turn off range weighting of the echo
  -b, --dB              plot echo with dB scale
  --png                 generate PNG output image
```

This program takes a GPRI raw data set and instrument profile and displays the two channels and the slant range echo. The start position in the file can be set by specifying -o or --offset and defaults to 0 (the start of the file). A specified number of points in the echo can be set to zero using the -z option to remove transients at the start of the echo.

5.5 Processing of GPRI raw data to SLC

5.5.1 gpri2_proc.py

Takes a GPRI-II echo data set and processes to generate SLCs for receivers with inputs RX1 and RX2. The SLC acquired from RX1 is called the upper (u) and RX2 the lower (l) SLC.

```
Usage: gpri2_proc.py: [raw_data] [raw_par] [slc1] [slc2] options

Process GPRI-II raw data to SLCs v2.7 29-May-2014 clw

Options:
  --help                show this help message and exit
  -F DATA_TYPE, --data-type=DATA_TYPE
                        Specify the data type (float32, int16)
                        [default = int16]
  -z ZERO, --zero=ZERO  Number of samples to weight at the start of the echo
                        [default=300]
  -d DEC, --decim=DEC   Raw data decimation factor to apply [default=1]
  -R RMAX,--rmax=RMAX   Maximum SLC slant range (meters), default is 0.9 of
                        the aliasing slant range for the chirp
  -r RMIN,--rmin=RMIN   Minimum SLC slant range (meters) [default=50.0]
  -a, --ati             Turn off azimuth interpolation, required for Along-
                        Track Interferometry [default=False]
  -e, --little_endian   Generate little-endian SLCs, Gamma Software default is
                        big-endian [default=False]
  -h HEADING            Heading of radar boresight clockwise from North (deg.)
                        [default=0.0]
  -k KBETA              Kaiser Window beta parameter [default=3.0]
  -t TX_ANTENNA         Specify TX antenna for C-band data acquired in HV mode
                        (H,V): [default=V]
```

Input to the program are the **raw** data and **raw_par** parameter files. Output are the SLC images **slc1** and **slc2** from each of the two channels. The user enters the names of the SLCs as the parameters slc1 and slc2. Two SLC meta data files are also created with extension **.par.**

```
20110715_105720u.slc  20110715_105720u.slc.par
20110715_105720l.slc  20110715_105720l.slc.par
```

The starting slant range RMIN for the SLC images is by default 50 meters. The **-r** parameter command line parameter can be set to a minimum value of 5 meters, . The maximum slant range in the SLC is given by th**e -R** *RMAX* command line parameter. The maximum slant range possible for a particular chirp is determined by the chirp length, the ADC sampling rate and the chirp bandwidth. Since we are using the full 200 MHz bandwidth for each chirp, the pixel spacing is fixed at ***delta_r = 0.75m***. The maximum possible range ***R_MAX*** for a particular chirp duration ***t_c*** is given by:

*R_MAX = 0.9 * t_c * 3.125e6 * delta_r*

Hence for a 2 ms chirp the maximum possible slant range is 4.218 km.

The decimation factor **-d** DEC is an azimuth averaging parameter and specifies the number of echoes averaged to improve the Signal to Noise Ratio (SNR). The aim is to set the DEC factor such that the azimuth spacing is 0.1 degrees. Hence given a 2ms chirp and rotation rate of 10 deg/sec, the decimation factor should be set to 5. Similarly, if rotating at 5 deg/sec with a 4 ms chirp, *DEC* should remain 5.

Data input can either be as floating point or short integer data format. All data collected by the GPRI-II is in short-integer format. The **-F** parameter specifies the data input format.

There is a transient signal at the start of the raw data due to the sudden change in the put signal frequency when restarting the chirp. This transient is attenuated using a weighting function at the beginning of the raw data. The width of the section (in samples) of the section that is weighted is specified by the **-z** parameter that is by default 300 samples. To further reduce range sidelobes, this window is also applied at the end of the received data.

The **-e** parameter sets the endian format for the floating point data with big-endian standard for Gamma software.

The heading parameter ***-h*** *HEADING* is used for terrain geocoding and is the nominal heading of the radar clockwise from North for the center of the radar scan. This parameter is copied to the SLC_par parameter file associated with the SLC image.

The *-k beta* parameter sets the Kaiser window BETA parameter. Larger beta values result in lower range sidelobes at the cost of reduced range resolution. The default value the beta parameter is 3.0 that results in range sidelobes < -35 dB.

5.5.2 gpri2_proc_all.py

Script to process a series of raw GPRI-II data files to produce SLC images using gpri2_proc.py:

```
usage: gpri2_proc_all.py  <RAW_list>  <SLC_dir> [-m mli_dir] [-d] [-r rmin] [-R rmax]
                          [-h heading] [-a] [-s scale] [-e exp] [--png]

  RAW_list    (input) list of raw data files (2 columns):
                1. GPRI-II raw data file (*.raw)
                2. GPRI-II raw data parameter file (*.raw_par)
  SLC_dir     directory to store output SLC images and SLC parameter files profile
  -m mli_dir  generate MLI images and store in directory mli_dir
  -d decim    raw data decimation factor (default = 5)
  -r rmin     starting slant range, default: 50 meters
  -R rmax     maximum slant range enter, default is maximum determined from chirp duration
  -h heading  radar heading at the center of the azimuth sweep (deg., default = 0.0)
  -a          process using ati option for gpri2_proc.py, turn off azimuth interpolation
  -s scale    display scale factor (default = .4)
  -e exp      display exponent (default = 0.35)
  --png       convert output to PNG format
```

This script is used to process an entire stack of raw data to produce SLC images. The script generates the arguments to call the processing program *gpri2_proc.py*. The input to the script is a list containing the raw data files and the raw_par parameter files as a two column list. This list is generated using the *mk_tab* script.

Output from running the script is a pair of SLC images from each raw data file. The images from the CH-1 lower antenna has an “l” at the end of the name. Images from CH-2, upper channel have a “u” at the end of the name. Important parameters are the directory where the processed data are placed <SLC_dir> and the maximum slant range for the SLC.

The maximum slant range possible for a particular chirp is determined by the chirp length, the ADC sampling rate and the chirp bandwidth. Since we are using the full 200 MHz bandwidth for each chirp, the pixel spacing is fixed at delta_r = 0.75m. The maximum possible range R_MAX for a particular chirp duration t_c is given by:

R_MAX = 0.9 * t_c * 3.125e6 * delta_r

Hence for a 2ms chirp the maximum possible slant range is 4.218 km.

The starting slant range for the SLC images is by default 50 meters. The **-r** parameter command line parameter can be set to about 5 meters.

The decimation factor is an azimuth averaging parameter and specifies the number of echoes averaged to improve the Signal to Noise Ratio (SNR). The aim is to set the decimation factor such that the azimuth spacing is 0.1 degrees. Hence given a 2 ms chirp and rotation rate of 10 deg/sec, the decimation factor should be set to 5. Similarly, if rotating at 5 deg/sec with a 4 ms chirp, *dec* should remain 5.

The heading parameter **-h** *heading* is used for terrain geocoding and is the nominal heading of the radar clockwise from North for the center of the radar scan. This parameter is copied to the SLC_par parameter file associated with the SLC image.

There is a transient signal at the start of the raw data due to the sudden change in the put signal frequency when restarting the chirp. This transient is attenuated using a weighting function at the beginning of the raw data. The width of the section (in samples) of the section that is weighted is specified by the **-z** parameter that is by default 300 samples. To further reduce range sidelobes, this window is also applied at the end of the received data.

The transmit antenna parameter **-t** *channel* is used only for processing of data acquired with the C-band RFA that supports 2 transmit channels H and V. By default the transmit channel is V since the Ku data are all acquired with V transmit polarization. For data acquired with alternating transmit polarization (e.g. C-Band), the channel value determines the data processed in the raw data set. The SLCs are t hen generated from the data with the selected transmit channel.

5.6 GPRI-II Software Utility Programs

5.6.1 get_pos.py

Get current positioner angle in degrees

5.6.2 home_run.py

Execute home run of the positioner to find the 0 position. Should be performed at startup and also before power-down of the instrument! It is very important to do this before power-down, or else there is a significant chance that the RFA power cable will be wrapped around the tower.

5.6.3 move_abs.py

Move the antenna the a absolute motor angle.

```
*** Move antenna positioner to an absolute angle ***

    Usage: move_abs.py <angle> [rate] [--nosemaphore]
    angle  relative angle (deg.)
    rate   rotational velocity (deg/s 0.5 --> 10., default: 10.)
    --nosemaphore do not check measurement semaphore before moving
```

5.6.4 move_rel.py

Move the antenna the given angle from the current position.

```
*** Move antenna positioner a relative angle ***

  Usage: move_rel.py <angle> [rate]
    angle  relative angle (deg.)
    rate   rotational velocity (deg/s 0.5 --> 10., default: 10.)
```

5.6.5 stop_scan.py

Immediately stop motion of the tower, even in the middle of an acquisition.

5.6.6 chupa_status.py

Get current CHUPA software version, voltages, and temperature. The CHUPA is located in the RFA enclosure.

5.6.7 gps_poweron.py

Turn on power to GPS receiver located in the RFA.

5.6.8 gps_poweroff.py

Turn off power to GPS receiver located in the RFA.

5.6.9 ima_poweron.py

Turn on power to SIMA located in the RFA.

5.6.10 ima_poweroff.py

Turn off power to IMA located in the RFA.

5.6.11 rfa_poweron.py

Turn on RFA power supplied by the DISTRII to the chirp generator (CHUPA), IF amplifiers (SIMA), and microwave electronics (except for the transmitter).

5.6.12 rfa_poweroff.py

Turn off RFA power supplied by the DISTRI to the chirp generator (CHUPA), IF amplifiers (SIMA), and microwave electronics (except for the transmitter).

5.6.13 rx_poweron.py

Turn on power to the Ku-Band receiver front-ends located in the RFA.

5.6.14 rx_poweroff.py

Turn off power to the Ku-Band receiver front-ends located in the RFA.

5.6.15 tscc_status.py

```
#program to print current TSCC status, voltage input and temperature

TSCC Software version: SW V1.02
```

```
TSCC Voltage: ['U1 23.8']
TSCC Temperature (C):  ['T1 31.3']
```

5.6.16 tx_poweron.py

```
Turn on power to the Ku-Band up-converter and transmitter amplifiers.
```

5.6.17 tx_poweroff.py

```
Turn off power to the Ku-Band up-converter and transmitter amplifiers
```

5.6.18 usrp_poweron.py

```
Turn on power to the USRP software defined radio in the Instrument computer
enclosure. USRP power consumption is about 10 Watts.
```

5.6.19 usrp_poweroff.py

```
Turn on power to the USRP software defined radio in the Instrument computer
enclosure. USRP power consumption is about 10 Watts.
```

5.7 GPRI-II File Formats

Meta data and measurement data are kept separate. The meta data is stored in text files in a "keyword : value" format. The data itself is stored as plain binary without headers.

5.7.1 GPRI-II Measurement Profiles

The measurement profile dataset, contains the instrument and observation geometry parameters used for a given observation. The format is self describing, an example is shown below:

```
RF_center_freq:    1.720000e+10
IMA_atten_dB:   38
CHP_freq_min:   100.0e6
CHP_freq_max:   300.0e6
CHP_num_samp:   12500
STP_antenna_start:  90
STP_antenna_end:    180.0
STP_gear_ratio:       72
STP_rotation_speed:  10.0
TX_power: on
TX_mode: None
ADC_capture_time: 0.0
ADC_sample_rate:   6.25000e+06
antenna_elevation: 10
```

Table 3: GPRI-II Measurement Profile

The keywords identify the chirp generator (CHP), transmitter (TX), Intermediate Frequency Amplifiers (SIMA), Stepper motor driver (STP), and Analog to Digital Converter (ADC). The parameter *RF_center_freq* is the center frequency of the RFA and cannot be changed. The Ku-band radar has a nominal center frequency of 17.2 GHz.

The IF amplifier attenuation (*IMA_atten_dB*) can be set between 2 and 60 dB. Nominal system values are between 40 and 46 dB. Increasing the attenuation decreases the signal level at the input to the analog to digital convertor (ADC). It is essential that the receiver ADCs do not saturate. A test data acquisition followed by examining the data with *gpri2_raw_plot.py* should be performed. Saturation of the ADC output is observed as clipping of the input level at approximately +/- 1.0 volts. If this is the case, increase the *IMA atten_dB* value in steps of 2 dB (always even) to attenuate the signal. Increasing the attenuation by 6 dB will cut the amplitude of the digitized signal level in half.

The start and stop frequency of the baseband chirp are specified by the *CHP_freq_min* and *CHP_freq_max* parameters. These values are approximate and should normally not be changed.

The number of samples in the chirp *CHP_num_samp* determines the chirp duration. The ADC sampling rate is 6.25 MHz (6250 samples/millisec). Hence a chirp with 12500 samples is a 2ms chirp, 25000 samples is a 4 ms and so forth. The radar uses chirps between 250 us and 8 ms.

The chirp length determines the maximum range that can be imaged. Longer chirp rates are also required for longer range imaging. Below is a table showing the recommended combinations of chirp-length and rotational velocity as a function of the maximum observation range:

Maximum Slant Range	***Chirp duration***	***Rotational Velocity deg./sec.***	***Decimation Factor***
< 1 km	500 us	10	20
1 → 2.0 km	2 ms	10	5
2.0 → 5 km	4 ms	5	5
>5 km	8 ms	2.5	5

Table 4: Recommended Chirp Duration, Rotation Rate, and Decimation Factor as a function of maximum distance

The transmitter power can be turned on or off using the TX_power option. The data acquisition program itself turns the transmitter on only during data acquisition.

TX_mode is only used when there are multiple transmit output channels. In the POL-GPRI, the TX_mode can be set to *TX_RX_SEQ*. For the standard GPRI this keyword should be set to *'None'*

In the nominal case where the antenna will be scanned in azimuth, the start and stop azimuth angles can be specified with the *STP_antenna_start* and *STP_antenna_end* keywords. The SLC image produced by the scan will have a slightly smaller azimuth span due to the acceleration and deceleration of the antennas.

The rotational velocity specified in the profile is approximate. The controller in the azimuthal scanner selects a velocity very close to the specified value derived from the gear reduction ratio and the possible rates derived from the quartz crystal reference clock. Velocities can be selected in steps of about 0.1 degree/sec. The exact value for the velocity in deg/sec is stored in the metadata file (*.raw_par) that is associated with the raw data and created by *gpri2_capture_uhd.py*. The *.raw_par files are also organized by *keyword:value* and described below.

If the start and end angles are the same, then the duration of the ADC capture is specified by the *ADC_capture_time* parameter. (seconds). The value of capture time should be set to 0.0 otherwise if performing an azimuth scan.

The ADC sample rate (*ADC_sample_rate*) parameter is a fixed value in the profile and should not be changed since it is related to the analog filters in the SIMA.

Finally, the *antenna elevation* parameter is a value placed in the profile by the user and documents the physical elevation angle of the antenna. The elevation angle is set manually when the radar is installed. The elevation angle should be selected to illuminate the center of the farthest region to be imaged by the GPRI instrument.

5.7.2 Raw Data Metadata: RAW_par

The raw data is stored in a binary file of integers in little endian format. The raw data metadata are stored in the *.*raw_par* text file:

```
time_start: 2010-11-05 10:57:06.025627+00:00   #UTC time at s tart of data
geographic_coordinates:    46.6809900000, 7.6398266667 613.00 47.3
RF_center_freq: 1.72000000000e+10
RF_freq_min:     1.71000578460e+10
RF_freq_max:     1.72999421541e+10
RF_chirp_rate:   9.99425537884e+10
CHP_num_samp:   12500
TX_mode:        None
IMA_atten_dB:   38
ADC_capture_time:    9.50679
ADC_sample_rate:     6.25000e+06
STP_antenna_start:   90.00000
STP_antenna_end:     180.00000
STP_rotation_speed: 10.00000
STP_gear_ratio:      72
antenna_elevation:  10.00000
CHP_temperature:  23.500
TSC_temperature:  28.400
```

Table 5: RAW_par meta-data file generated for each raw data file

The time is specified in UTC time the +00:00 is the offset in Hours and Minutes relate to UTC. Geographic coordinates are in latitude and longitude in the WGS84 horizontal data in decimal degrees. The geographic_coordinates string format is:

latitude	decimal degrees WGS84 horizontal datum
longitude	decimal degrees WGS84 horizontal datum
altitude	altitude (m) above the geoid. This will be generally be close to the value of the height you would read on a map in the local
Geoid height	Height of the geoid relative to the WGS84 ellipsoid (vertical datum)

The radar center frequency is used for reference and is copied from the GPRI-II profile. The values of *RF_freq_min*, *RF_freq_max*, and *RF_chirp_rate* are exact values required for processing the raw data to produce SLC images, The frequencies are in Hz and the chirp rate in Hz/sec. The number of samples in the chirp is recorded in the *CHP_num_samp* parameter. The transmit cycle uses 1 more sample to return to the chirp start frequency as required by the Direct Digital Synthesizer used to generate the chirp.

The *TX_mode* parameter specifies the transmitter mode. The value *None* is used for the current Ku-band GPRI.

The I*MA_atten_dB* value is value using for IMA attenuation an is copied from the GPRI-II profile.

The *ADC_capture_time* parameter is the actual time that samples are recorded by the Analog-to-digital converters (ADCs) in the digitizer.

The *STP_antenna_start*, *STP_antenna_end* are the starting and ending used in the antenna scan. The image covers a slightly smaller angular range that is documented in the SLC_par meta data file produced by *gpri2_proc.py*.

5.7.3 SLC (Single-Look Complex) Data

The detected radar data is store in the SLF file with accompanying slc_par. The data type is indicated in the slc_par text file. In general the data is in big endian format to be compliant with the standard byte order in the GAMMA Software. The slc file format is compatible with the GAMMA Software:

```
Gamma Interferometric SAR Processor (ISP) - Image Parameter File
title: 2010-11-05 10:57:06.025627 CH1 upper
sensor: GPRI 2.0
date:  2010 11 05
start_time:     39426.500665  s
center_time:    39430.776007  s
end_time:       39435.051349  s
azimuth_line_time: 1.008147e-01  s
line_header_size:0
range_samples:    2667
azimuth_lines:    856
range_looks:           1
azimuth_looks:         1
image_format:          FCOMPLEX
image_geometry:        SLANT_RANGE
range_scale_factor:    1.0
azimuth_scale_factor:  1.0
center_latitude:       0.00000000  degrees
center_longitude:      0.00000000  degrees
heading:               0.000000  degrees
range_pixel_spacing:   0.749912  m
azimuth_pixel_spacing: 0.000000  m
near_range_slc:        0.000000  m
center_range_slc:   1000.000000  m
far_range_slc:      2000.000000  m
first_slant_range_polynomial:  0.0 0.0 0.0 0.0 0.0 0.0
center_slant_range_polynomial: 0.0 0.0 0.0 0.0 0.0 0.0
last slant range polynomial:   0.0 0.0 0.0 0.0 0.0 0.0
incidence_angle:       0.0  degrees
azimuth_deskew:        OFF
azimuth_angle:         0.0 degrees
radar_frequency:       1.720000e+10  Hz
adc_sampling_rate:     1.998851e+08  Hz
chirp_bandwidth:       1.998843e+08  Hz
prf:                   9.919192  Hz
azimuth_proc_bandwidth: 0.0  Hz
doppler_polynomial:     0.0 0.0 0.0 0.0
doppler_poly_dot:       0.0 0.0 0.0 0.0
doppler_poly_ddot:      0.0 0.0 0.0 0.0
receiver_gain:          22.000  dB
calibration_gain:        0.000  dB
sar_to_earth_center:             0.0000  m
earth_radius_below_sensor:       0.0000  m
earth_semi_major_axis:      6378137.0000  m
earth_semi_minor_axis:      6356752.3141  m
number_of_state_vectors:   0
GPRI az start angle:     93.33750  degrees
GPRI_az_angle_step:       0.10081  degrees
GPRI ant elev angle:     10.00000  degrees
GPRI_ref_north:      46.68099000  #GPS lat/lon in the WGS84 horizontal datum
GPRI_ref_east:       7.63982667
```

```
GPRI_ref_alt:              453.0  m      #geoidal height of reference point
GPRI_geoid:                47.000 m      #geoid height relative to WGS84 ellipsoid
GPRI_scan_heading: 90.00000 degrees   #rel. to N. at image azimuth center
GPRI_tx_coord:    0.2218   0.0000-0.3694 m m m
GPRI_rx1_coord:   0.2218   0.0000  -0.0194  m m m
GPRI_rx2_coord:   0.2218   0.0000   0.2306  m m m
GPRI_tower_roll:   0.00000  degrees
GPRI_tower_pitch:  0.00000  degrees
GPRI_phase_offset: 0.00000  radians
```

The SLC parameter file contains metadata related to processing the GPRI raw data. A number of the keyword:value parameters are GPRI specific. The keywords of these parameters are all prefixed with GPRI. Most significant of these parameters are the starting azimuth rotation angle for the image and the spacing between image lines.

The positional information for the GPRI position are contained in the *GPRI_ref_north* (latitude in decimal degrees), *GPRI_ref_east* (longitude in decimal degrees) and GPRI_ref_alt (geoidal height in meters) parameters. The height of the geoid relative to the WGS84 ellipsoid is in the *GPRI_geoid* parameter. The reference position is the location of the GPS antenna on the top of the antenna tower. The *GPRI_tx_coord*, *GPRI_rx1_coord*, and *GPRI_rx2_coord* are the positions of the antenna phase centers in the local tower coordinate system. The origin of the tower coordinates is the intersection of the rotation axis and the central plane of the tower, 40 cm from the bottom mounting plate. The *GPRI_scan_heading* is the heading angle clockwise from north of the center azimuth line of the SLC image.

6. Gamma Software used for GPRI-II Processing

The processing strategy is to bring GPRI data in an SLC format as supported by the GAMMA Software. This has the advantage that a very broad functionality becomes available for the further processing. As a consequence it is required that at least licenses for the GAMMA ISP/DIFF&GEO modules are required to process the GPRI data.

Within the Gamma Software there is special provision for reading and processing GPRI-II data. Included with each GPRI-II data set are specific meta data that describes the GPRI-II imaging geometry, and GPS data. Gamma software programs that work directly with the GPRI-II data recognize and use these meta-data as required. There are also special programs for terrain geocoding of GPRI-II data.

The following is a concise overview of the GAMMA Software. For detailed documentation on processing sequences or individual programs the user is referred to the GAMMA Software documentation.

GAMMA Software supports the entire processing from SAR raw data to products such as digital elevation models, displacement maps and landuse maps. The software is grouped into five packages:

(3) Modular SAR Processor (MSP / not required for GPRI data processing)
(4) Interferometric SAR Processor (ISP)
(5) Differential Interferometry and Geocoding (DIFF&GEO)
(6) Land Application Tools (LAT)
(7) Interferometric Point Target Analysis (IPTA)

Each of the packages is very modular and can therefore be used in the way the user prefers. Programs can be run individually on the command line or they can be called from scripts that permit running often used processing sequences in a more operational and efficient way.

The Gamma software is written in ANSI-C. Many of the computationally intensive programs have been parallelized using OPENMP for multiple core processors. Standard binary distributions are available for:

- Intel/AMD processor Linux OS (e.g. Ubuntu, Debian, CentOS, Fedora) 64-bit
- Intel/AMD processor Microsoft Win7, Win8 64-bit OS systems
- Mac OS-X 10.9 Mavericks (64-bit binaries)

Distributions for other platforms may be provided on demand.

Besides GPRI data processing the software supports processing of a wide range of spaceborne and airborne SAR data, including data of the following space-borne SAR instruments:
ERS-1, ERS-2, ENVISAT, Radarsat-1, Radarsat-2, TerraSAR-X, Tandem-X, Cosmo-Skymed, KOMPSAT, JERS-1, ALOS PALSAR, and RISAT

The main processing software is complemented by quality control and display programs. The display of the final and intermediate products is supported with display programs and programs to generate easily portable images in SUN raster or BMP format. Data can also be exported in GeoTIFF format.

6.1 Interferometric SAR Processing Software (ISP):

The Gamma Interferometric SAR Processor (ISP) encompasses a full range of algorithms required for generation of interferograms, height and coherence maps. The processing steps include baseline estimation from orbit data, precision registration of interferometric image pairs, interferogram generation (including common spectral band filtering), estimation of interferometric correlation, removal of flat Earth phase trend, adaptive filtering of interferograms, phase unwrapping using either a branch cut algorithm or an approach based on a triangular irregular network with a minimum cost flow optimization technique, precision estimation of interferometric baselines from ground control points, generation of topographic height, and image rectification and interpolation of interferometric height and slope maps. Absolute radiometric calibration of ESA PAF processed SLC and PRI data is also supported. Offset tracking techniques starting from SLC pairs are also supported by the ISP. Importing TerraSAR-X SLC and interferometry with these SLCs is supported.

The ISP is also the base for the differential interferometry software.

6.2 Differential Interferometry and Geocoding (DIFF&GEO):

The differential interferometry module (DIFF&GEO) is designed to be very flexible with respect to separating topographic and displacement effects. If you have a DEM available from another source you can use this to simulate an interferogram and use that to subtract the topographic phase effects (that's probably the best solution in this case). The precision registration between the simulated interferogram and the true interferogram (due to uncertainties in the orbit data for example) can be done automatically.

Other approaches, which are independent of a DEM, are 3 and 4-pass interferometry. In this case an interferogram, preferably one without differential effects, is used as reference to subtract the topographic phase effects. It is necessary to unwrap this reference interferogram
(putting some limitations with respect of steep terrain and low coherence over forests and water).

In addition the DIFF&GEO package provides a complete set of programs for precision geocoding. Terrain and ellipsoid corrected geocoding from range-Doppler to map coordinates and vise versa are supported. Interpolation algorithms are applied for the resampling step. Due to inaccurate orbit information the geocoding requires a fine registration step. In order to automate this step a SAR image is simulated (based on the DEM) and used to automatically determine the fine registration using cross correlation analyses. The geocoding of images in ground-range geometry is also supported.

The DIFF&GEO also supports SLC co-registration considering terrain topography effects. Furthermore, offset tracking techniques starting from detected images are supported.

6.3 Land Application Tools (LAT)

The land application tools support filtering, parameter extraction, simple classification schemes, mosaicking, and additional data display tools.

Filtering tools include spatial filters (moving average, median, Frost, Lee, Enhanced Lee, Gamma Map) as well as multi-temporal filtering tools (based on Quegan et al). Data of specified polygon regions and lines can be extracted and investigated (mean values, standard deviations, histograms). Adaptive coherence, texture, and effective number of looks estimation programs as well as programs to conduct simple calculations with image data are included. Single or multiple classes can be classified based on one or several registered input data sets using a hierarchic thresholding scheme. Mosaicking of multiple data sets in map geometry is supported. Tools to generate RGB and HIS composites and tools to exchange the image intensity of one image with that of another image are also provided.

6.4 Interferometric Point Target Analysis (IPTA):

Instead of a full two-dimensional analysis of a stack of interferograms only the phases of selected points are analyzed. For points which correspond to point targets the geometric decorrelation observed for distributed targets does not occur, permitting to interpret interferometric phases even for pairs with baselines above the critical baseline. Consequently, a more complete interpretation of the SAR data becomes possible. More interferometric pairs can be included in the analysis, leading to an increase of the accuracy and temporal coverage achieved.

In the IPTA much of the data are kept in vector data format, in so-called point data stacks, which permits to dramatically increase the processing efficiency and reduce the disk and memory requirements. Another important element are programs for a systematic use of the temporal dimension of the data.

A typical IPTA processing sequence starts by co-registering multiple repeat-pass SLCs. Then, an important step is the identification of point targets. For the selected point targets the interferometric phases are further investigated. The physical models describing the dependence of the interferometric phase on system and target parameters are exactly the same as used in conventional interferometry. An iteration concept is used for the optimization of the information retrieval from the multi-temporal set. Parameters that are improved include the topographic heights of the scatterers, the deformations, the atmospheric path delays, and the baselines. Different phase terms can be discriminated based on its differing spatial, temporal, and baseline dependencies. The atmospheric phase delay, for example, is relatively smooth in the spatial dimension, but uncorrelated in the temporal dimension. The topographic phase shows a linear dependence on the perpendicular baseline component and the deformation can in many cases be assumed to be relatively smooth (or low-pass) in the spatial and temporal dimensions.

The main results derived with the IPTA are topographic heights, average deformation rates, deformation histories, and relative atmospheric path delays.

The IPTA is fully compatible with the other GAMMA software. Programs for conversion between the vector data used in the IPTA and the normal 2D raster formats used are included. For a convenient use of the IPTA access to the GAMMA ISP and DIFF&GEO modules is required.

The IPTA package also includes support for calculation of time-series from a set of unwrapped differential interferograms that form a 2-D graph with respect to baselines and time-intervals. This interferogram network can be solved for deformation phase, and height correction. In addition the solution can be optimized with respect to a set of smoothing constraints that can be useful for suppression of noise due to changes in the troposphere.

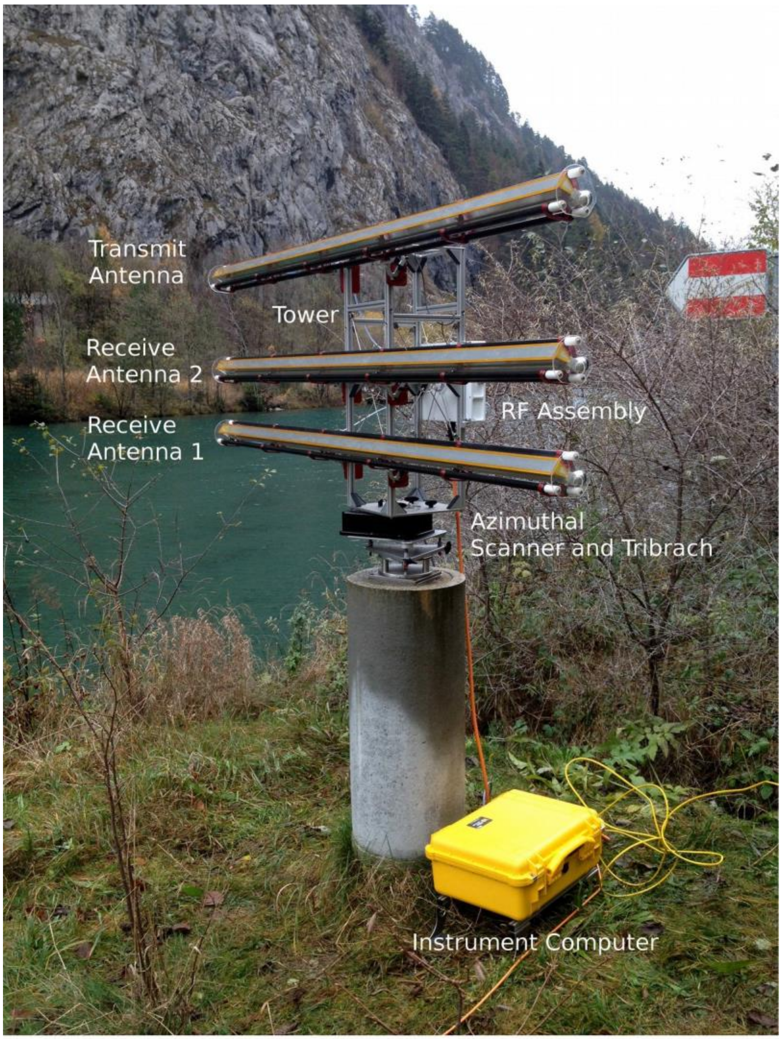
6.5 Maintenance and Support:

Gamma uses it's software for it's own research and development activities, which also means that the software is kept up-to-date with the newest developments. Your contacts for the support are those persons who developed the software and who use it regularly for their own work!

Additional information is available at GAMMA’s homepage http://www.gamma-rs.ch.

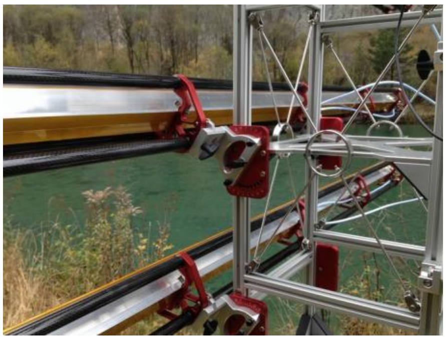
7. Instrument Specifications

Frequency Range	17.1 to 17.3 GHz, 200 MHz BW Frequency accuracy < 100 Hz
GPRI Antenna Pattern	0.385 deg -3 dB azimuth beamwidth (2-way) 35 deg. -3 dB elevation beamwidth (2-way)
GPRI Transmitter Modulation	FM-CW chirp duration 250 microsec. to 16 millisec. 200 MHz max. bandwidth (programmable)
GPRI Measurement Range	50 m to 10 km
Time and Frequency Reference	100 MHz GPS-disciplined crystal oscillator
Range sample spacing and resolution	0.75 m sample spacing, 0.95 m -3 dB peak width -26 dB peak range sidelobe
Azimuth Resolution (-3 dB)	6.8m at 1 km range, -3 dB peak-width -30 dB peak azimuth sidelobe
Deformation Measurement Precision and Accuracy	<u>Deformation Measurement Precision</u> 0.03 mm at 30 dB SNR 0.125 mm at 20 dB SNR <u>Deformation Measurement Accuracy</u> Typically less than 1 mm at 1 km, dependent on variability of atmospheric water vapor
Receiver Channels	2 independent receiver channels, dual 14-bit ADC dual receive channels, 6.25 MHz ADC sample frequency
Power Requirements	115 W average with 21-32 VDC input 125 W average with 110-240 VAC input
Instrument Computer and Operating System	Industrial mITX PC, Multi-Core I5 CPU, 8 GB RAM, 1 TB Disk Storage, Ubuntu Linux OS
Computer Interfaces	USB2, Gigabit Ethernet. Communication via HTTPS and SSH
Azimuth Scan Time	Nominal 10 deg/s Azimuth sweep rate is programmable in steps of 0.5 deg/s
Operation Temperature Range	-20 C to +50 C
Instrument Weight	Instrument Computer 16.3 kg, RF Assembly 5.5 kg, Tower 9.9 kg, Tribrach leveler and azimuth scanner 8.9 kg, Antennas 3 x 2.7 kg, Tripod 8.9 kg.
Instrument Dimensions	Tower: 80x28x28 cm, RF assembly: 30x26x6 cm Controller/Power: 52x42x30 cm Antennas: 210x12.5x12.5 cm



GPRI Radar on Pedestal

RF Assembly

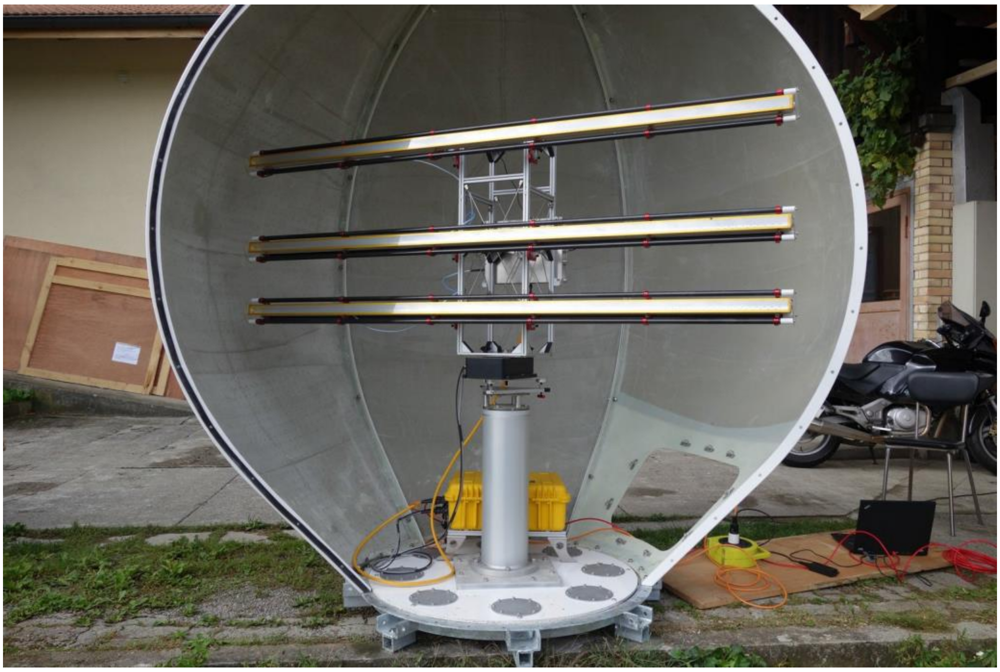


Elevation Adjustment

GPRI Tripod Mount

1. *Rapid Deployment: 15 Minutes*
2. *Tripod or Pedestal mounting*
3. *Modular construction*
4. *Precision design and fabrication for repeat measurement campaigns*
5. *Self-contained data acquisition, data storage and processing*
6. *Optional Lithium battery pack for 6 hr operation*

1. *Optional 2.5 m diameter radome with aluminum pedestal provides environmental protection for long-term observations. Designed for winds up to 150 km/h*
2. *Excellent environmental protection permits operation of radar possible in high winds*
3. *Radome attenuation < 2 dB, constant phase delay*
4. *Temperature control with active ventilation of radome interior*
5. *Radome can be trailer or truck-mounted for mobile deployment*
6. *1.2 meter galvanized steel base can be mounted on concrete pad*
7. *Optional extended base supports available for deployment without concrete pad*



8. Appendix A

Measurement Protocol

It is also recommended to take photos of the installation including the Antenna Elevation angle, radar location, and the region of interest.

Campaign Name	
Customer	
Site Name and Coordinates	
Date	
Weather (Temp, Wind)	
Antenna elevation angle	
Heading Angle at Scene Center (deg.)	
GPS Coordinates	
Power Source	
Chirp Waveform	
TX_mode (C-Band)	
RX Channel Attenuation	
Start Azimuth angle	
Stop Azimuth angle	
Azimuth Scanrate (deg/s)	
Start/End Time	
Acquisition Time Interval	
Dataset Names	
Pictures	
Remarks	

Soil Observation Topographic Differential Absorption Lidar (SOTDiAL)

User Manual

Overview

The Soil Obervation Topographic Differential Absorption Lidar (SOTDiAL) device was developed to remotely measure soil condition (burn severity, moisture content, and soil suction) and soil properties (fines content, plasticity). Contained within this manual are guidelines to safe operation conditions, assembly of the instrument in the field, operation of the device and data collection, and processing data.

Safe Operating Conditions

PLEASE READ CAREFULLY

Temperature: The SOTDiAL device has been designed to operate safely within a temperature range of 0°C to 40°C (32°F to 104°F). Operation of the device outside of this temperature range may damage individual components of the device and will result in erroneous readings. The temperature-critical components within the device are controlled by thermoelectric couple (TEC) circuits and will automatically compensate for fluctuations within the acceptable range of temperatures. If temperature range is not met or is exceeded, safe shutdown procedures should be enacted immediately.

Moisture and Humidity: The critical components of the device that are affected by moisture, including high humidity (water vapor) conditions, are hermetically sealed within the field box. The sealed box should NEVER be disassembled in the field. All maintenance must be performed in an air-conditioned laboratory environment. All other components are ruggedized for field deployment. Nonetheless, care should be taken to avoid direct exposure to moisture, particularly precipitation.

Direct Sunlight: The telescope should **NEVER** be pointed directly at the sun. When not acquiring readings, the cover should be placed onto the telescope aperture and the aperture should be pointed down at the ground or away from the sun.

Instrument Setup: In unusually rough or mountainous terrain, care must be taken to secure the legs of the telescope tripod. Furthermore, placement of the field box should be HORIZONTAL AT ALL TIMES. Whenever possible, the instrument should be set up in an area that is sheltered from unusually high wind speeds (>20 mph).

Fiber Optic Cables: Care must be taken to avoid damage to the fiber optic cables which connect the aperture to the field box. Although the cables are armored, all efforts should be made to avoid stretching or bending the cables sharply as this may damage the fibers.

Assembly Protocol

1) **Telescope:**
   a) The telescope tripod legs should be assembled according to the instructions provided on p.139 (insert).
   b) Place the telescope body onto the tripod platform and fasten securely using the threaded rod. **DO NOT** attempt to fasten the telescope to the tripod without the help of another person, as the telescope may slide and fall from the tripod platform.
   c) Once the telescope is securely mounted, loosen both the Dec. and R.A. locks (labeled '17' and '12', respectively, on p.140) and point the telescope to the desired scene. Tighten the Dec. and R.A. locks again (firm feel only).
   d) Connect power cable to the telescope base (12VDC IN).
   e) If using AutoStar II handbox, connect cable to telescope base (HBX port). If using external communication cable, connect cable to telescope base (RS232 port).
   f) Telescope computer control panel may be turned on and off with the ON/OFF switch.
   g) Primary mirror **MUST** be unlocked before attempting to focus telescope by turning primary mirror lock knob (labeled '9' on p.140).
   h) Manual focus is achieved by adjusting the focus knob (labeled '6' on p.140). Rotate the focus knob CW for closer objects and CCW for distant objects. Once focused, lock the primary mirror again (firm feel only).
   i) Slide the transmitter assembly onto the dovetail rail mounted to the top of the telescope body and align forward mount edge to the leading egde of the rail.
   j) Carefully connect the fiber optic transmitter cable (labeled T) to the back of the transmitter assembly (SMA connector).

2) **Dual-Channel Optical Receiver:**
   a) Remove the screw cap on the rear of the telescope (labeled 'on page 140). Thread the receiver adapter onto the telescope and loosen the set screw. Attach the receiver assembly to the telescope by inserting the longest tube (labeled 1) into the opening of the telescope. Slide the tube into the telescope until the marked ring (white) is aligned with the edge of the opening. Tighten the set screw on the adapter until the receiver assembly is mounted securely.
   b) Ensure that the adjustable aperture is set to CLOSE.
   c) Remove the aperture cover on the telescope.

d) Place transmitting mirror mount on front of telescope and secure with set screws (three screws). Take care not to scratch telescope aperture glass and do not overtighten set screws. Insert transmitting mirror so that it aligns with downward-facing transmitter assembly.

3) FieldSpec:

a) Remove the FieldSpec instrument from the case.

b) Connect the instrument to the laptop using the ethernet cable (unidirectional, connect each end as indicated).

c) Boot up the FieldSpec instrument, then boot up the laptop.

4) Fiber Optic Cables:

a) The FieldSpec cable (labeled F) should be connected to the optical receiver using provided adapter (tube labeled 2).

b) The receiver cable (labeled R) should be connected to the FiberPort on the optical receiver (tube labeled 3).

5) Data Acquisition (DAQ) System:

a) Open the front and back panels of the field box.

b) Plug the component power cables (labeled 1 - 5, and 8) into the power strip located within the field box.

c) Plug the power strip into the extension cord. Plug the extension cord into the generator.

d) Pull the keyboard and mouse out of the field box. Connect the monitor or laptop to the field computer.

6) Boot-Up Sequence:

Boot up the field computer by switching the button on the front of the chassis to ON. *Note: if temperature conditions warrant higher cooling capacity for the DAQ system, switch the fan button from Auto to High on the back of the DAQ chassis.* Log in to the welcome screen with the password. Boot up the FieldSpec instrument.

7) Warm-Up Period:

Allow all components of the system to warm up by idling for 30 minutes before acquiring measurements.

QUICK-START GUIDE

It is recommended that you attach the supplied tripod to the LX200-ACF for observing. Perform the telescope and AutoStar II setup indoors in the light so that you become familiar with the parts and operation before moving the telescope outside into the dark for observing. The setup is the same for the standard and giant field tripods.

NOTE: The LX200-ACF 8", 10", 12" and 14" models are equipped with Series 4000 26mm Super Plössl eyepiece and a 1.25" Diagonal. The LX200 ACF 16" model is equipped with Series 5000 26mm 5-element Super Plössl eyepiece, 2" Diagonal and the Zero Image-Shift Microfocuser.

The Field Tripod is supplied as a completely assembled unit, except for the spreader bar (**Fig. A, 4**). For visual observations and short exposure astro-imaging, the drive base of the telescope's fork mount is attached directly to the field tripod. The telescope in this way is mounted in an "Altazimuth" ("Altitude-Azimuth", or "vertical-horizontal") format.

CAUTION: "Firm feel" tightening is sufficient; over-tightening may strip the threads or damage the tripod and results in no additional strength.

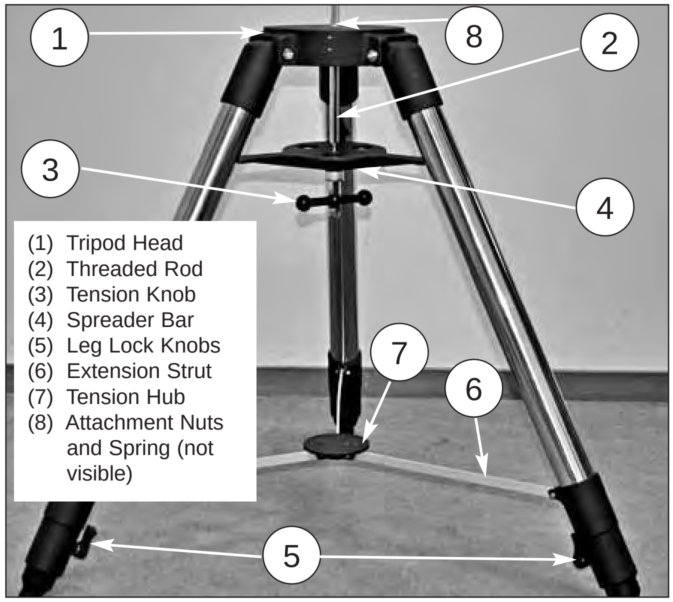


Fig. A: Field Tripod with legs extended.

Fig. B: Extend the tripod legs out.

❶ How to Attach the Tripod to the Telescope Assembly. After removing the field tripod from its shipping carton, stand the tripod vertically, with the tripod feet down and with the tripod still fully collapsed. Grasp two of the tripod legs and, with the full weight of the tripod on the third leg, *gently* pull the legs apart to a fully open position (**Fig. B**).

The spreader bar (**Fig. A, 4**) has been removed for shipment. Unscrew the attachment nuts and spring from the spreader bar's threaded rod (**Fig. A, 2**). Leave the washer on the bar. See **Fig. C**.

Slide the spring into the hole on top of the tripod head (**Fig. A, 1**).

Slide the spreader bar onto the threaded rod on top of the washer that is already on the threaded rod. Position the spreader bar with the flat side facing upward (**Fig. D**).

Slide the threaded rod back through the tripod head from underneath and through the spring. Rethread the first attachment nut over the threaded rod as far down as it will go. Then thread the second nut until it is on top of the first nut. Push the rod up higher from underneath to make it easier to attach the nuts. See **Fig. E, 1 and E, 2**.

Fig. C: Remove 2 nuts and spring from threaded rod. Leave the washer on the rod.

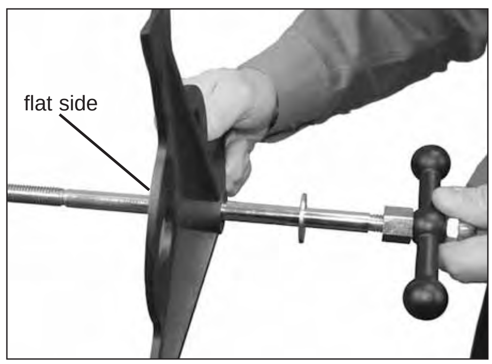


Fig. D: Slide spreader over threaded rod. Note the washer on the rod.

Fig. E, 1: Insert spring into hole on top of tripod head.

Fig. E, 2: Thread the first nut as far down as it will go. Then thread the second nut down onto the first nut.

TELESCOPE FEATURES

***Fig. 1**: The LX200-ACF Telescope; Computer Control Panel (inset); AutoStar II Handbox (inset).*

LX200-ACF: YOUR PERSONAL WINDOW TO THE UNIVERSE

Caution:
Using products other than standard Meade accessories may cause damage to the telescope's internal electronics and may void the Meade warranty.

➊ *Want to learn more about the **eyepieces available for your LX200-ACF telescope**?*
*See **OPTIONAL ACCESSORIES**, pages 44-46.*

➎ *Want to learn how to attach the microfocuser assembly to the rear cell port **of your LX200-ACF telescope**?*
*See **HOW TO ASSEMBLE YOUR TELESCOPE**, pages 13 and 14.*

➑ *Want to learn how to **install the batteries**?* *See page 13.*

➒ *Want to learn more about the primary mirror lock?* See ***MIRROR MIRROR**, page 38.*

⓫ *Want to learn more about the **Right Ascension and Declination setting circles**?* *See page 55.*

The Meade LX200-ACF models are extremely versatile, high-resolution telescopes. With pushbutton controls, precision GPS alignment, true-level and North electronic sensors, automatic tracking of celestial objects, periodic error correction for both axes, and a library of 145,000+ objects in the AutoStar II database, the LX200-ACF models offer unmatched state-of-the-art performance.

Note: The LX200 ACF 8", 10", 12" and 14" models are equipped with Series 4000 26mm Super Plössl eyepiece and a 1.25" Diagonal. The LX200 ACF 16" model is equipped with Series 5000 26mm 5-element Super Plössl eyepiece, 2" Diagonal and the Zero Image-Shift Microfocuser.

Observe the feather structure of an eagle from 50 yards or study the rings of the planet Saturn from a distance of 800 million miles. Focus beyond the Solar System on ancient star clusters, remote galaxies, and stars recently discovered to have planets orbiting about them. Meade LX200-ACF telescopes are capable of growing with your interest and can meet the requirements of the most demanding advanced observer.

➊ **Eyepiece**: Place the Series 4000 26mm Plössl eyepiece into the 90° diagonal prism (**Pg. 7, Fig. 1, 3**) and tighten in place with the eyepiece thumbscrew (**Fig. 1, 2**). The eyepiece magnifies the image collected in the optical tube.

➋ **Eyepiece Thumbscrew**: Tightens the eyepiece (**Fig. 1, 1**) in place. Tighten to a firm feel only.

➌ **1.25" Diagonal Prism**: Provides a more comfortable right angle viewing position.

➍ **Diagonal Prism Thumbscrew**: Tightens the diagonal prism in place. Tighten to a firm feel only.

➎ **Rear Cell Port**: The Diagonal Prism assembly threads onto this port.

➏ **Manual Focus Knob**: Moves the telescope's primary mirror in a finely-controlled motion to achieve image focus. The LX200-ACF telescopes can be focused on objects from a distance of about 25 ft. to infinity. Rotate the focus knob counterclockwise to focus on distant objects, and clockwise to focus on nearby objects.

➐ **Fork Arms:** This heavy-duty mount holds the optical tube securely in place.

➑ **Battery Compartments:** Insert four user-supplied C-cell batteries into each compartment (one compartment on each fork arm; eight batteries total).

➒ **Primary Mirror Lock:** Rotate this knob towards the "Lock" position and adjust the tension to a firm feel; this action serves to lock in the coarse focus and also to prevent mirror flop. Use in conjunction with the optional Zero Image-Shift Microfocuser.

➓ **Right Ascension (R.A.) Slow-Motion Control:** Make fine adjustments in the Right Ascension, *i.e.*, the horizontal axis, by turning this control with the R.A. Lock (see ⓬ below) in the unlocked position. Set the R.A. Lock to a "partially locked" position to create a comfortable drag for the R.A. Slow Motion Control.

> ***Caution:** Do not operate the R.A. Slow Motion Control with the R.A. Lock in the fully locked position, as such operation may result in damage to the internal gear system and also cause you to lose alignment.*

⓫ **Right Ascension (R.A.) Setting Circle:** See **APPENDIX A,** page 53, for detailed information.

⓬ **Right Ascension (R.A.) Lock**: Controls the manual horizontal rotation of the telescope. Turning the R.A. lock counterclockwise unlocks the telescope, enabling it to be freely rotated by hand about the horizontal axis. Turning the R.A. lock clockwise locks the telescope, prevents the telescope from being rotated manually, and engages the horizontal motor drive for AutoStar II operation.

> ***Definitions***
> *Throughout this manual, you will notice the terms "**Alt/Az**", "**Right Ascension**", and "**Declination**". Alt/Az or more properly, altazimuth, is frequently used to refer to **alt**itude or **Dec**lination (the up-and-down vertical movement of the telescope) and **az**imuth or Right Ascension (the side-to-side horizontal movement of the telescope). Right Ascension is abbreviated as "**R.A.**" and Declination as "**Dec.**".*

> ***Important Note:***
> *After the telescope is aligned (see page 18), the Dec. slow motion control ⑯ may be used and the telescope will remain in alignment. However, if the R.A. slow motion control ⑩ is used after the telescope has been aligned, alignment will be lost and the telescope will need to be realigned.*

> ***Caution:***
> *When loosening the Dec. lock, be sure to support the optical tube (**Fig. 1, 19**). The weight of the tube could cause the tube to swing through the fork arms suddenly.*

> ㉑ *Want to learn more about **mounting and adjusting the viewfinder**? See page 16.*

⑬ **Computer Control Panel (see Fig. 1 inset):**

A. **ON/OFF Switch**: Turns the computer control panel and AutoStar II ON or OFF. The red power indicator LED next to the switch illuminates when power is supplied to the AutoStar II handbox, the microfocuser, and to the telescope's motor drives (the LED can be turned off in the Panel Light menu; see page 28).

B. **12vDC Power Connector**: Provides a connection so that the telescope assembly may be powered from a standard 115v AC home outlet using the optional #547 Power Adapter with Cable or the optional 12v DC #607 Cigarette Lighter Adapter. See **OPTIONAL ACCESSORIES**, page 44.

C. **Focus Port**: Plug the optional microfocuser into this port. Control the microfocuser through the AutoStar II menus. See **HOT BUTTON MENUS**, page 32.

D. **Reticle Port**: Plug the optional reticle eyepiece into this port. Control the reticle through the AutoStar II menus. See **HOT BUTTON MENUS** page 32. Also see **OPTIONAL ACCESSORIES**, page 44.

Note: *See the instruction sheets that are included with the focuser, the reticle, and the autoguider for more details.*

E. **12vDC Output**: Use the 12vDC output to power telescope accessories.

F. **Handbox (HBX) Port**: Plug the AutoStar II coil cord into this port.

G. **RS232 Ports (2)**: Provides connection with a PC and for current and future Meade accessories. Your PC can control your LX200-ACF telescope using serial commands. Go to the Meade website (**www.meade.com**) to download the latest serial commands and device pinouts.

H. **Autoguider Port**: Plug the optional autoguider into this port. See the instruction sheet that came with your autoguider for more information.

⑭ **Tiltable AutoStar II Holder**: Attach to fork handles (see ⑮ below). Holds your handbox in a convenient location.

⑮ **Fork Handles:** Use to lift optical tube assembly or to rotate the telescope when attached to the tripod.

⑯ **Declination (Dec.) Slow-Motion Control:** Make fine adjustments in Declination (altitude) by turning this control with the Dec. Lock (see ⑰ below) in the locked position. In order for this control to operate properly, power must be off.

⑰ **Dec. Lock**: Controls the manual vertical movement of the telescope. Turning the Dec. lock counterclockwise unlocks the telescope enabling it to be freely rotated by hand about the vertical axis. Turning the Dec. lock clockwise (to a firm feel only) prevents the telescope from being moved manually, but engages the vertical motor drive for AutoStar II operation.

⑱ **Dust Cover**: Gently pry the dust cover from the front lens of the telescope.

Note: *The dust cover should be replaced after each observing session and the power turned off to the telescope. Verify that any dew that might have collected during the observing session has evaporated prior to replacing the dust cover.*

⑲ **Optical Tube:** The main optical component that gathers the light from distant objects and brings this light to a focus for examination through the eyepiece.

⑳ **Declination (Dec.) Setting Circle** (on left fork arm): See **APPENDIX A**, page 53, for detailed information.

㉑ **Viewfinder Collimation Screws**: Use these six screws to adjust the alignment of the viewfinder.

㉒ **8 x 50mm Viewfinder**: A low-power, wide-field sighting scope with crosshairs that enables easy centering of objects in the telescope eyepiece.

㉓ **GPS Receiver (see page 22 for photo):** Receives information transmitted from Global Positioning System satellites. See pages 19, 20, and 22 for more information.

㉔ **Tube Adapters:** The optical and mechanical axes of the LX200-ACF telescope have been carefully aligned at the factory to ensure accurate object pointing. Do not loosen or remove the optical tube assembly from the tube adapters. The resulting misalignment of the axes will result in inaccurate slewing of the telescope in the GO TO mode.

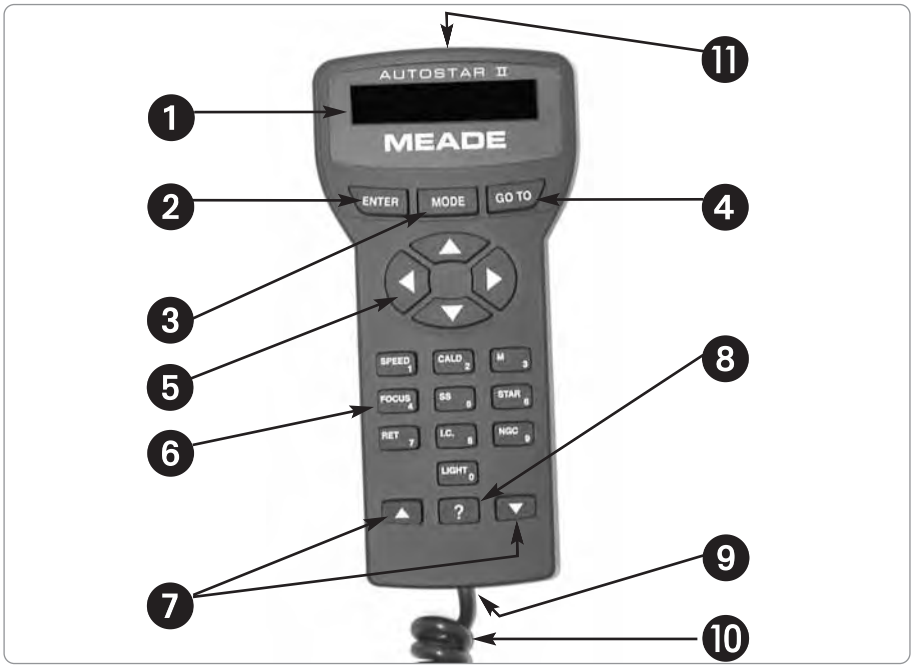


Fig. 2: The AutoStar II Handbox.

Tour the Cosmos with Just the Push of a Button

Control of the LX200-ACF telescope models is through the operation of the standard AutoStar II system. Nearly all functions of the telescope are accomplished with just a few pushes of AutoStar II's buttons.

Because the AutoStar II system uses flash (rewritable) memory, your system will be able to grow when new features and enhancements become available. Download the latest satellite data, star and object catalogs, tours, serial commands list, and software revisions, directly from the Meade website (**www.meade.com**). (Requires the optional LX200 Interface Cable. See **OPTIONAL ACCESSORIES**, page 44.)

*Want to learn more about **downloading the latest updates of AutoStar II software from the Meade website**?* *See page 32.*

Some of the major features of the AutoStar II system are:

- Automatically move the telescope to any of the more than 145,000 objects stored in the object library, including:

Library	Number of Objects
New General Catalog (NGC):	7,840
Index Catalog (IC):	5,386
Messier Catalog (M):	110
Caldwell Catalog:	109
Named Objects:	227
Herschel Catalog:	400
Abell Catalog of Galaxy Clusters:	2,712
Arp Catalog of Irregular Galaxies:	645
Uppsala Galaxy Catalog:	12,940
Morphological Catalog of Galaxies:	12,939
General Catalog of Variable Stars:	28,484
SAO:	17,191
Hipparcos Star Catalog:	17,325

- Take a guided tour of the best celestial objects to view on any given night of the year.
- Control your LX200-ACF with your PC using an RS232 interface.
- Align your telescope automatically using GPS (Global Positioning System).
- Access a glossary of astronomical terms.
- Mount the telescope in the "Alt/Az" mode (altitude—azimuth, or vertical—horizontal) for fully automatic tracking of celestial objects.

The AutoStar II system provides control of virtually every telescope function. The AutoStar II handbox has soft-touch keys designed to have a positive feel. The LCD (Liquid Crystal Display) is backlit with red LEDs (Light Emitting Diodes) for easy viewing in the dark. The backlit display, key arrangement, and sequential menu structure make AutoStar II extremely user friendly.

❶ **2-Line LCD Display:** This screen displays AutoStar II's menus and information about the telescope.

- **Top line:** Lists the primary menu.
- **Bottom line:** Displays other menus that may be chosen, menu options, telescope status, or information about a function that is being performed.

❷ **ENTER Key**: Press to go to the next menu level or to choose an option in a menu. The ENTER key is similar to the RETURN or ENTER key on a computer. See **MOVING THROUGH AUTOSTAR II'S MENUS**, page 19 and **AUTOSTAR II MENUS**, page 25.

❸ **MODE Key**: Press to return to the previous menu or data level. The top menu level is "Select Item". The MODE key is similar to the ESCAPE key on a computer.

__Note:__ Pressing MODE repeatedly while in the "Select Item" level moves AutoStar II to the topmost screen: "Select Item: Object".

__Note__: If MODE is pressed and held for two seconds or more, information about the telescope's status displays. When the status displays, press the Scroll keys (__Fig. 2, 7__) to display the following information:

• Right Ascension and Declination (astronomical) coordinates
• Altitude (vertical) and Azimuth (horizontal) coordinates
• Local Time and Local Sidereal Time (LST)
• Timer and Alarm Status
• Date
• Site coordinates
• Battery status

Press MODE again to return to the previous menu.

❹ **GO TO Key**: Press to slew (move) the telescope to the coordinates of the currently selected object. While the telescope is slewing, the operation may be aborted at any time by pressing any key except GO TO. Pressing GO TO again resumes the slew to the object. Also, press during the alignment or GO TO procedures to activate a "spiral search".

❹ *Want to learn more about using the __GoTo function__? See page 21.*

Want to learn how to perform a __spiral search__? See the tip on page 21.

❺ **Arrow Keys**: The Arrow keys have several functions. Press an Arrow key to slew the telescope in a specific direction (up, down, left, and right), at any one of nine different speeds. See **SLEW SPEEDS**, page 18. Use the Up and Down Arrow keys to move the telescope vertically up and down. The Left Arrow key rotates the telescope horizontally counterclockwise, while the Right Arrow key rotates it clockwise (unless reversed for Southern Hemisphere use).

Also, use the Arrow keys to scroll through numbers 0 through 9 and the alphabet. The Down Arrow key begins with the letter "A", the Up Arrow key begins with digit "9".

Additionally, use the Arrow keys to to move the cursor across the display: Use the Right or Left Arrow key (**Fig. 2, 5**) to move the cursor from one number to the next in the display.

❻ **Number Keys:** Press to input digits 0 to 9. Each Number key also has a specific function, which is printed on each key (these are commonly known as "hot buttons"—see page 31):

1 SPEED: Changes the slew speeds. To operate, press Speed and then a Number key (1 is the slowest speed, 9 is highest speed).
2 CALD (Caldwell): Press to display the Caldwell catalog on the AutoStar II handbox.
3 M (Messier): Press to display the Messier catalog library.
4 FOCUS: Press to display the Focus Control menu.

SPEED 1 *Want to learn more about __changing slew speeds__? See page 18.*

FOCUS 4 *Want to learn more about the __Focus menu__? See page 32.*

RET 7 *Want to learn more about the **Reticle menu**? See page 32.*

Tip:
*When an **astronomical term** appears in [**brackets**], press ENTER for a definition or more detailed information. Press MODE to return to the scrolling AutoStar II Help display.*

*If a **celestial object's name** appears in brackets (and your telescope is aligned), press ENTER and then GO TO to slew the telescope to the object.*

5 SS: Press to display the Solar System library.
6 STAR: Press to display the Star library.
7 RET (Reticle): Press to display the Reticle Control menu.
8 IC: Press to display the Index Catalog library.
9 NGC (New General Catalog): Press to display the NGC catalog library.
0 LIGHT: Press to turn on and off the red utility light on the top of the hand-box.

❼ **Scroll Keys**: Press to access options within a selected menu. The menu is displayed on the first line of the screen. Options in the menu are displayed, one at a time, on the second line. Press the Scroll keys to move through the options. Press and hold a Scroll key to move quickly through the options.

The Scroll keys also control the speed of text scrolling on the AutoStar II display. When text is scrolling, press and hold the Up Scroll key for a faster display speed and the Down Scroll key for a slower display speed.

❽ **? Key**: Press to access the "Help" file. "Help" provides on-screen information on how to accomplish whatever task is currently active.

Press the ? key and then follow the prompts on the display to access details of AutoStar II functions in the Help feature. The Help system is essentially an on-screen instruction manual.

If you have a question about an AutoStar II operation, *e.g.*, INITIALIZATION, ALIGNMENT, *etc.,* press the ? key and follow the directions that scroll on the second line. When satisfied with the Help provided, press MODE to return to the original screen and continue with the chosen procedure.

❾ **Coil Cord Port**: Plug one end of the AutoStar II coil cord (**Pg. 10, Fig. 2, 10**) into this port located at the bottom of the AutoStar II handbox.

❿ **Coil Cord**: Plug one end of the AutoStar II coil cord into the HBX port (**Pg. 7, Fig. 1, 13F**) of the computer control panel of the telescope and the other end into the AutoStar II coil cord port. See **#9** above.

⓫ **Utility Light**: Use this built-in red light to illuminate star charts and accessories without disturbing your eye's adaptation to darkness. Press "0" to turn the light on and off.

LX200-ACF TIPS

Join an Astronomy Club, Attend a Star Party

One of the best ways to increase your knowledge of astronomy is to join an astronomy club. Check your local newspaper, school, library, or telescope dealer/store to find out if there's a club in your area.

At club meetings, you will meet other astronomy enthusiasts with whom you will be able to share your discoveries. Clubs are an excellent way to learn more about observing the sky, to find out where the best observing sites are, and to compare notes about telescopes, eyepieces, filters, tripods, and so forth.

Often, club members are excellent astrophotographers. Not only will you be able to see examples of their art, but you may even be able to pick up some "tricks of the trade" to try out with your LX200-ACF telescope. See page 41 for more information about photography with the LX200-ACF.

Many groups also hold regularly scheduled Star Parties at which you can check out and observe with many different telescopes and other pieces of astronomical equipment. Magazines such as *Sky & Telescope* and *Astronomy* print schedules for many popular Star Parties around the United States and Canada.

Acknowledgements

The authors would like to acknowledge support from the United States Department of Transportation (U.S. DOT) Office of the Assistant Secretary for Research and Technology (OST-R) under Research and Innovation Technology Administration (RITA) Cooperative Agreement Award No. OASRTRS-14-H-UARK awarded to R.A. Coffman (PI) and T. Oommen (Co-PI). The views, opinions, findings, and conclusions reflected in this manual are the responsibility of the authors only and do not represent the official policy or position of the USDOT/OST-R, or any state or other entity. Furthermore, this material is based upon work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1450079, as awarded to S.E. Salazar.

Additional Resources

FieldSpec® 4
User Manual

ASD Inc.
A PANalytical Company
PANalytical

ASD Document 600979 | Rev. F | May 2016

Contents

Chapter 1: Getting Started

The following sections will help you get started using the FieldSpec®4 instrument:

1.1 About This Manual

This manual is for users of the FieldSpec 4 instrument and describes how to set up and use the instrument. It also includes reference information about how the instrument works.

This manual uses the following symbols and typographical conventions.

Convention	Definition
Bold	Words in **bold** show items to select or click, such as menu items or buttons.
File > Open	This notation shows software menu selections. (For example, from the **File** menu, select **Open**.)
NOTICE	This symbol indicates practices not related to personal injury.
CAUTION	This symbol indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.
	Items with this symbol indicate that the item should be recycled and not disposed of as general waste.

Cautions and notices throughout this manual are for the convenience of the reader. However, the absence of cautions and notices do not preclude the use of proper caution and handling. Take the normal precautions at all times, either written or otherwise, to avoid personal injury or equipment damage.

1.2 Technical Support

If you have any questions or concerns, please contact ASD Inc., a PANalytical company by phone, fax, or e-mail:

Phone: 303-444-6522 extension 3
Fax: 303-444-6825
e-mail: NIR.support@panalytical.com
Web: support.asdi.com

Technical support is available to answer your questions Monday through Friday, 8 a.m. to 5 p.m. Mountain Time.

1.3 FieldSpec 4 Instrument Overview

The FieldSpec 4 instrument is a general-purpose spectroradiometer that is useful for many applications requiring the measurement of reflectance, transmittance, radiance, or irradiance. A spectroradiometer is a special kind of spectrometer that can measure radiant energy (radiance and irradiance.) The FieldSpec 4 instrument has a fixed fiber optic cable that lets you calibrate it to units of radiant energy (irradiance and radiance).

The instrument is specifically designed for field environment remote sensing to acquire visible and near-infrared (VNIR) and short-wave infrared (SWIR) spectra. The instrument is a compact, field portable, and precision instrument with a spectral range of 350–2500 nm and a rapid data collection time of 0.2 second per spectrum.

The FieldSpec 4 is available in the following models:

Table 1.1: FieldSpec 4 models and spectral resolutions

	Spectral resolution	
Model	**VINR (nm)**	**SWIR (nm)**
Wide-Res	3	30
Standard-Res	3	10
Hi-Res	3	8
Hi-Res NG	3	6

For the complete specifications, see “Appendix A, Specifications and Compliance” on page 46.

To use the instrument, you must have a laptop computer (instrument controller) and the appropriate software. The instrument typically comes with both, but if you need to use your own computer, see “2.1 System Requirements” on page 9.

Figure 1.1 shows the front panel of the instrument.

Figure 1.1: FieldSpec 4 instrument front panel

Figure 1.2 shows the back panel of the instrument.

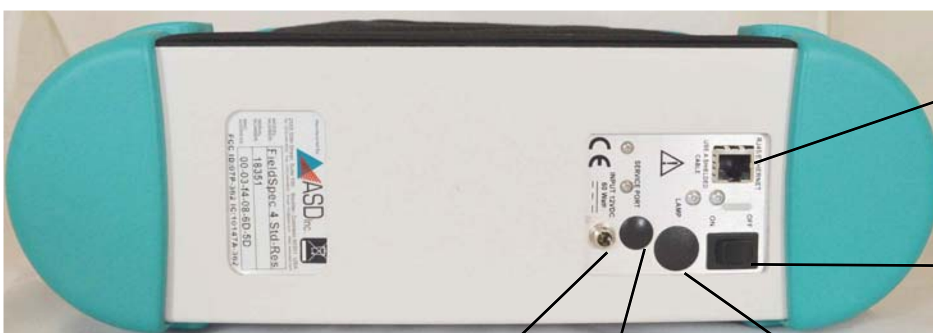


Figure 1.2: FieldSpec 4 instrument back panel

1.4 Unpacking the Instrument

The instrument ships in a hard-shell carrying case, as shown in Figure 1.3.

Figure 1.3: Instrument as it ships

The backpack and laptop carrier ship separately and are in the soft-sided case, as shown in Figure 1.4.

Figure 1.4: Backpack in soft-sided case

To unpack the instrument:

1. Inspect the shipping containers and note any damage.
    - Save all packing materials, foam spacers, and paperwork for future use.
2. Open the shipping containers, following all instructions and orientation labels.
3. Remove the instrument from its shipping case and place it on a sturdy bench or counter with an electrical outlet available.
    - If an electrical outlet is not available, you can use the battery instead. The battery was partially charged at the factory, and we recommend you fully charge it before use.
4. Remove the instrument controller (computer).
5. Remove the cables for the instrument controller.
6. Remove the backpack (accessories inside) from the soft-sided case.
    - Some accessories are optional.

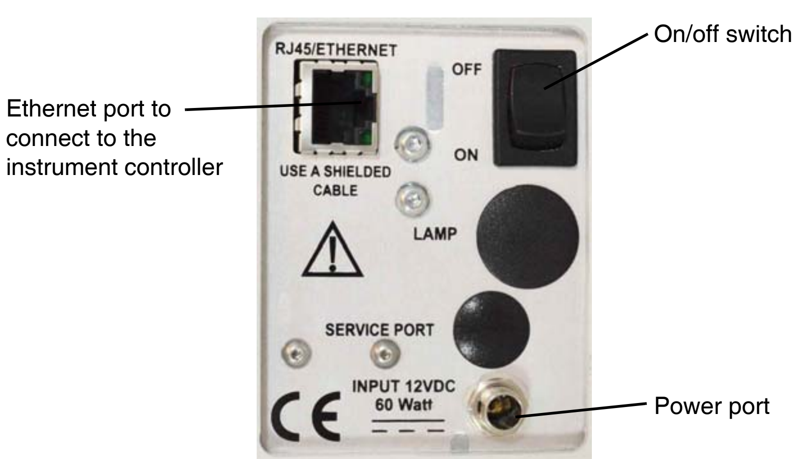
1.5 Setting Up the Instrument

You must connect the instrument, the instrument controller (computer), and accessory light source (if required). If you plan to use your own computer, see “System Requirements” on page 9.

NOTICE	The instrument can have only one active network connection (Ethernet or wireless) at a time. The Wi-Fi/Ethernet button on the back of the instrument determines the active connection. When the button is green, the wireless connection is enabled.

To set up the instrument:

1. Connect the power cable to the back of the instrument (screw it into the port) and to an electrical outlet.
    - For information about using the battery instead, see “Using the Battery” on page 11.



2. Connect the Ethernet cable to the instrument controller's Ethernet port and to the back of the instrument.
   - The location of the Ethernet port varies on different instrument controllers.
   - If you want to use wireless communication between the instrument and instrument controller, do not connect the cable. For more information, see "2.4 Setting Up Ethernet or Wireless Communication" on page 12.
3. Connect the power cable to the instrument controller and to an electrical outlet.
4. If you are using a contact probe or Muglight, connect the accessory power connector to the accessory power source and insert the fiber optic cable into the accessory.
   - For more information, see "Using Accessory Light Sources" on page 16.
5. If you are using the pistol grip or the remote trigger, connect them.
   - For more information, see "Using the Remote Trigger" on page 17 and "Using the Pistol Grip" on page 16.
6. Turn on the instrument.
7. If using an optional accessory light source, turn it on.
8. Let the instrument warm up for at least 15 minutes.
   - If you are collecting radiometric spectra, let the instrument warm up for at least one hour before collecting radiance or irradiance data.
9. Turn on the instrument controller.
   - A Windows message indicating that the connection was unsuccessful may display. Click **Close**, and the wireless network should show Limited Access. Start the RS^3 software, and the status will change to Connected.

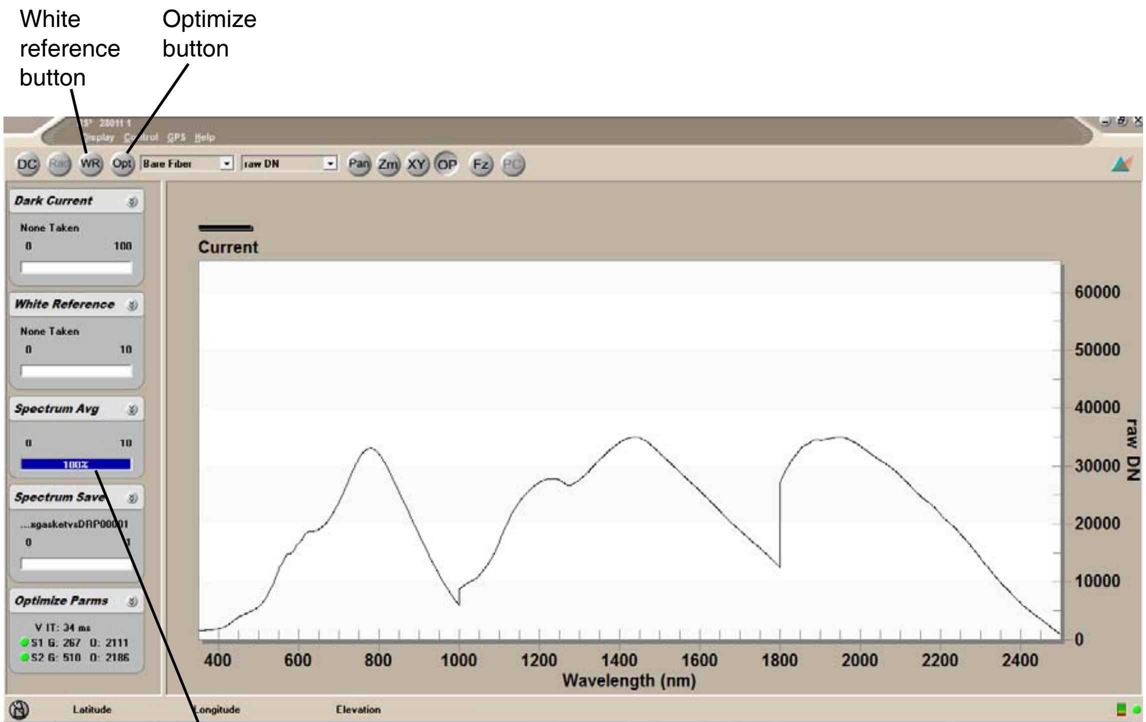
For information about using the instrument with the backpack and laptop carrier, see "Using the Laptop Carrier (Belly Board)" on page 20 and "Using the Backpack" on page 22.

1.6 Setting Up RS^3 and Saving Spectra

After you start the RS^3 software, you must optimize and set a white reference. You can then collect and save spectra.

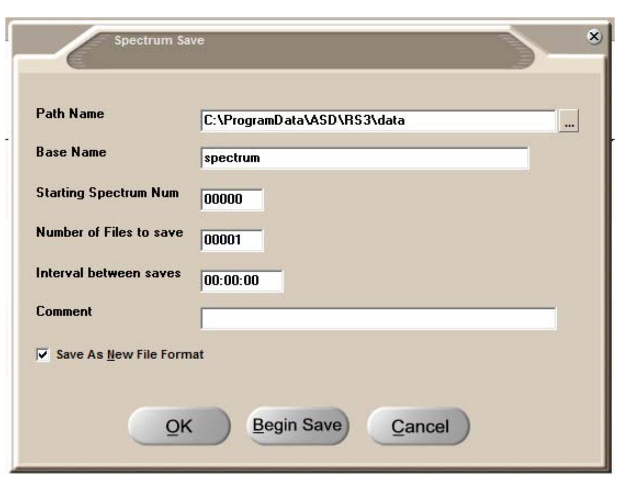
To set up the software and save spectra:

1. Start the RS^3 software.
   - Double-click the RS^3 icon  from the instrument controller's desktop.
   - If you are using one of the default network configurations, RS^3 automatically detects and connects to the instrument. For more information, see "2.4 Setting Up Ethernet or Wireless Communication" on page 12.



The software starts collecting spectra immediately. The Spectrum Avg progress bar shows the spectra collection.

2. Point the end of the fiber optic cable at the white reference panel and hold it there.
3. Click **Opt** to optimize the instrument.
   - The optimization is complete when the Spectrum Avg progress bar resumes.
4. Click **WR** to take a white reference.
   - A white reference is only useful when collecting reflectance data. This step is not necessary when collecting radiance or irradiance data.
   - The white reference is complete when the Spectrum Avg progress bar resumes.
5. Point the end of the fiber optic cable at the sample and hold it there until the spectrum average collection is complete.
6. Select **Control > Save Spectrum**.



7. If you would like to change the file save location of your spectrum, browse to where you want to save the spectrum and enter a file name.
   - For more information about the Spectrum Save window, refer to the *RS³ User's Guide*.
8. Do one of the following:
   - To save the settings in the Spectrum Save window but not save any spectra yet, click **OK**. Then use the instrument controller's space bar or the remote trigger to save spectra.
   - To begin saving spectra immediately, click **Begin Save**.

Use the ViewSpec™ Pro software to view and post-process the saved spectra. For more information about using the RS³ or ViewSpec Pro software, refer to the *RS³ User's Guide* or the *ViewSpec Pro User's Guide*.

Chapter 2: Using and Maintaining the Instrument

The following sections will help you use and maintain your instrument:

2.1 System Requirements

To use the instrument, you must have a laptop computer (instrument controller) and the appropriate software. If you did not purchase an instrument controller from ASD or need to use your own computer, the following sections provide the system requirements:

- "Computer Requirements" on page 9
- "Software Requirements" on page 10

Computer Requirements

The instrument controller is a computer that manages the instrument, stores data, and processes the results.

The minimum requirements for the instrument controller are:

- 1.0 GHz or higher CPU
- 512 MB or higher RAM
- 600 MB or higher of free disk space
- Microsoft® Windows® XP or Windows 7
- 800 x 600 or higher graphics resolution 24-bit color or better, 32-bit recommended

- 10/100 Base-T Ethernet interface
- Ethernet wireless (Wi-Fi) adapter: PCMIA, USB, or internal that is compatible with the 802.11g/n standard
- (Optional) Serial communications port (RS-232 COM, Bluetooth®, or USB; only needed if a GPS is used). Contact ASD for information about using GPS receivers with ASD instruments.

Software Requirements

The instrument controller requires the following software:

- Microsoft Internet Explorer 6.0 or higher
- RS^3 spectral acquisition software from ASD

You should have a basic understanding of the Microsoft Windows operating system, including software installation.

International customers using non-English versions of Windows must change the **Regional Settings** under **Start > Settings > Control Panel**. The default language must be set to English (United States) for the software to be registered and operate correctly. The numbering format must also be set to English.

2.2 Ventilation Requirements

When used inside, provide adequate room ventilation for the instrument. Insufficient ventilation can result in overheating of the instrument, corrupted data, and possible physical damage to the instrument.

Follow these additional tips about using the instrument:

- Do not cover the vents of the instrument. Be sure the vents line up with the mesh in the backpack to ensure adequate ventilation and make sure the mesh and vents are not obstructed.
- Prevent objects from obstructing ventilation holes.
- Keep objects and spills from entering or falling onto the instrument and power supplies.

2.3 Power Options

The instrument requires input power of 12 VDC (60 W). It does not contain an internal power supply or battery.

The three options for providing the instrument with the appropriate DC voltage are:

- A power cable that connects to an electrical outlet (included).
- An external battery (included). For more information, see "Using the Battery" on page 11.
- A power cable for a 12 V DC vehicle outlet (included; should not be used with vehicle engine running).

NOTICE Use only ASD-approved power supplies or connectors to power the instrument.

Using the Battery

When electrical power is not available, use the battery that came with the instrument. The Nickel-Metal Hydride (NiMH) battery can power the instrument and accessories.

CAUTION Use only batteries supplied by ASD. Use ASD batteries only as authorized by ASD. Using improper batteries or improper use of ASD batteries could result in bodily injury or damage to the instrument.

A fully charged battery's life depends on the battery age, instrument configuration, environment, and accessories powered by the accessory power port. The expected battery life is over four hours using a contact probe in an ambient environment.

NOTICE The instrument will stop collecting spectra when the battery drains to about 10 Volts, and the software displays a message that says it is unable to collect. However, the instrument and any attached accessory will continue to draw current if power is left on. Turn off the instrument and remove all accessories as soon as possible when the above message displays.

For the complete battery specifications, see "A.3 Battery Specifications" on page 47.

The battery charger is designed for indoor use and should not come in contact with water or dust.

NOTICE Do not unplug the charger and leave the battery in the charger. Remove the battery first, or the battery will discharge through the charger.

For the complete battery charger specifications, see "A.4 Battery Charger Specifications" on page 47. Refer to the charger instruction manual for usage details.

The backpack has two pouches on the hip belt, either of which can hold the battery. However, the battery should be on the opposite side from the fiber optic cable.

Charging the Battery

Charge a new NiMH battery fully before using it the first time, even if it shows full voltage and power. The battery pack reaches its peak performance after three to five charge-and-discharge cycles. A fully discharged battery takes about eight hours to charge.

After five to ten days from fully charging, the battery starts to lose its charge at the following rates:

- At normal room temperature—Loss of about 1% per day.

- At higher temperatures—Loss increases.
- At lower temperatures (40-60°F)—Loss decreases.

The more you use and charge NiMH batteries, the longer they last. Whether discharged or not, you should charge the NiMH battery at least every 60 days. New NiMH batteries can last from 500 to 1000 charges.

The LED Status indicator on the battery charger has the following states:

- Orange—Indicates one of the following:
  - The battery is not connected.
  - The charger is initializing and analyzing.
- Red—Indicates a fast charge.
- Green with intermittent orange—Indicates a top-off charge.
- Green—Indicates a trickle charge.
- Alternating orange/green—Indicates an error.

Power Status Icon

The software from ASD has a Power Status icon at the bottom of the main window next to the Connection Status. When you hold the mouse pointer over the icon, a pop-up window shows the voltage level of the instrument.

- 11-12 Volts is considered good (full).
- <11 Volts issues a warning.

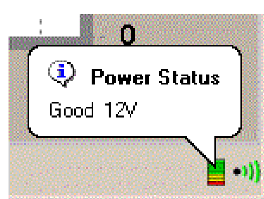


Figure 2.5: Example Power Status

2.4 Setting Up Ethernet or Wireless Communication

The instrument communicates with the instrument controller to collect spectra using standard protocols for computer networks.

By default, the instrument and instrument controller (if purchased from ASD) are set up to work in the following configurations:

- Ethernet connection—Connect the instrument to the instrument controller with the Ethernet cable provided with the instrument.
  - The ASD software automatically finds and connects to the instrument using the instrument's default IP address (169.254.1.11).

- Wireless connection—The instrument and instrument controller communicate directly with each other using wireless communication.
  - This method does not require the availability of a wireless network in your location. The instrument and instrument controller communicate directly, similar to the Ethernet connection method, only without a cable.
  - The ASD software automatically finds and connects to the instrument using the instrument's default IP address (169.254.1.11).

If you did not purchase the instrument controller from ASD or have configured the instrument controller to connect to a network, you must change the instrument controller's network settings to connect to the instrument. See "Changing the Network Settings on the Instrument Controller" on page 40.

2.5 Understanding the Fiber Optic Cable

ASD offers a variety of fiber optic cable lengths to use with the instrument. A single cable, without any interruption in the fiber optic connections, allows for accurate measurement of radiance and irradiance in absolute units, and ensures the highest level of signal throughput.

The fiber optic cable is made up of fifty-seven (57) randomly distributed glass fibers:

- Nineteen 100-micron fibers for the VNIR region.
- Nineteen 200-micron fibers for the SWIR 1 region.
- Nineteen 200-micron fibers for the SWIR 2 region.

Each broken fiber results in a response loss of approximately 5% in the associated region.

Handling the Fiber Optic Cable

The fibers of the fiber optic cable are well protected inside the cable, but the fibers can be damaged through rough usage. You should periodically inspect the fibers for breakage by following the procedures in "Checking the Fiber Optic Cable for Broken Fibers" on page 14.

NOTICE The fiber optic cable should never be stored with a bend of less than a 5" diameter for long periods of time.

If left in a tight coil for longer than a week, the fibers may develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal.

Store the fiber optic cable in the netting compartment on the instrument or on the fiber optic spool.

Follow these tips for handling the fiber optic cable:

- Do not pull or hang the instrument by the fiber optic cable.
- Avoid whipping the fiber optic cable, dropping it, or slamming it into objects, as this can cause fractures to the glass fibers.
- Avoid twisting the fiber optic cable, such forces may cause fractures to the fibers.

While the tip of the fiber optic cable is not particularly susceptible to damage, we recommend using the tip cover to protect against abrasion and exposure to contamination. You can make a replacement cover using eighth-inch shrink tubing cut 1.5" and shrinking it onto the fiber cable tip. The tubing will slide on and off the cable easily.

Checking the Fiber Optic Cable for Broken Fibers

In the rare instance that a fiber is broken, you will see a loss in response. Fiber Check is a utility that lets you inspect the fiber optic cable for broken fibers.

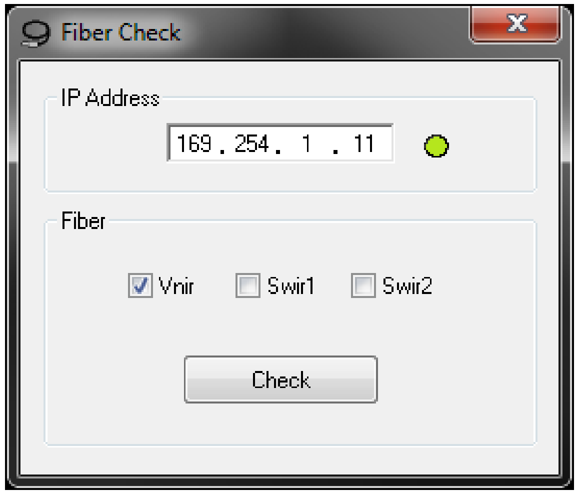
NOTICE The Fiber Check utility produces rapid flashing lights in the SWIR 1 and 2 regions' optical fibers. If you are susceptible to epileptic seizures, exercise caution or avoid using the Fiber Check utility.

You can use the instrument with a few broken fibers in each region, but the signal strength is reduced. You should replace the fiber optic cable if the number of broken fibers causes the signal-to-noise ratio to drop below an acceptable level.

To check the fiber optic cable for broken fibers:

1. Remove any fore optic accessories from the instrument's fiber optic cable.
2. Attach the fiber inspection scope/magnifier to the end of the fiber optic cable.

3. On the instrument controller, exit any ASD software that might be running and communicating with the unit.
4. Ensure that the instrument is turned on.
5. Start the Fiber Check software from the **Start** menu under **All Programs > ASD Programs > RS^3 Tools > Fiber Check**.



6. Verify the IP address for the instrument.
   - If you are directly connected to the instrument with an Ethernet cable or a wireless connection, the default IP address is 169.254.1.11.
7. Select the LEDs to turn on: VNIR, SWIR 1, or SWIR 2.
8. Click **Check** to turn on the selected LEDs.
9. Look through the magnifier to see which fibers illuminate.
   - Count the number of fibers that light. Refer to "Understanding the Fiber Optic Cable" on page 13.
   - If applicable, change the LED options and click **Check** to turn on and off different LEDs to help determine which range might be affected. It is best to check only one region at a time.
   - The white LED for VNIR may be hard to see when the other ranges are enabled.
10. When you are finished, shut down the Fiber Check software.
11. Carefully remove the magnifier.

2.6 Options for Collecting Spectra

You can use various accessories to aid in collecting spectra, depending on your needs. Some accessories come standard with the instrument, and some require a separate purchase. You can use the remote trigger with any of the collection methods. For information about the remote trigger, see "Using the Remote Trigger" on page 17.

You can collect spectra the following ways:

- Without any attachment—Use the fiber optic cable on its own, without any accessory attached to it, using ambient light.
- Pistol grip—Provides a convenient way to hold and aim the fiber optic cable to collect spectra using ambient light. For more information, see "Using the Pistol Grip" on page 16.
- Accessory light sources—Provide artificial light for sample illumination. For more information, see "Using Accessory Light Sources" on page 16.

- Fore optics—Narrow the field of view for collecting spectra. For more information, see "Using Fore Optics" on page 17.
- Remote trigger—Provides a way to start spectra collection without using the keyboard on the instrument controller. For more information, see "Using the Remote Trigger" on page 17.

Using the Pistol Grip

The pistol grip is a convenient way to hold and aim the fiber optic cable. The pistol grip comes standard with the instrument and does not affect the fiber optic cable's 25° field of view.

To use the pistol grip:

1. Insert the fiber optic cable through the strain relief spring

2. Insert the fiber optic cable all the way through the pistol grip until it clicks.
   - Make sure that the fiber optic cable tip is fully seated into the nose of the pistol grip.
3. If needed, gently tighten the set screw on the top of the pistol grip with a 1/8" flat blade screwdriver.
   - Tighten the set screw just enough to hold the fiber optic cable in place.

NOTICE Do not pull hard on the cable after tightening the set screw. Pulling hard on the cable could potentially break the cable fibers. Loosen the set screw to remove the fiber optic cable from the pistol grip.

NOTICE Do not adjust the factory set screw.

Using Accessory Light Sources

If needed for your application, you can use an accessory light source, such as the contact probe or other ASD-approved accessory, with your instrument.

Use the accessory power port on the front of the instrument to connect accessories to power.

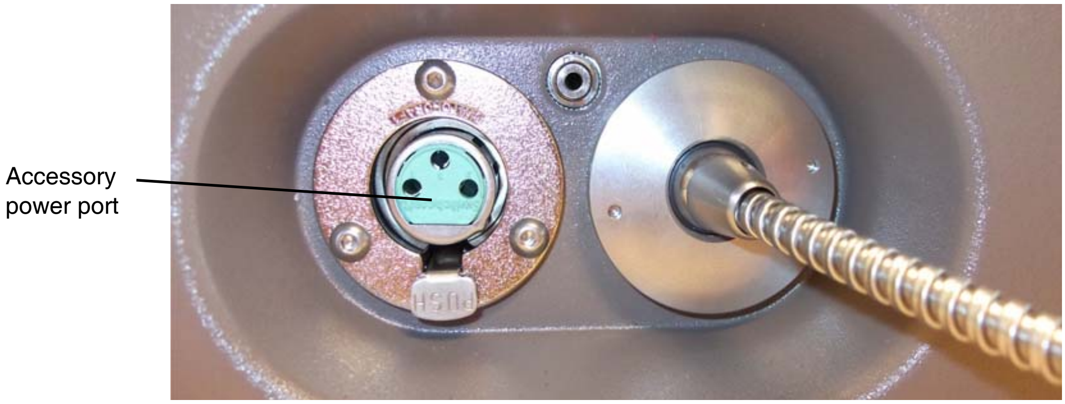


Figure 2.6: Accessory power port

Contact ASD or refer to the manual for the accessory for more information.

Using Fore Optics

ASD offers a wide selection of fore optic accessories to meet a variety of application needs, including:

- Lenses that decrease the field of view from the fiber optic's 25° field of view to as little as 1°
- Radiometric calibration for radiance ($W/m^2/sr/nm$) measurements
- Diffuse transmission and reflective-type cosine receptors and radiometric calibrations for measuring full sky irradiance ($W/m^2/nm$)

For more information about field of view, see "Understanding the Field of View" on page 17. For more information about fore optic accessories, contact ASD.

Understanding the Field of View

The field of view determines the size of the data collection area. Using just the bare fiber optic cable or the pistol grip accessory, the field of view is 25°.

As a general rule when using the bare fiber, the diameter of the field of view is equal to half the distance the fiber optic cable is from the sample. For example, if the cable is four feet from the sample, the field of view is about two feet wide.

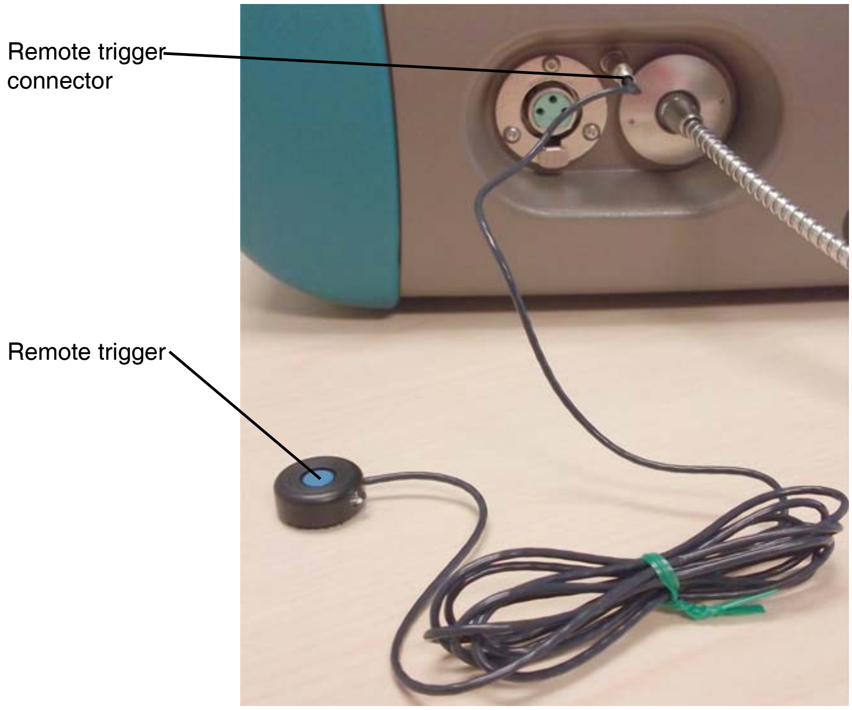
When collecting data, be sure that the sample or reference panel is the only object within the field of view.

Using the Remote Trigger

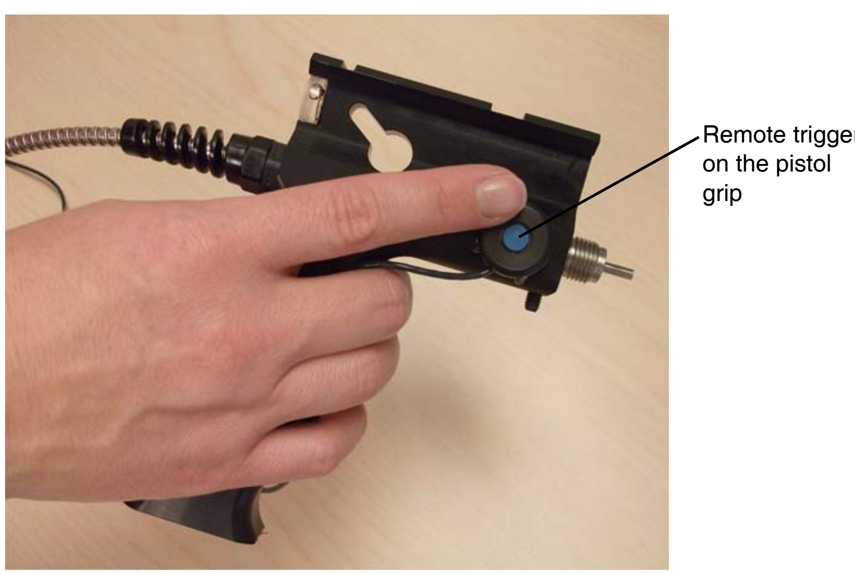
A remote trigger comes with the instrument to let you save spectra without pressing the space bar on the instrument controller (the normal method of saving spectra). This is convenient when you have both hands holding the sample and the fiber optic cable. You can attach the remote trigger to the pistol grip and save spectra by pressing the button on the trigger.

To use the remote trigger:

1. Attach the remote trigger cable to the instrument.



2. Use the hook and loop fasteners that come with the remote trigger to attach it to the pistol grip.
    - Place a piece of hook fastener on the back side of the remote trigger button.
    - Place a piece of loop fastener on each side of the accessories, such as the pistol grip, so you can use the trigger with either hand, if necessary.



3. When collecting spectra, press the trigger button to collect spectra, instead of pressing the space bar on the instrument controller.
    - The LEDs on the trigger are bright enough to be seen even on a sunny day. The LEDs light when the trigger is pushed (briefly) and turn off when the capture is complete.

2.7 Shipping and Carrying the Instrument

The following sections describe how to ship and carry the instrument:

- "Shipping the Instrument" on page 19
- "Carrying the Instrument in the Field" on page 19
- "Using the Laptop Carrier (Belly Board)" on page 20
- "Setting Up the Laptop Carrier for First Use" on page 20
- "Using the Backpack" on page 22
- "Adjusting the Backpack Straps to Fit" on page 26
- "Carrying Accessories and Supplies" on page 30
- "Protecting the Instrument from Bad Weather" on page 30

Shipping the Instrument

The instrument ships in a hard-shell container that you should use whenever you ship the instrument to different locations. Pack the instrument and its accessories as shown in Figure 1.3 on page 4. Store the fiber optic cable in the netting on top of the instrument, not in the fiber optic spool.

Use the soft-sided case only for nonbreakable items such as the backpack and laptop carrier.

Carrying the Instrument in the Field

The instrument comes with a laptop carrier and backpack that let you carry all of the equipment you need to collect spectra in the field.

To use the instrument in this way, you must complete the following tasks:

1. Set up the laptop carrier.
    - You only need to do this the first time you use the laptop carrier. See "Using the Laptop Carrier (Belly Board)" on page 20.
2. Set up the instrument in the backpack.
    - See "Using the Backpack" on page 22.
3. Adjust the backpack straps.
    - See "Adjusting the Backpack Straps to Fit" on page 26.
4. (Optional) Attach the pistol grip clip.
    - See "Attaching the Pistol Grip Clip" on page 27.

For additional information about using the backpack in the field, see:

- "Carrying Accessories and Supplies" on page 30
- "Protecting the Instrument from Bad Weather" on page 30

Using the Laptop Carrier (Belly Board)

The laptop carrier or belly board lets you carry the instrument controller in the field as you collect spectra. You can use it the following ways:

- With the neck strap—The laptop carrier can hold the instrument controller without the backpack when two people are operating the equipment.
- Without the neck strap—You can attach the laptop carrier directly to the shoulder straps of the backpack to let one person operate the instrument.

Setting Up the Laptop Carrier for First Use

If you are using an ASD-provided instrument controller, you do not need to set up the laptop carrier. The laptop carrier was factory adjusted to fit your instrument controller before shipment.

If you want to use an instrument controller that was not provided by ASD, you must adjust the brackets to firmly secure and center the instrument controller. You may need a 2 mm hex key, also known as an Allen wrench.

In addition, two rubber spacers are factory installed for use with standard ASD-provided instrument controllers to stabilize the instrument controller. If needed, two additional spacers are included with the carrier for your use.

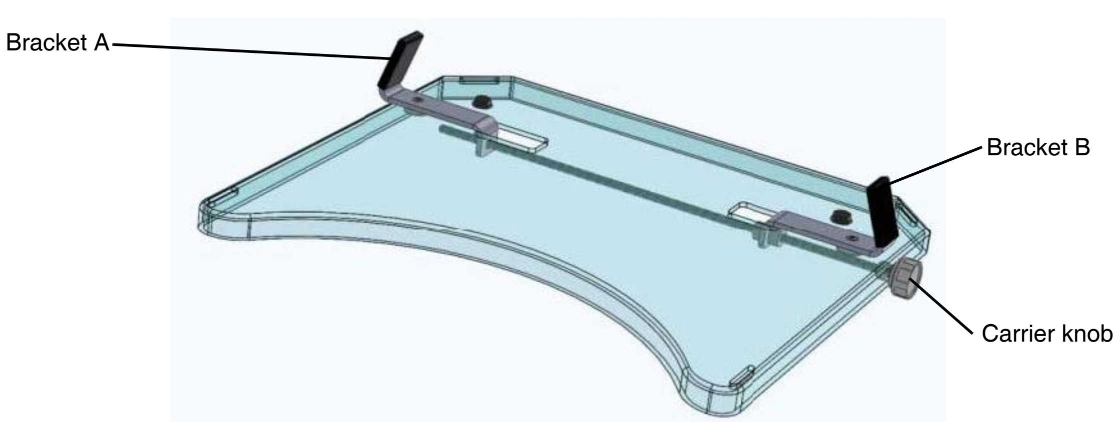
To secure and center instrument controller:

1. Remove the instrument controller from the backpack.

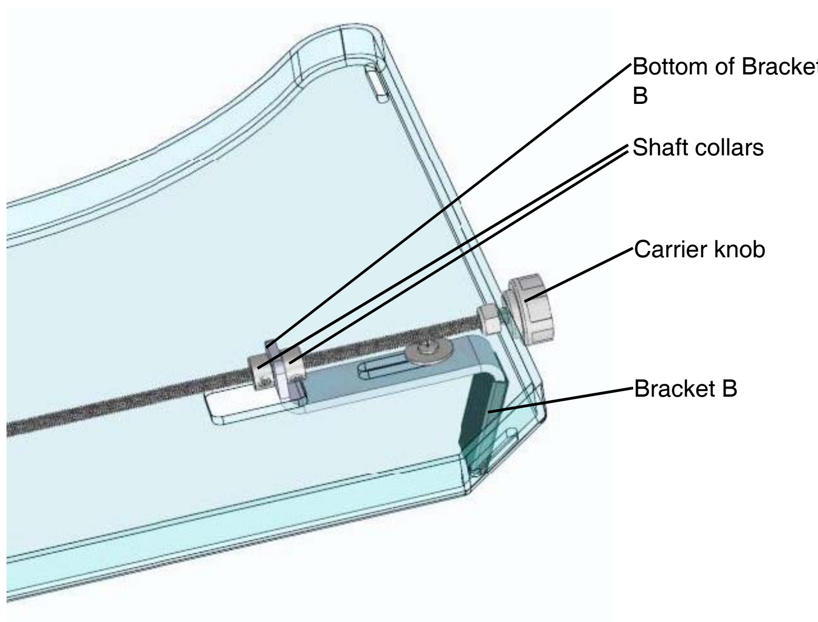
NOTICE Hold the instrument controller securely at all times.

---

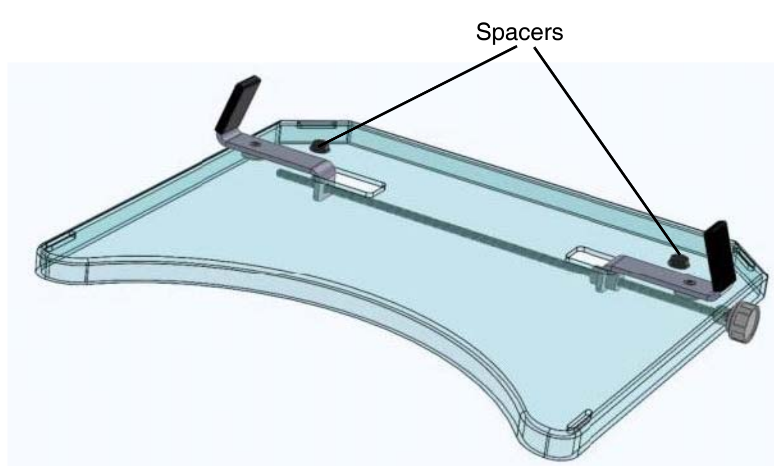
2. Open the instrument controller, position it on the carrier, and secure it in place by turning the carrier knob clockwise until the knob can no longer tighten.
   - The carrier knob makes minor adjustments to Bracket A.
   - If this secures and sufficiently centers the instrument controller on the laptop carrier, so that it does not move around, skip to step 9.
   - If the instrument controller does not fit properly between the brackets, continue with the next step to adjust the brackets.



3. Determine where Brackets A and B need to be to center the instrument controller on the laptop carrier.
4. Turn the carrier knob counterclockwise to move Bracket A to the position determined in step 3.
5. Remove the instrument controller and turn the laptop carrier upside down.
    - This lets you make major adjustments to Bracket B using the shaft collars.
6. Using a 2 mm hex key, loosen the set screw on each of the two shaft collars.



7. Slide Bracket B to the position determined in step 3, leaving a small gap between the shaft collars and the bottom of Bracket B.
    - This lets the shaft turn freely when you turn the carrier knob.
8. Using the 2 mm hex key, tighten the set screws to lock the collars in place.
9. Secure the open instrument controller on the laptop carrier using the carrier knob to adjust Bracket A.
10. Turn the laptop carrier upside down.
11. While looking through the clear plastic carrier, locate the instrument controller’s back support feet (located near the screen’s hinge) and mark the center points of those feet.



12. Remove the instrument controller and affix both rubber spacers to the marked points.
    - These help stabilize the instrument controller on the laptop carrier.

Attaching the Laptop Carrier to the Backpack

To attach the laptop carrier to the backpack:

1. Put on the backpack and fasten the belt and adjust the shoulder straps for comfort.
2. Detach the laptop carrier from the neck strap and attach it to the shoulder straps and the belt straps of the backpack.

3. Adjust the straps of the laptop carrier for comfort and location.

Using the Backpack

When arriving on site, unpack the instrument from the shipping case, and set up the instrument in the backpack before use.

You can use the instrument in the backpack with either hand. Determine which hand you want to use for collecting spectra with the fiber optic cable and which you need available to type on the keyboard and handle samples.

Aiming the fiber optic cable or accessory will probably require less dexterity than operating the instrument controller and typing. You may want to set up the instrument with the fiber optic cable on the side of your nondominant hand and keep your dominant hand free for other tasks, like one-handed typing.

To set up the instrument in the backpack:

1. Follow the instructions for unpacking the instrument from the shipping case.
    - See "1.4 Unpacking the Instrument" on page 4.
2. Place the backpack on a flat surface with the shoulder straps down.

3. Determine which hand you want to use for the fiber optic cable.
4. Orient the instrument in the backpack with the fiber optic cable on that side.
    - The only requirement for orienting the instrument is that the plastic end-caps must be at the top and bottom of the backpack.
5. Close the five strap connectors to secure the instrument in the backpack.

6. If you are using the fiber optic spool, feed the fiber optic cable into the spool.
7. If you are using the fiber optic spool, attach it to the backpack one of the following ways:

- With the hook and loop material to the back of the backpack. If needed you can run the fiber optic cable through the loop on one of the battery pouches. The hip belt of the backpack has a battery pouch on each side.

- With snaps to a battery pouch. Use the pouch on the opposite side from where the battery is.

Fiber optic spool snaps onto the battery pouch on the belt of the backpack.

- If the fiber optic cable is short, it can go directly from the instrument through the loop on the battery pouch.

8. Place the battery into the pouch on the opposite side of the backpack from where the fiber optic cable is.
9. Feed the battery cable from the battery pouch under the cross strap to the power port of the instrument.

10. Attach the laptop carrier to the plastic connectors on the shoulder straps of the backpack.

11. Place the instrument controller onto the laptop carrier, matching the strips of hook and loop material.
    - The laptop carrier is equipped with a pistol grip holder.

Adjusting the Backpack Straps to Fit

For better weight distribution and comfort, adjust the shoulder straps and yoke to your height while wearing the fully loaded backpack.

NOTICE The torso adjustment system is controlled by gravity. You must have the backpack on your back and fully loaded for the adjustments to work properly.

To shorten the torso adjustment:

- Pull the strap on left of backpack (as shown) until the yoke and shoulder straps raise up to the desired position, and the weight is comfortably distributed.

To lengthen torso adjustment:

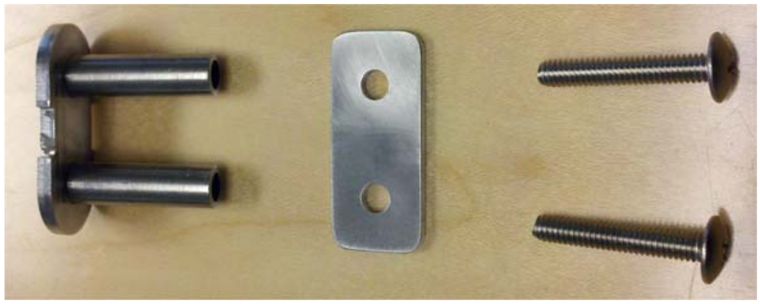
- Push up on the plastic speed grip clamp on the left of the backpack to release the strap, lower pack, and lengthen straps, as shown.

Attaching the Pistol Grip Clip

If you want to attach the pistol grip to the backpack, you must assemble and attach the pistol grip clip. The clip lets you securely attach the pistol grip to the backpack strap.

The pistol grip clip has two components that you must assemble before use:

- Pistol grip link that screws onto the pistol grip.



Link Plate Screws

Figure 2.7: Pistol grip link

- Pistol grip latch housing that clamps onto the backpack.

Bottom part Top part

Figure 2.8: Pistol grip housing

Required tools:

- Phillips screwdriver

To prepare the pistol grip:

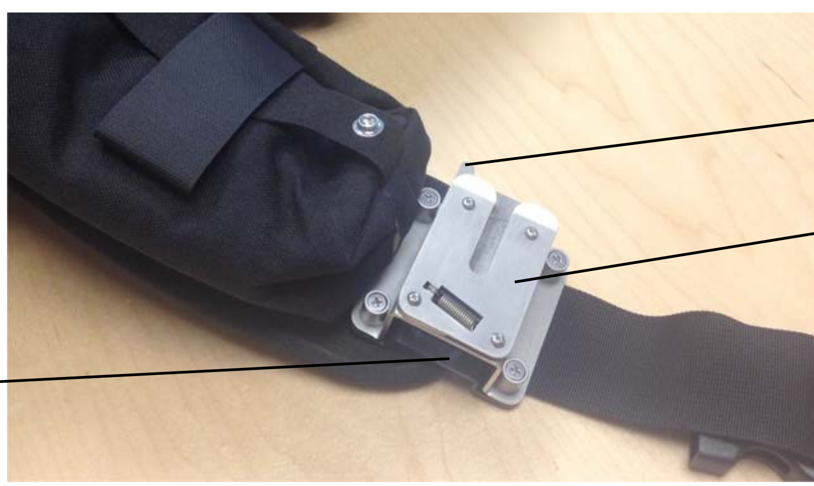
1. Determine which hand you want to use for the pistol grip.
2. Remove the screws from the pistol grip link and separate the plate and the link.

3. Attach the pistol grip link to the pistol grip based on the hand you want to use, as shown.
    - Make sure the plate is seated flat against the side of the pistol grip.

Placement for left hand use

Placement for right hand use

4. Locate the waist strap on the side where you want the pistol grip.
5. Loosen the four screws on the pistol grip clip housing and remove the bottom part.
6. Place the bottom part of the pistol grip clip housing under the strap and the top part on top of the strap.
    - Make sure the top part of the housing will be on the outside when you put on the backpack.



7. Tighten all four screws, but leave them loose enough to slide the housing on the strap.
8. Put on the backpack and slide the housing where you want it.
9. Tighten all four screws.

10. Slide the pistol grip link into the housing until it clicks to keep the pistol grip securely attached.

- To remove the pistol grip, use the latch release and pull the pistol grip up.

Carrying Accessories and Supplies

The backpack is designed specifically for the instrument. The large mesh pocket at the bottom of the pack provides ventilation to keep the instrument from overheating.

NOTICE Do not block the lower mesh pocket with clothing or other supplies.

Protecting the Instrument from Bad Weather

The backpack has a small interior pocket near its top that holds a rain flap, as shown in Figure 2.9. The rain flap is water resistant, but not waterproof.

NOTICE Do not use the instrument with the rain flap deployed. The instrument may overheat, because the rain flap prevents adequate air circulation.

In bad weather, place the instrument controller into its compartment on the outside of the backpack. Turn off both the instrument and instrument controller. Then pull the rain flap out of its compartment and over the outside of the pack.

Figure 2.9: Rain flap

2.8 Setting Up GPS

If you want to include location data when you collect spectra, you must use a GPS device and configure it to work with your instrument controller. If you purchased the instrument controller and GPS device from ASD, you should not have to configure anything. You can begin using the GPS device as you collect spectra with no additional configuration. See "Using a GPS Device While Collecting Spectra" on page 36.

If you purchased your GPS device or instrument controller from a third party, you must configure both to use GPS while collecting spectra.

GPS devices communicate with a computer in different ways, depending on the GPS device's and the computer's available connections. Table 2.2 lists each combination of connection and includes the applicable setup steps.

Table 2.2: GPS device and instrument controller connection options and setup

GPS device connection	Instrument controller connection	Additional hardware or software	Setup required
Serial	Serial	None	1. Configure the GPS device to output NMEA data. • See "Configuring the GPS Device" on page 33. 2. Configure the COM port on the instrument controller. • See "Configuring the Instrument Controller COM Port" on page 35. 3. Configure the COM port in RS^3. • See "Configuring the RS^3 Software for GPS Use" on page 35.
Serial	USB	USB-to-serial converter (hardware and software)	1. Configure the GPS device to output NMEA data. • See "Configuring the GPS Device" on page 33. 2. Install the USB-to-serial converter. • See "Setting Up a USB-to-Serial Converter" on page 33. 3. Configure the COM port on the instrument controller. • See "Configuring the Instrument Controller COM Port" on page 35. 4. Set the COM port in RS^3. • See "Configuring the RS^3 Software for GPS Use" on page 35.
USB	USB	GPSGate Client software (free)	1. Configure the GPS device to output NMEA data. • See "Configuring the GPS Device" on page 33. 2. Install and configure the GPSGate Client software. • See "Install and Configure the GPSGate Client Software" on page 33. 3. Configure the COM port on the instrument controller. • See "Configuring the Instrument Controller COM Port" on page 35. 4. Set the COM port in RS^3. • See "Configuring the RS^3 Software for GPS Use" on page 35.
Bluetooth	Bluetooth	None	1. Configure the Bluetooth connection. • "Configuring a Bluetooth Connection" on page 34. 2. Configure the COM port on the instrument controller. • See "Configuring the Instrument Controller COM Port" on page 35. 3. Set the COM port in RS^3. • See "Configuring the RS^3 Software for GPS Use" on page 35.

Configuring the GPS Device

If you purchased your GPS device from ASD, it should already be configured properly.

If you purchased your GPS device from a third party, you must configure the GPS device output format, based on the type of connection you are using:

- Serial or USB-to-serial connection—Configure the GPS device to output National Marine Electronics Association (NMEA) 018 GGA text.
- USB connection
  - Garmin® devices—Configure to use the GPSGate Client Interface option.
  - Other GPS devices—Configure to use the NMEA format, but it may require additional configuration to communicate with RS^3.
- Bluetooth connection—No configuration needed. Bluetooth GPS devices automatically output in NMEA format.

Consult the documentation for your device for how to configure it for the output needed.

Setting Up a USB-to-Serial Converter

If you purchased your GPS device and instrument controller from ASD, they should already be configured properly.

If you purchased your instrument controller or GPS device from a third party and your GPS device outputs serial data and your computer does not have a serial connection, you must purchase a USB-to-serial converter. The NMEA format sends data in a serial format. Most computers no longer have serial connections, but a USB-to-serial converter lets you use a USB connection with a serial GPS device.

To set up a USB-to-serial converter:

1. Install the software that came with USB-to-serial converter.
2. Connect the USB-to-serial cable to the USB port on the instrument controller and to the GPS device.
   - Be sure to select a USB connection on the instrument controller that you normally want to use for the GPS device. The configuration is specific to this port. To use a different port, you must repeat the port configuration.

Continue the GPS setup process with "Configuring the Instrument Controller COM Port" on page 35.

Install and Configure the GPSGate Client Software

If you purchased your GPS device and instrument controller from ASD, they should already be configured properly.

If you purchased your instrument controller or GPS device from a third party and your GPS devices uses a USB connection to your instrument controller, you must install the GPSGate Client software. This software "translates" the NMEA serial data from the GPS device to communicate through the USB port.

To install and configure the GPSGate Client software:

1. Download and install GPSGate Client.
    - The software is available from: http://gpsgate.com/download.
    - Use a second computer to download the GPSGate Client, so the instrument controller IP settings are not changed.
2. Turn on the GPS device.
3. Start the GPSGate Client software and start the setup wizard.
4. Accept the defaults on the first screen and click **Next**.
    - The wizard should find the GPS device and list it by name.
5. In the Select Output window of the wizard, deselect the option related to nRoute/MapSource and click **Next**.
6. Note the numbers of the COM ports listed in the Summary window and click **Finish**.
    - The GPSGate icon displays in the system tray (lower-right corner of your screen) and is one of the following colors:
        - Green—GPSGate detects a valid GPS position.
        - Yellow—GPSGate detects valid GPS data, but the GPS data has no fix, that is, it cannot determine its position.
        - Red—GPSGate does not detect valid GPS data.

Continue the GPS setup process with "Configuring the Instrument Controller COM Port" on page 35.

Configuring a Bluetooth Connection

If you purchased your instrument controller or GPS device from a third party and your GPS device uses Bluetooth, you must set up the Bluetooth connection.

To configure a Bluetooth connection:

1. Turn on the GPS device and make sure it is discoverable.
    - Refer to the documentation for the GPS device.
2. Enable Bluetooth on your instrument controller.
    - How you do this varies by computer/Bluetooth combination.
    - On a Lenovo™ laptop, press and hold **Fn** and press **F5**, then click **Power On** next to Bluetooth Radio. This puts a Bluetooth icon in your system tray (lower-right corner of your screen.)
3. On the instrument controller, display the Add a Device window.
    - How you do this varies by computer/Bluetooth combination. The following should work on Windows 7 computers: Select **Start > Devices and Printers**, then click **Add a Device**.
    - On a Lenovo laptop, click the Bluetooth icon in the system tray and select **Add a Device**.
4. Select your GPS device and click **Next**.

5. Enter the device's pairing code and click **Next**.
   - Refer to the documentation for the GPS device.
   - A message tells you that the device was added successfully.
6. Click **Finish**.

Continue the GPS setup process with "Configuring the Instrument Controller COM Port" on page 35.

Configuring the Instrument Controller COM Port

If you purchased your GPS device and instrument controller from ASD, they should already be configured properly.

If you are setting up an instrument controller purchased from a third party, you must configure the COM port for the GPS device.

If your GPS device is not communicating with the RS^3 software, check the COM port as described below.

To configure the instrument controller COM port:

1. With the instrument controller turned on, connect to your GPS device.
   - For USB connections, be sure to select a USB port on the instrument controller that you normally want to use for the GPS device. The configuration is specific to this port. To use a different port, you must repeat the port configuration.
2. Turn on the GPS device.
3. From the instrument controller, select **Start > Control Panel**.
4. Click **Hardware and Sound**.
5. Click **Device Manager**.
6. Double-click **Ports (COM & LPT)**.
7. Select the port you want.
   - If you are using a USB-to-serial cable, select the port that says something similar to: USB-to-Serial COMM Port (COMx).
   - If you are using Bluetooth, select one of the Bluetooth ports.
8. Verify that the port number is between 1 and 9.
   - The port number is in parentheses. For example, it may show (COM4). If the number is higher than 9, you must change the port number. The RS^3 software only supports port numbers between 1 and 9.
9. If you need to change the port number, right-click the port, select **Properties**, click the **Port Settings** tab, click **Advanced**, select a new number from the COM Port Number drop-down list, and click **OK**.
   - Select a number that is not in use.

Continue the GPS setup process with "Configuring the RS^3 Software for GPS Use" on page 35.

Configuring the RS^3 Software for GPS Use

If you purchased your GPS device and instrument controller from ASD, they should already be configured properly.

If you purchased your instrument controller from a third party, you must set up the RS^3 software to communicate with the correct port.

If you are not seeing GPS data in the RS^3 software, make sure the COM port number in the software matches the COM port set up in Device Manager. See "Configuring the Instrument Controller COM Port" on page 35.

The default COM port settings usually work, but if you require unique GPS settings, look in the documentation for your GPS device for the following information:

- Baud rate
- Data bits
- Parity
- Stop bits

To configure RS^3 software for GPS use:

1. Start the RS^3 software.
2. Select **GPS > Settings**.
3. From the Port drop-down list, select the COM port number that corresponds to the port you found or set up in the Device Manager.
    - See "Configuring the Instrument Controller COM Port" on page 35.
4. Based on the information for your GPS device, change the other settings in the GPS Settings window to match the device.
5. Click **OK**.
6. Select **GPS > Enabled**.
    - Be sure you see a check mark next to Enabled. This turns on the GPS function in the software.
    - Your GPS device and instrument controller are now ready for use. See "Using a GPS Device While Collecting Spectra" on page 36.

Using a GPS Device While Collecting Spectra

If you purchased the GPS device and instrument controller from ASD or if you have already completed the GPS setup, you can now use the GPS device while you collect spectra.

Be sure that you have a clear view of the sky to let the GPS device lock on to at least three satellites.

To use the GPS device:

1. Connect the instrument controller and GPS device.
2. Turn on the instrument controller.
3. Turn on the GPS device.
4. From the instrument controller, start the RS^3 software.
5. Select **GPS > Enabled**.
    - Be sure you see a check mark next to Enabled. This turns on the GPS function in the software.

6. See if the lock icon on bottom-left corner looks locked and if the Latitude, Longitude, and Altitude information displays across the bottom of the window.
   - You may need to wait a brief period for the GPS device to lock on to three satellites for the data to display. Refer to the GPS device documentation for how long this may take.
   - If you do not see the GPS data, see Table 2.2 on page 32 and refer to the GPS device documentation. If the GPS device is showing location data, check that the device is set to output NMEA format. See "Configuring the GPS Device" on page 33 and check the device documentation.

2.9 Maintaining the Instrument

The following topics describe how to maintain the instrument and white references:

Cleaning the Fiber Optic Tip

You can clean the fiber optic tip if it has dirt or debris on it.

To clean the fiber optic tip:

- Use a soft cloth and isopropyl alcohol to clean off the tip.

Maintaining White Reference Panels

Although the reference panel is very durable, take care to prevent contaminants such as finger oils from contacting the reference panel's surface. Always handle the reference panel by the edges of the panel.

To clean a lightly soiled white reference panel

- If the reference panel is lightly soiled, clean it with a jet of clean dry air or nitrogen.

NOTICE Do not use any freon or compressed gas with freon propellant to clean or dry a white reference panel. Freon will damage the white reference panel surface.

To clean a heavily soiled white reference panel:

1. Use a flat surface, such as a thick, flat piece of glass.
2. Place the glass into the sink.
3. Place 220 grade wet sandpaper onto the glass.
4. Gently move the white reference panel in a figure-eight motion on the sandpaper, using water as needed to wash away the thin layer that is sanded off.
5. Blow dry with clean air or nitrogen or allow the reference panel to air dry.
6. If the reference panel requires high resistance to deep UV radiation, do one of the following:
   - Flush the reference panel with >18 milli-ohm distilled, de-ionized water for 24 hours.
   - Vacuum bake the reference panel at 75° C for a 12-hour period at a vacuum of 1 Torr or less. Then purge the vacuum oven with clean dry air or nitrogen.

Annual Maintenance

ASD recommends that the instrument be serviced once a year. This will ensure the proper functioning of the instrument. Annual maintenance is covered for the first year under the ASD warranty. Extended warranties also cover annual maintenance, or you can purchase additional years of maintenance at the time of service. To purchase annual maintenance or an extended warranty, contact your sales representative.

Returning the Instrument for Service

To return the instrument to ASD for maintenance or repair, contact ASD technical support for a Return Merchandise Authorization (RMA). The RMA includes scheduling details, contact information, shipping instructions, and a brief description of the maintenance or repair requirements. For contact information, see "Technical Support" on page 2.

Chapter 3: Troubleshooting

The following sections will help you troubleshoot the instrument:

3.1 Common Communication Fixes

To fix many communication errors (particularly if the instrument has been functioning at some point), below are steps to try:

1. If you did not purchase the instrument controller from ASD or have configured the instrument controller to connect to a network, you must change the instrument controller's network settings to connect to the instrument.
    - See "Changing the Network Settings on the Instrument Controller" on page 40.
2. Power cycle the instrument and/or the instrument controller.
3. For a wireless connection, make sure you have a clear line of sight between the instrument and instrument controller.
    - Obstructions between the instrument and instrument controller or radio frequency interference in close proximity can cause loss of communication or significantly shorten the communication range.
    - The instrument uses industry-standard components. You should see the same general connection speed and distance capabilities as other wireless devices.
4. For a wireless connection, make sure the wireless function is turned on.
    - The instrument controller may have a switch on the side of the instrument controller that turns the wireless function on and off. Other controllers may use a software switch (typically located on the keyboard's Function keys) to control the wireless connection. Be sure the wireless function is turned on.

5. If you receive a 400 command error while starting the ASD software, you need to reload the instrument .ini file to the instrument.
   - Use the Instrument Configuration utility from ASD to do this. Contact technical support for assistance.

Changing the Network Settings on the Instrument Controller

If you did not purchase the instrument controller from ASD, you must confirm the instrument controller's network settings.

The default IP settings should be:

- Wireless—Obtain an IP address automatically
- Ethernet—Obtain an IP address automatically

You must also change the user account control settings to avoid communication errors.

To change the user account control settings:

1. Select **Start > Control Panel**.
2. Click **User Accounts**.
3. Click the **Change User Account Control settings** link (bottom of the list at the center).
4. Move the slider to "Never notify" (all of the way to the bottom).
5. Click **OK**.
6. In the upper-left corner, click the **Control Panel Home** link to return to the Control Panel.

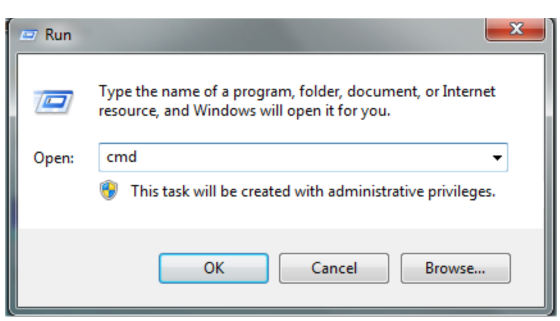
To change the network settings on the instrument controller:

1. Connect an Ethernet cable to the instrument controller's Ethernet port and to the back of the instrument.
2. From the Control Panel, click **Network and Internet**.
3. Click **Network and Sharing Center**.
4. On the left side, click the **Change adapter settings** link.
5. Right-click the Local Area Connection and select **Properties**.
6. Select Internet Protocol Version 4 (TCP/IPv4) and click **Properties**.
7. Select the "Obtain an IP address automatically" and "Obtain DNS server address automatically" options.
8. Click **OK** twice to return to the Network Connections window.
9. Right-click the Local Area Connection again and select **Properties**.
10. Click **Configure** in the upper-right side of the window.

11. Click the **Power Management** tab.
12. Deselect the “Allow the computer to turn off this device to save power” option.
13. Click **OK** to return to the Network Connections window.
14. Right-click the Wireless Network Connection and select **Properties**.
15. Select Internet Protocol Version 4 (TCP/IPv4) and click **Properties**.
16. Select the “Obtain an IP address automatically” and “Obtain DNS server address automatically” options.
17. Click **OK** twice to return to the Network Connections window.
18. Right-click the Wireless Network Connection again and select **Properties**.
19. Click **Configure** in the upper-right side of the window.
20. Click the **Power Management** tab.
21. Deselect the “Allow the computer to turn off this device to save power” option.
22. Click **OK** to return to the Network Connections window.
23. In the upper-left corner of the window’s title bar, click the back button twice to return to the Control Panel.

3.2 Instrument Controller Does Not Connect to the Instrument with the Ethernet Cable

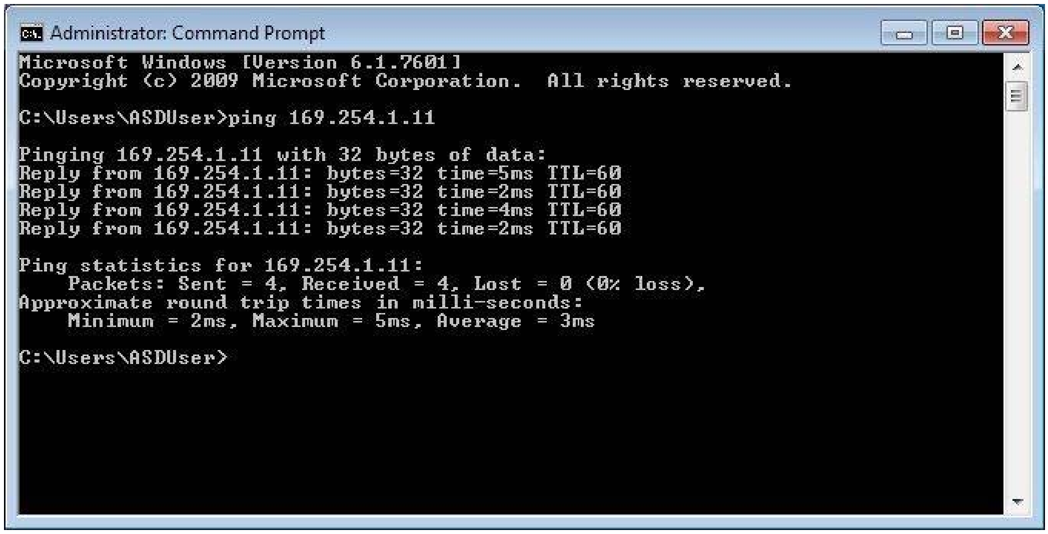
1. See the section: “3.1 Common Communication Fixes” on page 39.
2. Check that the Ethernet cable is securely connected to the instrument and instrument controller.
3. Check that the Ethernet LED near each connection is on.
4. Confirm that the IP address of the instrument is set to 169.254.1.11.
   - The default subnet mask is 255.255.0.0.
   - The instrument controller must be set to the "Obtain an IP address automatically" and "Obtain DNS server address automatically" options.
5. Do a ping test to make sure the instrument is responding.
   - Open up a command window by selecting **Start > Run**
   - Type **cmd** in the Run window.



   - Click **OK**.

- For an Ethernet connection, type: **ping 169.254.1.11**
- For a wireless connection, type: **ping 169.254.1.11**

Successful ping example

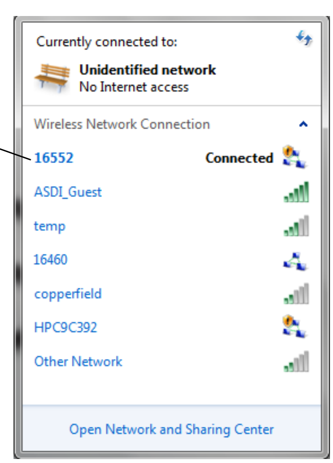


3.3 Instrument Controller Does Not Connect Wirelessly to the Instrument

1. See the section: "Common Communication Fixes" on page 39.
2. Disconnect the Ethernet cable from the instrument controller and instrument, then turn the instrument off and back on.
3. Connect the instrument controller to the instrument's wireless connection.
   - Click the wireless icon  in the lower-right corner of your screen.
     - If you do not see the icon, select **Start > Control Panel**, click **Network and Sharing Center**, click **Connect to a Network**.

List of available wireless connections.

The default connection for the instrument is the instrument's serial number.



4. Select the connection you want and click **Connect**.
   - If you are using encryption, make sure you are using the same WPA (security) key as set for the connection.
   - The instrument has a default WPA of: 0123456789
   - When first connecting to the instrument, the connection status may show, “Limited access.” After you start the ASD software, the status will change to, “Connected.”

3.4 Instrument Loses its Wireless Connection

1. See section “Common Communication Fixes” on page 39.
2. Try to minimize the radio frequency noise in your environment.
   - Radio frequency noise interference can come from: 2.4 GHz cordless phones, microwaves, monitors, electric motors, ceiling fan, lights, security systems, etc.
3. Minimize obstructions between the instrument and the instrument controller.
   - Positioning of the instrument and instrument controller can affect the wireless range. Walls, ceilings, doors, buildings, hills, etc. can degrade the signal.

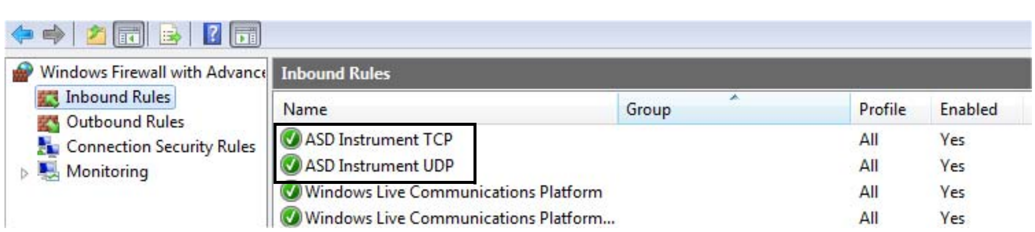
3.5 Windows Firewall Messages Display When You Try to Connect

The Windows firewall must be set to permit connections to specific ports on the instrument controller. Without these inbound and outbound rules for the ports, the firewall displays messages when you try to connect and when you try to configure the network settings using the ASD IP Setup software.

You may want to contact your network administrator about these settings.

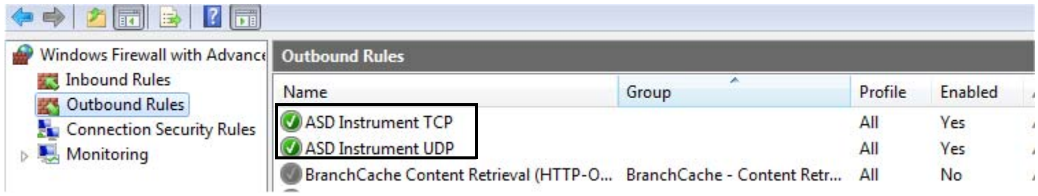
To troubleshoot the Windows firewall:

1. Select **Start > Control Panel**.
2. Click **System and Security**.
3. Click **Windows Firewall**.
4. Click **Advanced Settings**.
5. Click **Inbound Rules.**
6. Make sure you see the two ASD rules.



7. Click **Outbound Rules**.

8. Make sure you see the two ASD rules.



9. If the rules are there, but are not enabled, right-click each rule and select **Enable Rule**.
10. If these rules are not listed at all, you must add them using the following settings:
    - Inbound rule settings:
        - Port, TCP, port number 8080, allow the connection, select Domain, Private, and Public, and give it a name you will recognize.
        - Port, UDP, port number 20034, allow the connection, select Domain, Private, and Public, and give it a name you will recognize.
    - Outbound rule settings:
        - Port, TCP, port number 8080, allow the connection, select Domain, Private, and Public, and give it a name you will recognize.
        - Port, UDP, port number 20034, allow the connection, select Domain, Private, and Public, and give it a name you will recognize.

3.6 ASD Software Displays Saturation Error

The ASD software displays a saturation error and plays an audible error alarm when the instrument is overwhelmed with light (signal) and cannot discern the spectrum of the sample.

Saturation does not damage the instrument, but collection while in the saturation state will result in inaccurate data.

To resolve the software saturation error:

1. Click **Opt** to optimize the instrument in the RS^3 software.
    - The optimization is complete when the Spectrum Avg progress bar resumes.
2. Click **WR** to take a white reference.
3. Collect spectra from the sample.
4. If the saturation error continues, contact ASD technical support.
    - Depending on the specific situation, you may need an attenuator attachment, available from ASD, to resolve the error.

3.7 Instrument Needs Updated Firmware or .ini File

The Instrument Configuration utility from ASD can automatically perform the following functions:

- Update the instrument's firmware.
  - Use only when directed to do so by ASD support personnel.
- Update the instrument's .ini file.
  - Use only when directed to do so by ASD support personnel.

You can also do the following manually using the Configuration Utility:

- Update the instrument's firmware.
  - Use only when directed to do so by ASD support personnel.
- Update the instrument's .ini file.
  - Use only when directed to do so by ASD support personnel.

Appendix A: Specifications and Compliance

The following sections contain the specifications and WEEE compliance:

A.1 Physical Specifications

Below are the physical specifications of the instrument.

Height	12.7 cm	5 inches
Width	36.8 cm	14.5 inches
Depth	29.2 cm	11.5 inches
Weight	5.44 kg	12 lbs

- Enclosure is made of durable satin powder-coat finish with urethane end-caps and handles.
- All vital components are in a dust-proof enclosure and EMI sealed.
- Fiber optic inputs directly to the instrument.

A.2 Power Input and Output

Below are the power input and output.

AC power supply type	Auto ranging, Switching, SELV
AC input	90-240 VAC, 50/60 Hz
DC input	+12 VDC, 60 W
Accessory power port (front of instrument)	Output, +12 VDC, 27 W (max).

A.3 Battery Specifications

Below are the NiMH battery specifications.

Type	NiMH (Nickel-Metal Hydride)
Rating	12 V, 9 amp hour
Life	Over four hours using a contact probe in an ambient environment.
	Recycle batteries and do not dispose of as general waste.

* Battery life may be affected by high or low temperatures.

A.4 Battery Charger Specifications

Below are the battery charger specifications.

Type	External desktop
AC input	90-240 VAC, 50/60 Hz
Charge time	Under 8 hours for a fully discharged 9 AH battery

A.5 Environmental Specifications

Below are the environmental specifications.

Operating temperature	0 to 40°C
Operating and storage humidity	Non-condensing
Storage temperature	-15 to 45°C

A.6 Wavelength Configuration

Below is the wavelength configuration.

Wavelength name	Wavelength range
VNIR-SWIR 1-SWIR 2	350 - 2500 nm

The spectral resolution is:

- 3 nm @ 700 nm.
- 30 nm @ 1400 nm for the Wide-Res model, 10 nm for Standard-Res, 8 nm for High-Res, and 6 nm for Hi-Res NG.
- 30 nm @ 2100 nm for the Wide-Res model, 10 nm for Standard-Res, 8 nm for High-Res, and 6 nm for Hi-Res NG.

The sampling interval is:

- 1.4 nm for the spectral region 350-1000 nm.
- 2 nm for the spectral region 1001-2500 nm.

The spectrometer is configured to have three separate holographic diffraction gratings with three separate detectors. Each detector is also covered with the appropriate order separation filters to eliminate second and higher order light.

- VNIR: 512 element silicon photo-diode array for the spectral region 350 to 1000 nm.
- SWIR 1: graded index, TE-cooled, extended range, InGaAs, photo-diode for the spectral region 1001 nm to 1800 nm.
- SWIR 2: graded index, TE-cooled, extended range, InGaAs, photo-diode for the spectral region 1801 nm to 2500 nm.

A.7 Network Interface Requirements

The instrument has a 10/100 Base T Ethernet port. You can connect the instrument to the instrument controller using an Ethernet cable.

The instrument can also communicate with the instrument controller using the 802.11g/n wireless card. If you are not using the instrument controller that comes with the instrument, the instrument controller needs to be 802.11g/n compatible.

A.8 WEEE Compliance

Recycle. Items with this symbol indicate that the item should be recycled and not disposed of as general waste.

A.9 Certifications

- CE certified
- NIST traceable calibration
- 21 CFR, Part 11 (installed per customer request)
- USP 1119 (installed per customer request and purchase of applicable USP Standards)

Conforms to the following EU Directives:

- Safety: Low Voltage Directive, 2006/95/EC
- EMC: Electromagnetic Compatibility Directive, 2004/108/EC

The product complies with the requirements of the following Harmonized Product Standards and carries the CE-Marking accordingly:

- EN61010-1:2001 2nd Edition—Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use
- EN61326-1:2013 Basic—Class A, Electrical Equipment for Measurement, control and Laboratory use-EMC Requirements

Appendix B: FAQs

The following sections will help you with questions about the FieldSpec®4 instrument:

B.1 General

What Is a Spectrometer?

Spectrometer — An optical instrument that uses detectors, other than photographic film, to measure the distribution of radiation in a particular wavelength region. All ASD instruments are spectrometers. The SWIR component of the ASD spectrometer is a scanning spectrometer, while the VNIR component is an array spectrometer.

Spectroradiometer — An optical instrument for measuring the radiant energy (radiance or irradiance) from a source at each wavelength throughout the spectrum. A spectroradiometer is a special kind of spectrometer.

Spectrograph — An optical instrument for forming the spectrum of a light source and recording it on a film. The dispersing medium may be a prism or a diffraction grating. This term was common prior to the digital age. ASD instruments do not use film.

How Long Does It Take for the Instrument to Warm Up?

The warm-up time of the instrument depends on the environment in which it is used.

One hour is recommended for radiometric work.

Only 15 minutes is needed for reflectance measurements, especially if you need to conserve the battery life.

What Does a Broken Fiber Mean?

A few broken fibers are not critical when measuring reflectance, because reflectance is a relative measurement. However, if too many fibers are broken, the signal decreases too much and the spectra will be excessively noisy. How many broken fibers are too many depends on the application and the types of samples you are using the instrument with.

Radiance and irradiance are measured using the raw data and comparing to numbers that exist in the calibration file. Therefore, a few broken fibers will result in lower values.

The fibers are well protected by the cable casing. If there are kinks in your cable, the fibers are not necessarily damaged. However, if your cable has been severely damaged, chances are high that the fibers have been damaged, too. To determine if any fibers are broken, see “Checking the Fiber Optic Cable for Broken Fibers” on page 14.

The fibers can be damaged by coiling the cable up too tightly. If left in a tight coil for longer than a week, the fibers are likely to develop longitudinal fractures that will not be detectable. These fractures in the fiber will cause light leakage, resulting in a weaker signal. Store the fiber optic cables loosely in the netting compartment on the instrument.

NOTICE The fiber cable should never be stored with a bend of less than a 5" diameter for long periods of time.

How Long Is the Battery Life?

A fully charged NiMH battery’s life depends on the battery age, instrument configuration, environment, and accessories powered by the accessory power port. The expected battery life is over four hours using a contact probe in an ambient environment.

The limiting factor for how long you can work in the field may be the battery in the instrument controller rather than the instrument’s battery.

Where Is My Serial Number?

The serial number is a five-digit number located on a label on the back of the instrument where the power switch is, as shown in Figure B.1. The label also contains the model number and MAC address for the instrument.

The serial number is also accessible in the ASD software by selecting **Help > About**. When corresponding with ASD about any instrument questions, you should provide the instrument serial number.

Figure B.1: Label with serial number

B.2 Collecting Spectra

How Often Do I Need to Optimize?

Optimization is the process of setting the instrument's electronics to optimally process the incoming signal. This means that the digitalization of the light signal is within a range of values that provide good signal-to-noise performance and does not allow the instrument to saturate at the current light levels.

The instrument must be re-optimized if:

- Atmospheric conditions change.
- The light source changes.
- The instrument is in the process of warming up and the response changes substantially.
- The instrument is saturating.

Outdoor conditions can change rapidly or slowly. It all depends on clouds, wind (affecting temperature), instrument warm-up time, etc.

Use the white reference panel when optimizing and for taking a white reference measurement. The position of the reference panel when taking a white reference should be as similar as possible to the position for collecting data from the samples.

When saving reflectance data, point the fiber optic cable at the white panel once every few measurements for a minute or two with the same viewing geometry. If the relative reflectance of the white reference panel is less than or greater than one, a new white reference may be needed. If the relative reflectance of the white reference panel is greater than one, reoptimization is recommended.

The ASD software provides a saturation warning. We recommend leaving the volume on the instrument controller loud enough to hear the warning.

How Often Do I Need a Baseline or White Reference?

Inside Use or Using an Accessory Light Source

When using the instrument inside under constant lighting conditions or when using an accessory with its own light source, collect a white reference every 10 to 15 minutes while the instrument is warming up and every 30 minutes thereafter.

Outside Use

When using the instrument outside, you should collect a new white reference at least every ten minutes.

The more frequent the white references, the better the resulting reflectance spectra will be. You need more frequent white references outdoors because of changing illumination, atmospheric conditions, and temperatures.

The light intensity when collecting the white reference should be the same when collecting spectra of samples.

When outside, continue to take measurements of the white reference panel and observe the stability of the white reference line. This will give you an idea of how the current fluctuations in weather affect your measurements.

What Spectrum Average (or Sample Count) Should I Use?

The default averages are as follows:

- Spectrum—10
- Dark current—100
- White reference—25

When outside, these defaults may work well for you. In general, we suggest that the white reference be set to about double the spectrum and dark current averages.

The noise decreases at the square root of the number of scans used in the averaging.

The actual spectrum average will be a compromise between noise reduction through spectra averaging and the time required for each spectral collection. For example, if you are using the instrument to measure a large number of samples, you want a smaller number of spectra in the average to decrease the collection time required. If you are collecting a few spectra, you'll want to increase the number of spectra in the averaging to obtain the cleanest spectra possible. When building models, the number should stay constant regardless of the number of samples.

How Do I Collect a Reference with a Spot Size Larger Than the White Reference Panel?

Purchase a bigger reference panel or move the fiber optic cable closer to it.

If you are indoors using artificial light, make sure that the distance and angle from the reference panel is the same as for samples.

If you are outdoors and the sun is your light source, the reference panel can be closer to the fiber optic cable than the samples.

When Do I Use Absolute Reflectance?

It depends on how you are analyzing your data. An absolute reflectance most likely will not be needed when using an accessory with its own light source.

There are no negatives to using absolute reflectance. The difference between absolute and relative reflectance is small for wavelengths less than 2000 nm.

Because relative reflectance relies on a physical white reference, you will see deviations from the absolute wavelength ranges 350-400 nm and 2000-2500 nm.

How Do I Know the Field of View That I'm Using?

The field of view is labeled on the fore optic that you use. The bare fiber has a 25° field of view.

When you are measuring radiance, set the correct field of view in the RS^3 software using the fore optics drop-down list.

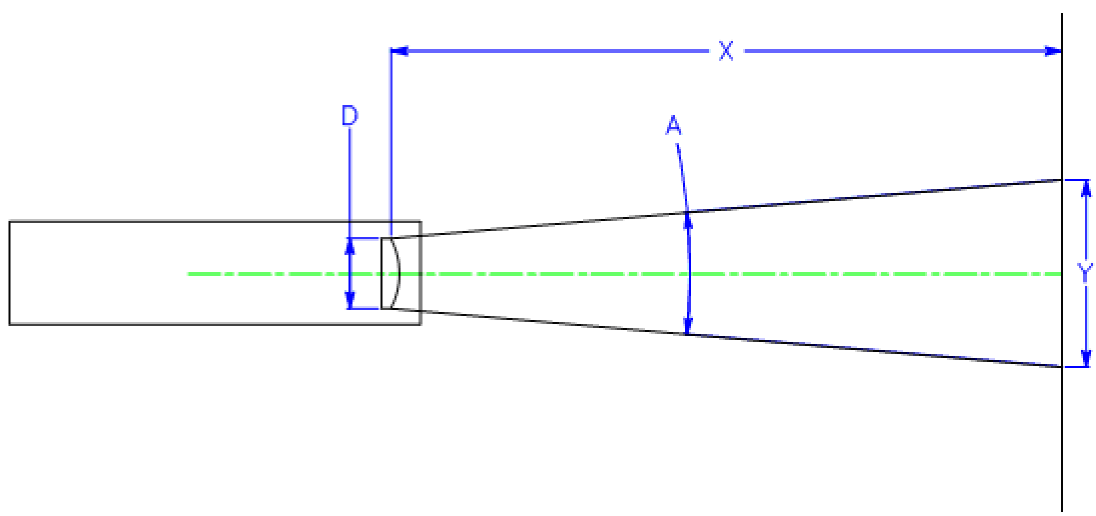


Figure B.2: Spot size diagram

D = effective diameter of fore optic lens

A = fore optic's angular field of view

X = distance to viewed surface

Y = diameter of field-of-view

Near field (less than 1 meter):

Y = D + 2 * X * Tan(A/2)

Far field (greater than 1 meter):

Y = 2 * X * Tan(A/2)

What Are the Units of Radiance?

Radiance is measured in Watts per square meter per steradian ($W/m^2/sr$).

However, the instrument measures spectral radiance, which is the amount of radiance per unit wavelength. Spectral radiance is measured in Watts per square meter per steradian per nanometer ($W/m^2/sr/nm$).

Reflectance and transmission measurements are ratios of the optical energy from a sample compared to the optical energy from a reference panel. The units cancel out, so these measurements do not use the calibration files to calculate radiance.

The instrument measures irradiance in Watts per square meter per nanometer ($W/m^2/nm$).

B.3 Working with Data

Can I Post-process My Data?

Yes. The ViewSpec Pro software is one of many programs that can post-process your data. You can import the spectral data into many different programs or export to ASCII text files for incorporation into other applications.

The complete specification of the ASD file format is available upon request.

Why Do I See Oscillations (Sine Wave) in My Data?

Your light source may use AC power. A single SWIR scan is about 100 ms. If you observe five or six waves in a single SWIR detector, the AC light source is the cause.

Waves can also occur if the lamp reflector and/or cover glass behave as a white-light interferometer. Solution: remove the glass and/or use a more diffuse reflector.

What Are These Two Large Noise Bands in My Data?

Water vapor in the atmosphere absorbs light in the 1400 nm and 1800 nm bands. This results in little to no signal at these wavelengths. When the reference and target spectra are ratioed to create reflectance measurements, very small, randomly fluctuating numbers (that is, noise) create large fluctuations in the spectra.

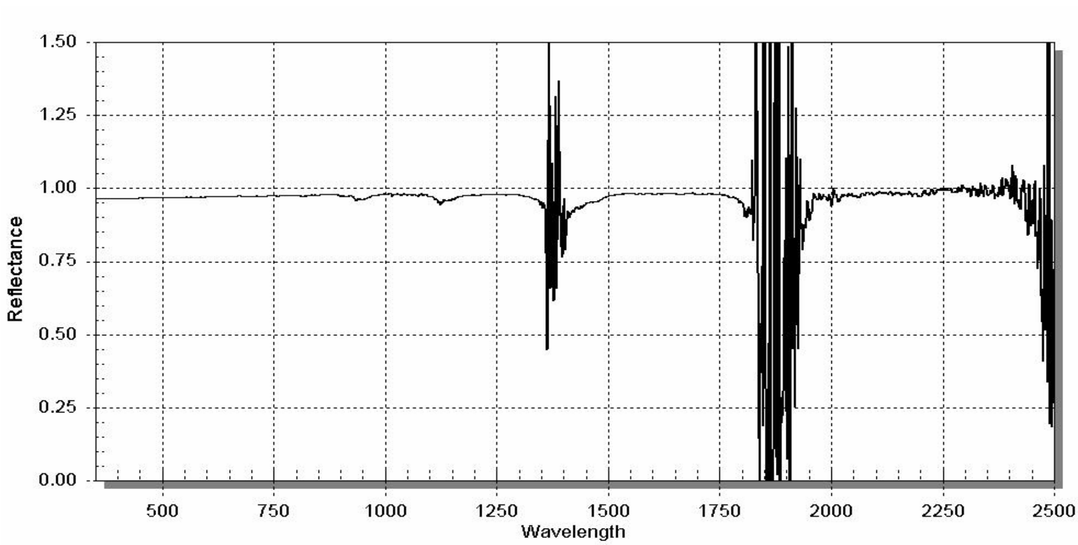


Figure B.3: Examples of water vapor absorbing light

Information on other causes of absorption bands is available in "D.2 Atmospheric Characteristics" on page 64.

What Are These Upward or Downward Spikes in VNIR Data?

Figure B.4 shows upward spikes resulting from artificial light sources, in particular fluorescent lights.

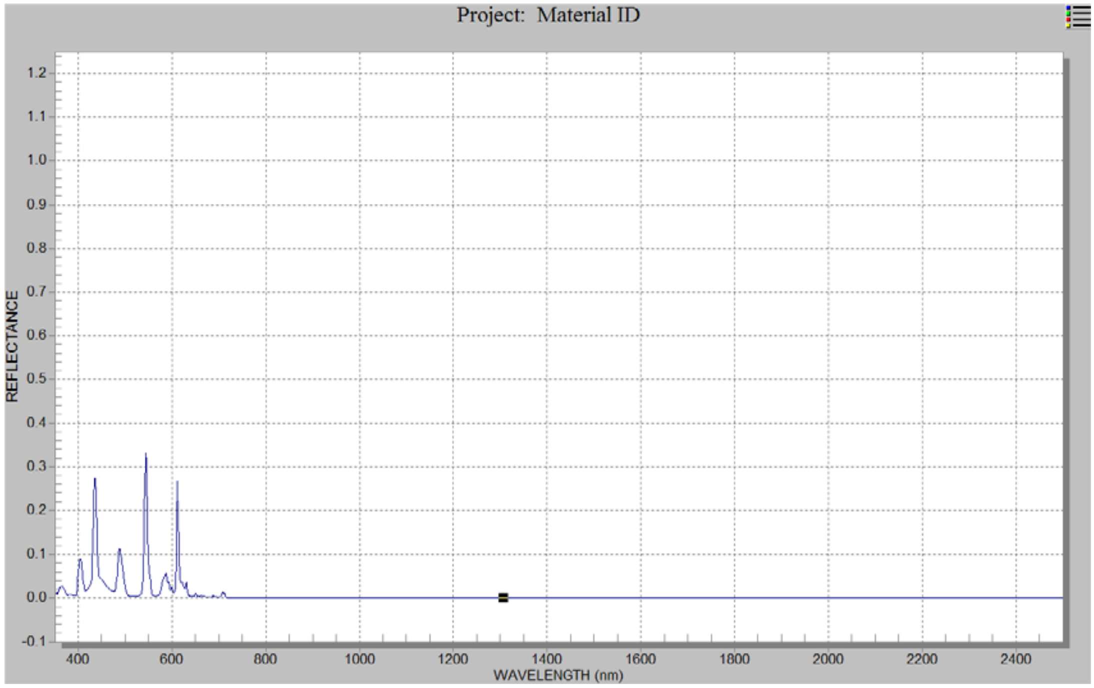


Figure B.4: Spectrum of fluorescent lights.

What Are These Steps in My Data?

Light is brought into the instrument by various combinations of the strands in the fiber optic cable. Each strand has its own field of view. When the cable is held close to the sample, each strand views slightly different portions of the sample. This can result in the stepped data.

Hold the end of the fiber cable farther away from the sample to allow the field of view of the individual strands to overlap and mesh together.

Stepping of data is common when the fore optic has a lens and less common when using the bare fiber optic cable or sampling devices. Large persistent steps can indicate broken fibers. The ViewSpec Pro software can remove large steps in reflectance data through the Splice Correction utility.

What Can Cause More Noise in My Data from Last Time?

Many factors can cause noise in your data from one session to another. Noise in a measurement is related to the instrument, the signal level, and noise in the light source. Many times the appearance of noise is actually a decrease in the strength of the signal, as opposed to an increase in noise.

Under normal operating conditions, noise visible in a spectrum is always the result of a trade-off between the inherent noise in the system and the signal.

The angle of the sun at high noon in the fall has a reduced light level compared with high noon in summer. Likewise, the time of day and the sun's position affect light levels, as well as atmospheric conditions.

Also, broken fibers in the fiber optic cable can contribute to noise. Perform a fiber optic check to verify. See "Checking the Fiber Optic Cable for Broken Fibers" on page 14.

An increase in noise can be due to a problem in the instrument such as an electronic component malfunction or a grounding problem. This is usually indicated by a regular pattern to the noise or periodic bursts of noise that are visible over the normal spectra.

Why Does the VNIR Drop to Zero after a Dark Current Collection?

When the VNIR drops to zero after a dark current has been collected, this may indicate a problem with the dark current calibration file or dark current collection routine.

To verify, observe if you have both of the following:

- A normal response curve in the VNIR region before optimizing or before taking a dark current.
- A flat line displayed after the optimization/dark current routine completes.

If you do not obtain a normal response curve in the VNIR region, contact technical support.

How Can I Convert My Data?

The ViewSpec Pro software can convert spectral data to ASCII text files and several other file formats. Conversion can be done one file at a time, or several files can be merged into a single text file.

B.4 Network and GPS

How Do I Set Up GPS?

See "2.8 Setting Up GPS" on page 31.

What Type of Ethernet Cable Can I Use for the Static IP Configuration?

You can connect the instrument directly to the instrument controller using an Ethernet cable.

When the instrument and instrument controller communicate over a network, use standard Ethernet cables and IP addresses compatible with the network. The instrument imposes significant traffic on the network, which can cause packet delays to other users. More importantly, network traffic from other users can negatively impact the reliability of the communication between instrument and instrument controller.

B.5 Instrument Controller

Can I Install Additional Software on the Instrument Controller?

Yes, but with qualifications.

The types of software that can interfere with the measurement of data are utilities, network software, and those working in the background, such as virus checkers.

ASD software requires real-time access to the data that is being streamed from the instrument at a high rate of speed. Software running in the background can cause packets to be lost.

Microsoft Office software, image processing software, and other software generally do not interfere with ASD software, particularly if they are not running and competing for CPU cycles and RAM at the same time that data is being collected from the instrument.

Why Does the Software Seem to Do Unexpected Things?

To ensure accuracy in the collection and processing of data, the ASD software finishes its current operation before moving on. The instrument outputs a lot of data at a high rate of speed for the ASD software to collect.

In addition, the ASD software will stack up your keystroke entries and execute them later, in the order they were received.

Wait for the collection to finish before entering the commands to launch another operation. Do not rush into new operations or into issuing new commands until you see the results of the current command.

Appendix C: Standard Accessories

- FieldSpec 4 User Manual (PDF on flash drive)
- FieldSpec 4 Quick Start Guide (printed and PDF included with installer)
- Instrument power supply 12 V
- One 12 V, 9 amp hour Nickel-Metal Hydride battery, one AC battery charger, and one battery-to-instrument power cable.
- DC vehicle power cable (6 m/20 ft)
  - When using this cable, turn off the engine to the vehicle. Electromagnetic fields from the engine can generate noise in the acquired signals.
- Remote trigger with LEDs and hook and loop strips
- RJ45 CAT 5e UTP Ethernet, shielded, cable
- Ergonomic backpack with soft-sided travel bag
- Fiber optic spool
- Pistol grip and pistol grip clip
- Laptop carrier
- Fiber inspection scope/magnifier
- Durable transport/shipping case
- Documentation packet that contains the following: Quality Control documentation, Mylar wavelength reference, and USB flash drive loaded with ASD software.
- 3.62" diameter white reference panel
- Bag containing hook and loop straps and instructions
- Bag of fiber optic tip covers

C.1 Accessories for Light Sources and Probes

ASD offers several accessories for:

- Delivering illumination to the sample.
- Collecting reflected or transmitted light from the sample and transmitting the collected light to the instrument.
- Collecting radiance and irradiance data (where solar light is the primary source of illumination).

Many accessories, including the optional fore optic lenses, rely on external illumination sources, including solar illumination.

Visit the FieldSpec 4 product pages on the ASD website at www.asdi.com to see more recommended accessories.

Appendix D: Understanding Field Measurement Conditions

Field spectrometry is the quantitative measurement of radiance, irradiance, reflectance, or transmission in the field. It involves the collection of accurate spectra and requires an awareness of the influences of:

- Sources of illumination
- Instrument field of view
- Sample viewing and illumination geometry
- Instrument scanning time
- Spatial and temporal variability of the sample characteristics

Many of these parameters are controlled when using one of the ASD standard sampling interfaces (for example., Muglight or contact probe).

To develop a field experiment, you must first define the overall experimental design. Unfortunately, the formulation of an appropriate experimental design is not always obvious.

In light of the objectives of the study, you must consider issues such as the:

- Timing of the data collections
- Spatial scale of the field measurement
- Target viewing and illumination geometry
- Collection of ancillary data sets

A lack of appropriate ancillary data sets may make previously collected data sets unusable for a new application.

Frequently, you must change the experimental design to account for the characteristics of the available instrumentation.

For example, vegetation canopy spectra collected using a slow scanning instrument will sometimes have small wind-induced "absorption" features in those portions of the spectra when the instrument was viewing more shadow.

The following sections describe more about collecting spectra in the field:

- "D.1 Illumination" on page 63
- "D.2 Atmospheric Characteristics" on page 64
- "D.3 Clouds" on page 66
- "D.4 Wind" on page 67
- "D.5 Vegetation" on page 67

- "D.6 Rocks, Soils, and Man-Made Materials" on page 68
- "D.7 White Reference" on page 69

D.1 Illumination

To determine the reflectance or transmittance of a material, two measurements are required:

- The spectral response of a reference sample
- The spectral response of the target material

You must compute the reflectance or transmittance spectrum by dividing the spectral response of the target material by that of a reference sample. The ASD software handles both the collection of the two spectral responses and the calculation of reflectance or transmittance.

Using this method, all parameters that are multiplicative in nature and present in both the spectral response of a reference sample and the target material, are ratio-ed out, such as:

- The spectral irradiance of the illumination source
- The optical throughput of the field spectrometer

This process assumes that the characteristics of the illumination are the same for the reference and target materials. Variability of the illumination characteristics between the time the reference and target materials are measured will result in errors in the resultant spectra.

Characteristics of Natural Illumination

Field spectrometry typically involves ambient solar illumination. As such, the target can be illuminated by three or more sources (see Figure D.1), each with its own spectral characteristics. Unless the target is in a shadow, the direct solar illumination is the dominant source of illumination.

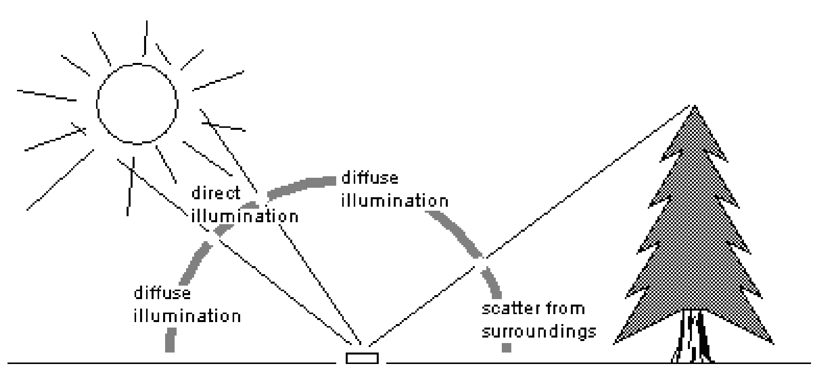


Figure D.1: The major sources of illumination

You may have several sources of light scattered off surrounding objects, each with its own unique spectral distribution.

Parameters such as solar elevation angle and atmospheric conditions will affect the overall intensity and spectral characteristics of direct solar illumination. Diffuse skylight illumination can contribute as much as 5-10% of the total illumination reaching a surface. At shorter wavelengths, diffuse skylight can contribute as much as 20-25% of the total.

The spectral characteristics of the illumination scattered off surrounding objects is determined by their reflectance characteristics. In the case of a forest clearing, as much as 20% of the illumination in the 750-1200 nm wavelength range can be attributed to sunlight scattered off the surrounding forest canopy.

One important source of surrounding scattered light is the person and the instrumentation making the measurement. Objects in the surroundings also affect the overall illumination of the target surface by obscuring a portion of the diffuse skylight and, possibly, shading the target from direct solar illumination.

The magnitude of both the diffuse skylight and scattered light is determined by the solid angle subtended by these sources when viewed from the reference frame of the target surface.

The surface texture of the material being measured also affects the relative portion of the various sources of illumination. When compared to a smooth surface, a surface with a rough texture will tend to have a higher portion of illumination from the diffuse and scattered light relative to the direct solar illumination.

Characteristics of Artificial Illumination

The use of artificial illumination allows:

- More control over illumination and viewing geometry.
- More control over sample geometry.
- Measurements during non-optimal conditions (for example, cloud cover or at night).
- Measurement of reflectance and transmittance in the deep atmospheric absorption bands.

Several problems with using artificial illumination include:

- Difficulty in maintaining a constant distance between the sample or reference and the light source when measuring samples with irregular geometry.
- "Cooking" vegetation samples under the lights (water loss, chlorophyll degradation).

In a typical lamp configuration for indoor use, you view the sample with the collecting optics of the spectrometer nadir to the sample. Use one or two 200 to 500 Watt quartz-halogen cycle tungsten filament lamps (~3400°K color temperature) in housings with aluminum reflectors about one meter above the surface being measured.

Alternatively, the light source can be either incorporated into the field spectrometer (often precluding the use of solar illumination) or can be provided in the form of an optional accessory that mounts to the light collecting optics of the instrument.

D.2 Atmospheric Characteristics

Absorbing molecules in the atmosphere strongly modify the incoming solar irradiance. All of the absorption features will increase in intensity as the atmospheric path length of the incoming solar radiation increases (e.g. with changing solar elevation angle).

By far, water vapor is the strongest modifier of the incoming solar spectrum. Water vapor has absorption features spanning the solar reflected region of the spectrum (see Figure D.2), and varies both spatially and temporally.

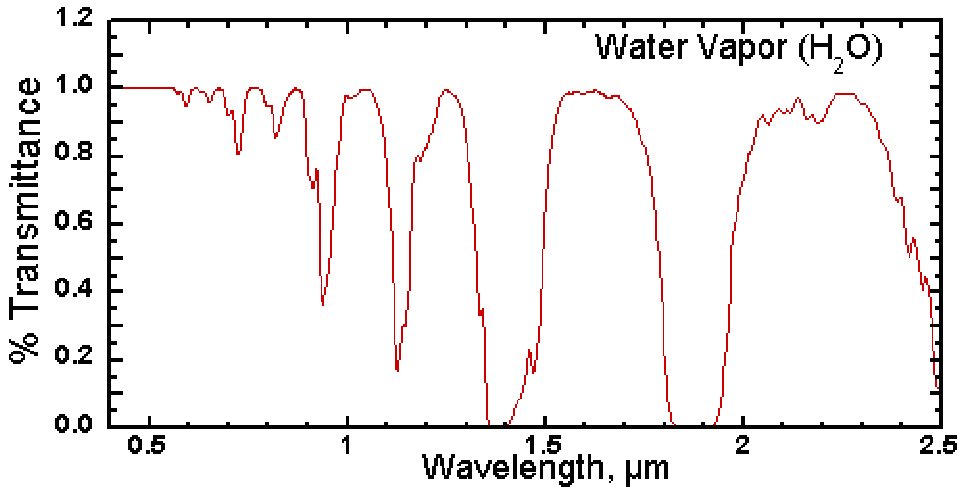


Figure D.2: Transmission spectrum of water vapor for typical atmospheric conditions

Carbon dioxide has strong features in the 2000-2200 nm range (see Figure D.3), a region of major interest for the identification of layered silicate minerals. Carbon dioxide is a well mixed gas, thus the intensity of the absorption features associated with carbon dioxide are not as variable as those of water vapor, but they do decrease with increasing altitude.

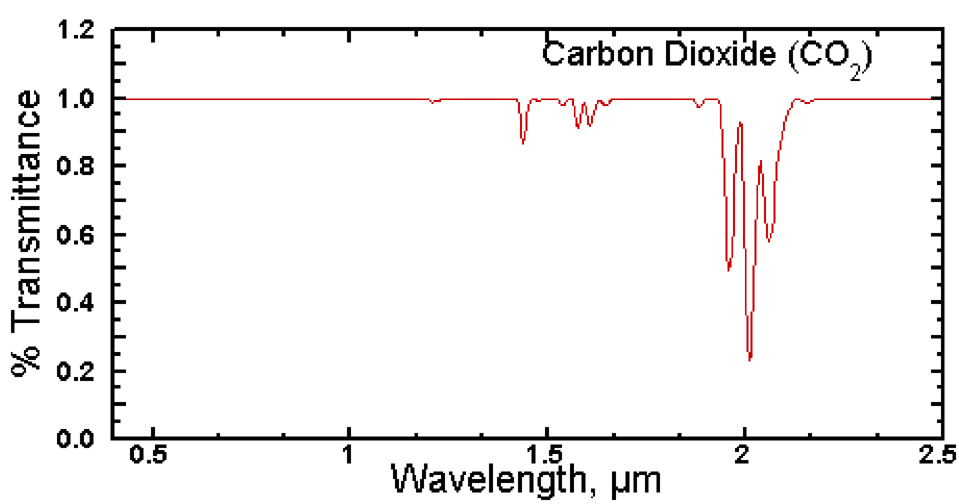


Figure D.3: Transmission spectrum of carbon dioxide for typical atmospheric conditions.

Other major atmospheric components that influence the atmospheric transmission spectrum are shown in Figure D.4.

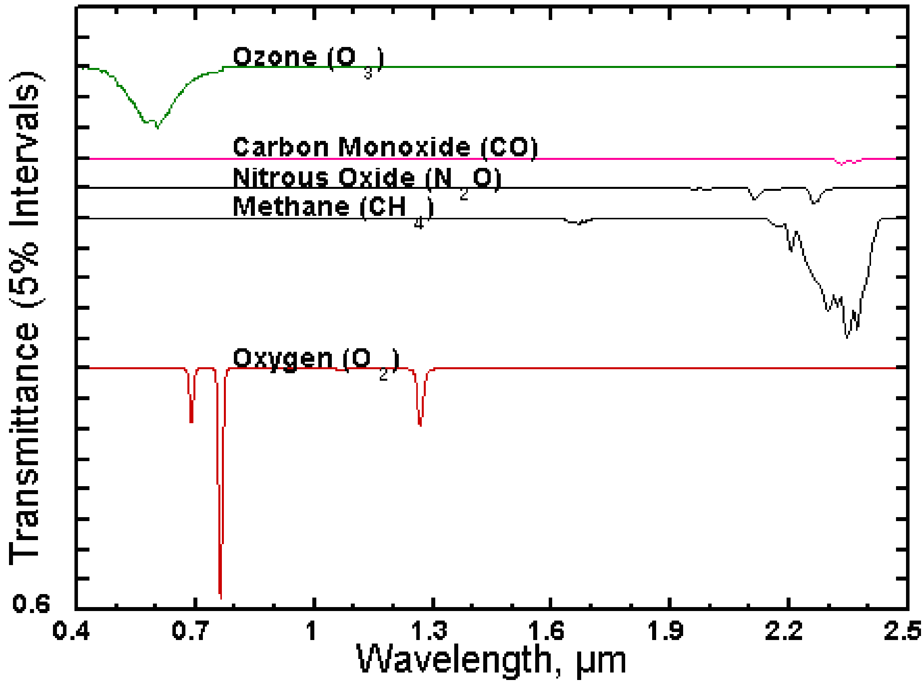


Figure D.4: Transmission spectrum of various gases for a typical atmospheric conditions

D.3 Clouds

Partial cloud cover is indicative of highly spatially and temporally variable atmospheric water vapor.

Because of the large influence of water vapor on the atmospheric transmission, variability of atmospheric water vapor between the time when the reference and target measurements are made will result in errors in the resultant spectrum.

You can reduce this error by minimizing the length of time between the measurement of the reference sample and the target.

While they are difficult to see and often appear inconsequential, the presence of cirrus clouds tends to produce significant variability in atmospheric water vapor.

Partial cloud cover also greatly increases the intensity of diffuse skylight illumination. This tends to “fill in” shadows and reduce the contrast between surfaces with dissimilar surface textures.

If you want to collect field spectra for image calibration or interpretation, collect spectra under illumination conditions similar to those at the time the image was collected.

Measure the Magnitude of the Effect of Cirrus Clouds

Here is a way to measure how much cirrus clouds affect spectra collection:

1. Standardize the field spectrometer on the reference panel.
2. Continue to view the reference panel with the instrument.
   - If the atmospheric conditions are stable, the computed reflectance of the panel will be a flat spectrum with near 100% reflectance.
   - If atmospheric conditions are unstable, the computed reflectance of the panel will vary over time and will show absorption minima or maxima (depending on whether atmospheric water vapor is increasing or decreasing) at the wavelengths corresponding to the water vapor absorption features.

With this method, you can determine if you can collect sufficiently accurate spectral data.

D.4 Wind

Wind can be a source of error if the material being measured moves as you collect spectrum.

If a spectrum is slowly scanned, changes in the amount of shadow in the instrument field of view will result in erroneous "features" in the spectrum.

Vegetation canopies, with their large portion of shadow, are especially susceptible to wind-induced errors.

Instruments using an array detector or that scan the spectrum rapidly are not significantly affected by wind.

D.5 Vegetation

The absorption features seen in vegetation spectra are all related to organic compounds common to the majority of plant species.

Thus, the information about a plant canopy is contained in the relative intensity of the various absorption features, rather than in the presence or absence of a specific absorption feature.

The major spectral absorption features can be attributed to:

- Water
- Plant pigments
  - Chlorophyll
  - Zanthophyll
  - Carotenoids

Other, minor, absorption features are attributable to other chemical components, including:

- Cellulose

- Lignin
- Proteins
- Starches
- Sugars

Non-photosynthetic components of the canopy have spectra that are dominated by absorption features attributed to lignin and cellulose.

The spectral radiance leaving a vegetation canopy is significantly impacted by many factors, such as those listed in Table D.1.

Table D.1: Major variables affecting the spectral radiance of a vegetation canopy

<table>
<tr><td>Illumination</td><td>• Geometry
  • Angle-of-incidence of sun (or radar)
  • Azimuth
• Spectral characteristics</td></tr>
<tr><td>Sensor</td><td>• Canopy
  • Type (plant or tree nominal class)
  • Closure
  • Orientation
    • Systematic (for example, rows)
    • Unsystematic (random)
• Crown
  • Shape (or example, circular, conical)
  • Diameter (m)
• Trunk or stem
  • Density (units per m^2)
  • Tree diameter-at-breast-height: tree trunks or plant stems have a certain density.
• Leaf
  • Leaf-area-index: defines the area that interacts with solar radiation; the surface that is responsible for carbon absorption and exchange with the atmosphere.
  • Leaf-angle-distribution: may change throughout the day as the leaves orient themselves toward or away from the incident radiation.</td></tr>
<tr><td>Understory</td><td>Same as vegetation</td></tr>
<tr><td>Soil</td><td>• Texture
• Color
• Moisture content</td></tr>
</table>

D.6 Rocks, Soils, and Man-Made Materials

The shape of the spectral signature of rocks and soil tends not to change with respect to the viewing geometry. The overall brightness of the observed spectrum does change with illumination and viewing geometry, due to changes in the amount of shadow in the field of view of the spectrometer.

Absorption features in the spectra of rocks and minerals are due to the presence of specific molecular groups and are often diagnostic of the minerals present in the sample.

D.7 White Reference

A material with relatively uniform reflectance across the entire spectrum is called a white reference panel or reference standard.

The raw measurement made by the spectrometer is influenced by both the sample and the light source. You need an independent measure of the light source illumination on a reference of known reflectance to calculate the reflectance of the sample. The use of a white reference standard with near 100% reflectance simplifies this calculation.

The ASD software can calculate the ratios for reflectance or transmittance of the material being sampled by the spectrometer using the reference panel as the standard.

A Spectralon panel from Labsphere is an example of a reference standard that is very suitable for the VNIR and SWIR spectral ranges of ASD instruments.

Spectralon reference panels are made of polytetraflouroethylene (PTFE) and cintered halon. It has the characteristic of being nearly 100% reflective within the wavelength range of 350 nm to 2500 nm. A Spectralon white reference scatters light uniformly in all directions within that wavelength range.

Appendix E: Theory of Operation

The following sections describe the instrument's theory of operation:

E.1 Overview

The instrument measures the optical energy that is reflected by, absorbed into, or transmitted through a sample. Optical energy refers to a wavelength range that is greater than the visible wavelengths, and is often called electromagnetic radiation or optical radiation.

In its most basic configuration, the instrument views and detects the form of radiant energy defined as radiance. With accessories, various set-ups, and built-in processing of the radiance signal, the instrument can measure:

- Spectral reflectance
- Spectral transmittance
- Spectral absorbance
- Spectral radiance
- Spectral irradiance

E.2 Fiber Optic Collection of Reflected/ Transmitted Light

Optical energy is collected through a bundle of specially formulated optical fibers that are precisely cut, polished, and sealed for extremely efficient energy collection. The fibers themselves are of low hydroxyl molecule composition providing the maximum transmission available across the wavelength range of the instrument.

E.3 Inside the Instrument

The fiber cable delivers the collected optical energy to the instrument, where it is projected onto a holographic diffraction grating. The grating separates and reflects the wavelength components for independent measurement by the detectors.

E.4 Visible and Near-Infrared (VNIR)

The visible and near-infrared (VNIR: 350-1000 nm wavelength) portion of the spectrum is measured by a 512-channel silicon photodiode array overlaid with an order separation filter. Each channel (or detector) is geometrically positioned to receive light within a narrow (1.4 nm) range. The VNIR spectrometer has a spectral resolution (full-width half-maximum of a single emission line) of approximately 3 nm at around 700 nm.

Each detector converts incident photons into electrons. This photocurrent is continually converted to a voltage and is periodically digitized by a 16-bit analog-to-digital converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis.

The 512-channel array can scan the entire VNIR spectrum in parallel at 1.4 nm wavelength intervals. A single sample can be acquired in as little as 8.5 ms.

E.5 Short-Wave Infrared (SWIR)

The near-infrared (NIR), also called short-wave infrared (SWIR), portion of the spectrum is acquired with two scanning spectrometers:

- SWIR 1 for the wavelength range of 1001 nm to 1800 nm.
- SWIR 2 for the wavelength range of 1801 nm to 2500 nm.

The SWIR scanning spectrometer has one detector for SWIR 1 and another for SWIR 2. This is different from the VNIR spectrometer that has an array of 512 detectors. The SWIR spectrometer collects wavelength information sequentially rather than in parallel.

Each SWIR spectrometer consists of a concave holographic grating and a single thermo-electrically cooled indium gallium arsenide (InGaAs) detector. The gratings are mounted about a common shaft that oscillates back and forth through a 15° swing. As the grating moves, it exposes the SWIR 1 and SWIR 2 detectors to different wavelengths of optical energy. Each SWIR spectrometer has ~600 channels or ~2 nm sampling interval per SWIR channel. The spectrometer firmware automatically compensates for the overlap in wavelength intervals.

Like the VNIR detectors, the SWIR 1 and SWIR 2 detectors convert incident photons into electrons. This photocurrent is continually converted to a voltage and is periodically digitized by a 16-bit analog-to-digital converter. This digitized spectral data is then transmitted to the instrument controller for further processing and analysis.

The grating is physically oscillating with a period of 200 ms. It performs a forward scan and a backward scan, resulting in 100 ms per scan. This is the minimum time required for any SWIR samples or full-range samples.

E.6 Fore Optics

You typically collect reflected radiance and surface reflectance measurements using a hand-held configuration, though you can use a tripod. The pistol grip is available with both a sighting scope and leveling device when required for more precise orientation.

These accessories allow viewing the exact spot where the fore optic is pointed and orienting the fore optic in precise, nadir-viewing, geometry. The majority of irradiance measurements are performed with the irradiance receptor mounted level on a tripod because of the need for precise geometric orientation.

The small size of the instrument's fore optics allows positioning the fore optics at a greater distance from the surface under observation.

A larger field of view means that fewer measurements are needed to approximate the spatial resolution of the imaging sensor, because the pixel size of most imaging sensor systems is several meters or more.

The small size of the pistol grip and fore optics greatly reduce errors associated with instrument self shadowing. Even when the area viewed by the fore optic is outside the direct shadow of the instrument, the instrument still blocks some of the illumination that would normally be striking the surface under observation, either diffuse skylight or light scattered off surrounding objects. Position the instrument as well as other objects — including the user — as far as possible from the surface under observation. This also applies to white reference measurements.

E.7 Dark Current Measurement

Dark current refers to current generated within a detector in the absence of any external photons. Dark current is the amount of electrical current that is inherent in the spectrometer detectors and other electrical components and is additive to the signal generated by the measured external optical radiation.

Noise is the uncertainty in a given measurement, one channel at a time. Noise, by definition, is random. You can reduce noise by using more samples and averaging the spectra or by increasing the sample count. Dark current is different from noise; it is relatively stable and can be characterized.

This manual uses dark current to refer to all systematic contributions to the detector signal. Dark current is a property of the detector and the associated electronics (not the light source). Dark current varies with temperature. In the VNIR region, dark current also varies with integration time.

Whenever you take dark current, the dark current calibration file is referenced. This signal is subtracted from each subsequent spectrum until another dark current is taken. The SWIR spectrometers take and subtract dark current on every scan.

You can update the dark current measurement at any time, but should update it more frequently in the beginning of a given session while the instrument warms up.

The VNIR spectrometer is fitted with a unique software and hardware combination called driftlock. Driftlock corrects for dark current changes over time. It automatically updates dark current for every measurement by looking at a series of masked pixels at the front portion of the VNIR array. The driftlock feature corrects for the majority of dark current variation over time.

E.8 White Reference

A material with approximately 100% reflectance across the entire spectrum is called a white reference panel or white reference standard.

The raw measurement made by the spectrometer is influenced by both the sample and the light source. An independent measure of the light source illumination on a reference of known reflectance is required to calculate the reflectance of the sample. The use of a white reference standard with near 100% reflectance simplifies this calculation.

Reflectance and transmittance are inherent properties of all materials and are independent of the light source.

- Reflectance is the ratio of energy reflected from a sample to the energy incident on the sample. Spectral reflectance is the reflectance as a function of wavelength.
- Transmittance is the ratio of the radiant energy transmitted through a sample to the radiant energy incident on the surface of the sample. Spectral transmittance is the transmittance as a function of wavelength.
- Relative reflectance is computed by dividing the energy reflected from the sample by the energy reflected off a white reference panel or standard.

Spectralon® from LabSphere is a white reference standard that is very suitable for the VNIR and SWIR spectral ranges of ASD instruments.

Spectralon Reflectance Data

Figure E.1 shows reflectance data for an uncalibrated white Spectralon panel. When using a calibrated white Spectralon panel as the white reference for a reflectance measurement with the instrument, an even closer reflectance value for the sample can be calculated.

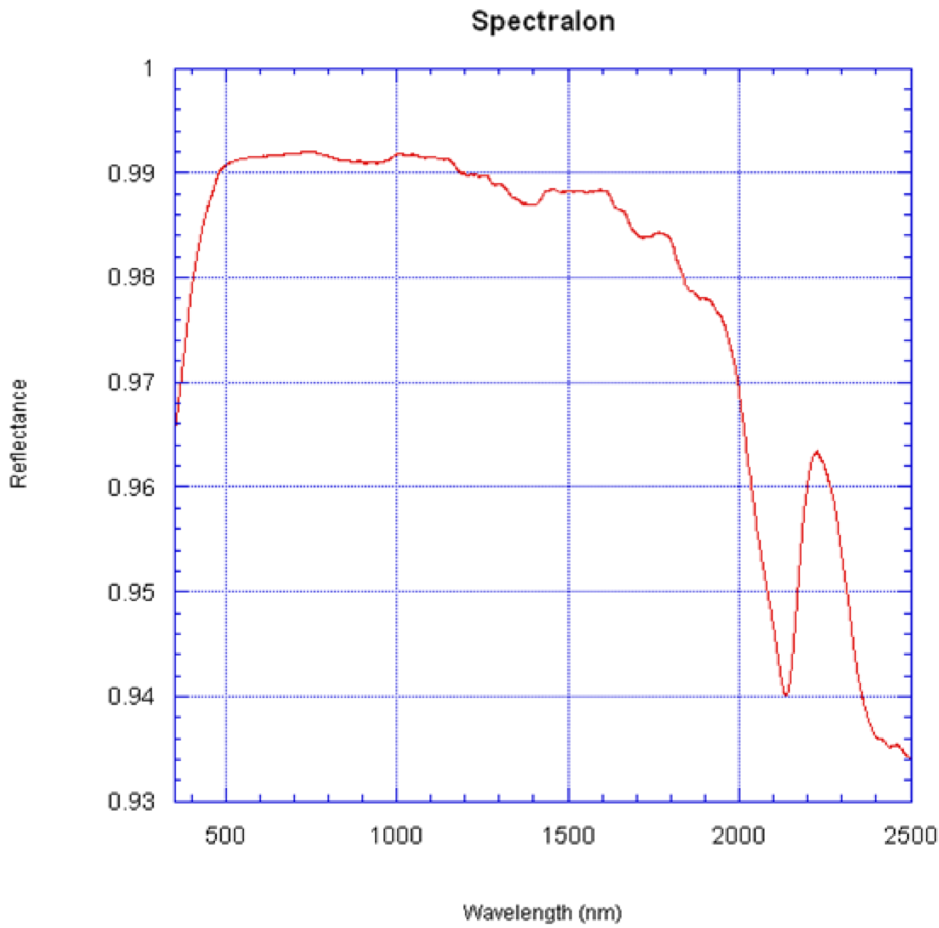


Figure E.1: Typical 350–2500 nm spectral response of Labsphere 99% Spectralon

E.9 Gain and Offset

The gain value is the inverse of actual gain. A decrease in gain value will produce a higher gain. The maximum gain value is 16. Under the low light levels that create such a gain, small changes in offset will translate into large changes in dynamic range.

Offset causes a downward shift (from Y=32,768 DN) in a SWIR spectrum such that the maximum value of the spectrum and the minimum value of the spectrum (dark current - off screen) are equidistant from the line y=32,768. Under ideal conditions, where there is enough light, there will be about 32,768 DN of signal immediately after optimization, +/- 1,000.

This means that optimization "creates" about 16,000 DN of dark current and about 16,000 DN of dynamic range. But this dynamic range will disappear with either a slight increase in signal (if the signal started out low to begin with) or a slight increase in dark current (increases with ambient temperature).

Appendix F: Declaration of Conformity

Declaration of Conformity

According to EN ISO/IEC 17050 Series

Manufacturer's Name: ASD Inc, a PANalytical company

Manufacturer's Address: 2555 55th St., Ste. 100, Boulder, CO 80301 USA

Declares that the product:

Product Name: FieldSpec® 4

Product Options: None

Conforms to the following EU Directives:

Safety: Low Voltage Directive, 2006/95/EC

EMC: Electromagnetic Compatibility Directive, 2004/108/EC

Supplementary Information:

The product complies with the requirements of the following Harmonized Product Standards and carries the CE-Marking accordingly:

EN61010-1:2001 2nd Edition

Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory use

EN61326-1:2013 Basic

Class A, Electrical Equipment for Measurement, Control and Laboratory use-EMC Requirements

Signature: [signature]

Name: **Brent Olsen**

Title: **Vice President & General Manager, ASD Inc.**

Date: **12-11-2013**

For compliance information ONLY, contact:

Product Regulations Manager, ASD Inc.
2555 55th St., Ste. 100, Boulder, CO 80301
USA Phone: (303) 444-6522

Index

2555 55th Street, Suite 100
Boulder, CO 80301

Phone: 303.444.6522

Fax: 303.444.6825

NIR.info@panalytical.com

www.asdi.com

FieldSpec 4 User Manual

ASD Document 600979 | Rev. F | May 2016

To obtain a copy of this instruction manual online, visit our website at http://support.asdi.com

ASD Inc.
A PANalytical Company
PANalytical

Appendix

Meade Telescope Serial Command Protocol

Introduction
This paper documents the Meade Telescope Serial Control Protocol utilized to remotely command and control Meade Telescopes. This command language contains a core of common commands supported by all telescope. Due to different implementation and technological advances the command has extension that are not supported by all model. The differences are noted in the descriptive text for the commands. Finally, there are a series of new commands proposed for the LX200GPS. These commands are indicated in the Appendix A at the end of this document.

As an extension to the Telescope Protocol beginning with the LX200GPS, a possible response to any command is ASCII NAK (0x15). Should the telescope control chain be busy and unable to accept an process the command, a NAK will be sent within 10 msec of the receipt of the '#' terminating the command. In this event, the controller should wait a reasonable interval and retry the command.

Telescope Command Groupings:

		------------------ Supported ------------			
Command Group	Command Designator Symbol	AutoStar	LX200<16"	LX 16"	LX200GPS
Alignment Query	<ACK>	x	x	x	x
Alignment*	A	x	x	x	x
Active Backlash	$B	-	-	-	x
Reticule Control*	B	x	p	p	x
Sync Control	C	p	p	p	x
Distance Bars	D	x	x	x	x
Fan*	f	-	-	p	x
Focus Control Commands	F	p	p	p	x
GPS Commands	g	-	-	-	x
Get Information	G	x	x	x	x
Home Position Commands*	h	x	-	x	x
Hour	H	x	x	x	x
Initialize Telescope	I	-	-	-	x
Library	L	p	p	p	x
Movement	M	x	p	x	x
High Precision	P	x	x	x	x
Smart Drive Control*	$Q	x	x	x	x
Quit Command	Q	x	x	x	x
Field De-rotator	r	-	-	p	x
Rate Control	R	p	p	p	x
Set Information	S	x	x	x	x
Tracking Frequency	T	p	p	p	x
User Format Control	U	p	x	x	x
Way point (Site)	W	x	x	x	x
Help Commands	?	-	x	x	-

Notes:
Commands accepted by the telescopes are shown in the table above indicated by an x entry. This means that the telescope will accept these commands and respond with a syntactically valid response where required. A "p" indicated only a subset of this command class is supported. Due to the differing implementations of the telescopes, some of the commands may provide static responses or may do nothing in response to the command. See the detailed description of the commands below to determine the exact behavior.

ACK - Alignment Query

ACK <0x06> Query of alignment mounting mode.
Returns:
- A If scope in AltAz Mode
- L If scope in Land Mode
- P If scope in Polar Mode

Meade Telescope Protocol

A - Alignment Commands

:Aa# Start Telescope Automatic Alignment Sequence [LX200GPS only]
Returns:
1: When complete (can take several minutes).
0: If scope not AzEl Mounted or align fails

:AL# Sets telescope to Land alignment mode
Returns: nothing

:AP# Sets telescope to Polar alignment mode
Returns: nothing

:AA# Sets telescope the AltAz alignment mode
Returns: nothing

$B – Active Backlash Compensation

:$BAdd#
Set Altitude/Dec Antibacklash
Returns Nothing

:$BZdd#
Set Azimuth/RA Antibacklash
Returns Nothing

B - Reticule/Accessory Control

:B+# Increase reticule Brightness
Return: Nothing

:B-# Decrease Reticule Brightness
Return: Nothing

:B<n># Set Reticle flash rate to <n> (an ASCII expressed number)
<n> Values of 0..3 for LX200 series
<n> Values of 0..9 for Autostar and LX200GPS
Return: Nothing

:BDn# Set Reticule Duty flash duty cycle to <n> (an ASCII expressed digit) [LX200 GPS Only]
<n> Values: 0 = On, 1..15 flash rate
Return: Nothing

C - Sync Control

:CL# Synchonize the telescope with the current Selenographic coordinates.

:CM# Synchronizes the telescope's position with the currently selected database object's coordinates.
Returns:
LX200's - a "#" terminated string with the name of the object that was synced.
Autostars & LX200GPS - At static string: " M31 EX GAL MAG 3.5 SZ178.0'#"

D - Distnace Bars

:D# Requests a string of bars indicating the distance to the current library object.
Returns:
LX200's – a string of bar characters indicating the distance.
Autostars and LX200GPS – a string containing one bar until a slew is complete, then a null string is returned.

f - Fan Command

:f+# LX 16”– Turn on the tube exhaust fan
LX200GPS – Turn on power to accessor panel
Autostar & LX200 < 16” – Not Supported
Returns: nothing

:f-# LX 16”– Turn off tube exhaust fan
LX200GPS - Turn off power to accessory panel
Autostar & LX200 < 16” – Not Supported
Returns: Nothing

:fT# LX200GPS – Return Optical Tube Assembly Temperature
Returns <sdd.ddd># - a ‘#’ terminated signed ASCII real number indicating the Celsius ambient temperature.
All others – Not supported

F – Focuser Control

:F+# Start Focuser moving inward (toward objective)
Returns: None

:F-# Start Focuser moving outward (away from objective)
Returns: None

:FQ# Halt Focuser Motion
Returns: Notrhing

:FF# Set Focus speed to fastest setting
Returns: Nothing

:FS# Set Focus speed to slowest setting
Returns: Nothing

:F<n># Autostar & LX200GPS – set focuser speed to <n> where <n> is an ASCII digit 1..4
Returns: Nothing
LX200 – Not Supported

g – GPS/Magnetometer commands

:g+# LX200GPS Only - Turn on GPS
Returns: Nothing

:g-# LX200GPS Only - Turn off GPS

:gps# LX200GPS Only – Turns on NMEA GPS data stream.
Returns: The next string from the GPS in standard NEMA format followed by a ‘#’ key

:gT# Powers up the GPS and updates the system time from the GPS stream. The process my take several minutes to complete.
During GPS update, normal handbox operations are interrupted. [LX200gps only]
Returns: ‘0’ In the event that the user interrupts the process, or the GPS times out.
Returns: ‘1’ After successful updates

G – Get Telescope Information

:G0# Get Alignment Menu Entry 0
Returns: A ‘#’ Terminated ASCII string. [LX200 legacy command]

:G1# Get Alignment Menu Entry 0
Returns: A ‘#’ Terminated ASCII string. [LX200 legacy command]

Meade Telescope Protocol

:G2# Get Alignment Menu Entry 0
Returns: A '#' Terminated ASCII string. [LX200 legacy command]

:GA# Get Telescope Altitude
Returns: sDD*MM# or sDD*MM'SS#
The current scope altitude. The returned format depending on the current precision setting.

:Ga# Get Local Telescope Time In 12 Hour Format
Returns: HH:MM:SS#
The time in 12 format

:Gb# Get Browse Brighter Magnitude Limit
Returns: sMM.M#
The magnitude of the faintest object to be returned from the telescope FIND/BROWSE command.
Command when searching for objects in the Deep Sky database.

:GC# Get current date.
Returns: MM/DD/YY#
The current local calendar date for the telescope.

:Gc# Get Calendar Format
Returns: 12# or 24#
Depending on the current telescope format setting.

:GD# Get Telescope Declination.
Returns: sDD*MM# or sDD*MM'SS#
Depending upon the current precision setting for the telescope.

:Gd# Get Currently Selected Object/Target Declination
Returns: sDD*MM# or sDD*MM'SS#
Depending upon the current precision setting for the telescope.

:GF# Get Find Field Diameter
Returns: NNN#
An ASCIi interger expressing the diameter of the field search used in the IDENTIFY/FIND commands.

:Gf# Get Browse Faint Magnitude Limit
Returns: sMM.M#
The magnitude or the birghtest object to be returned from the telescope FIND/BROWSE command.

:GG# Get UTC offset time
Returns: sHH# or sHH.H#
The number of decimal hours to add to local time to convert it to UTC. If the number is a whole number the sHH# form is returned, otherwise the longer form is return. On Autostar and LX200GPS, the daylight savings setting in effect is factored into returned value.

:Gg# Get Current Site Longitude
Returns: sDDD*MM#
The current site Longitude. East Longitudes are expressed as negative

:Gh# Get High Limit
Returns: sDD*
The minimum elevation of an object above the horizon to which the telescope will slew with reporting a "Below Horizon" error.

:GL# Get Local Time in 24 hour format
Returns: HH:MM:SS#

The Local Time in 24-hour Format

:Gl# Get Larger Size Limit
Returns: NNN'#
The size of the smallest object to be returned by a search of the telescope using the BROWSE/FIND commands.

:GM# Get Site 1 Name
Returns: <string>#
A '#' terminated string with the name of the requested site.

:GN# Get Site 2 Name
Returns: <string>#
A '#' terminated string with the name of the requested site.

:GO# Get Site 3 Name
Returns: <string>#
A '#' terminated string with the name of the requested site.

:GP# Get Site 4 Name
Returns: <string>#
A '#' terminated string with the name of the requested site.

:Go# Get Lower Limit
Returns: DD*#
The highest elevation above the horizon that the telescope will be allowed to slew to without a warning message.

:Gq# Get Minimum Quality For Find Operation
Returns:

SU#	Super
EX#	Excellent
VG#	Very Good
GD#	Good
FR#	Fair
PR#	Poor
VP#	Very Poor

The mimum quality of object returned by the FIND command.

:GR# Get Telescope RA
Returns: HH:MM.T# or HH:MM:SS#
Depending which precision is set for the telescope

:Gr# Get current/target object RA
Returns: HH:MM.T# or HH:MM:SS
Depending upon which precision is set for the telescope

:GS# Get the Sidereal Time
Returns: HH:MM:SS#
The Sidereal Time as an ASCII Sexidecimal value in 24 hour format

:Gs# Get Smaller Size Limit
Returns: NNN'#
The size of the largest object returned by the FIND command expressed in arcminutes.

:GT# Get tracking rate
Returns: TT.T#
Current Track Frequency expressed in hertz assuming a synchonous motor design where a 60.0 Hz motor clock would produce 1 revolution of the telescope in 24 hours.

:Gt# Get Current Site Latitdue
Returns: sDD*MM#
The latitude of the current site. Positive inplies North latitude.

:GVD# Get Telescope Firmware Date
Returns: mmm dd yyyy#

:GVN# Get Telescope Firmware Number
Returns: dd.d#

:GVP# Get Telescope Product Name
Returns: <string>#

:GVT# Get Telescope Firmware Time
returns: HH:MM:SS#

:Gy# Get deepsky object search string
Returns: GPDCO#
A string indicaing the class of objects that should be returned by the FIND/BROWSE command. If the character is upper case, the object class is return. If the character is lowercase, objects of this class are ignored. The character meanings are as follws:
G – Galaxies
P – Planetary Nebulas
D – Diffuse Nebulas
C – Globular Clusters
O – Open Clusters

:GZ# Get telescope azimuth
Returns: DDD*MM#T or DDD*MM'SS#
The current telescope Azimuth depending on the selected precision.

h – Home Position Commands

:hS# LX200GPS and LX 16" Seeks Home Position and stores the encoder values from the aligned telescope at the home position in the nonvolatile memory of the scope.
Returns: Nothing
Autostar,LX200 – Ignored

:hF# LX200GPS and LX 16" Seeks the Home Position of the scope and sets/aligns the scope based on the encoder values stored in non-volatile memory
Returns: Nothing
Autostar,LX200 - Igrnored

:hN# LX200GPS only: Sleep Telescope. Power off motors, encoders, displays and lights. Scope remains in minimum power mode until a keystroke is received or a wake command is sent.

:hP# Autostar, LX200GPS and LX 16"Slew to Park Position
Returns: Nothing

:hW# LX200 GPS Only: Wake up sleeping telescope.

:h?# Autostar, LX200GPS and LX 16" Query Home Status
Returns:
0 Home Search Failed
1 Home Search Found
2 Home Search in Progress

LX200 Not Supported

H – Time Format Command

:H# Toggle Between 24 and 12 hour time format
Returns: Nothing

I – Initialize Telescope Command

:I# LX200 GPS Only - Causes the telescope to cease current operations and restart at its power on initialization.

L – Object Library Commands

:LB# Find previous object and set it as the current target object.
Returns: Nothing
LX200GPS & Autostar – Performs no function

:LCNNNN#
Set current target object to deep sky catalog object number NNNN
Returns : Nothing
LX200GPS & Autostar – Implemented in later firmware revisions

:LF# Find Object using the current Size, Type, Upper limit, lower limt and Quality contraints and set it as current target object.
Returns: Nothing
LX200GPS & Autostar – Performs no function

:Lf# Identify object in current field.
Returns: <string>#
Where the string contains the number of objects in field & object in center field.
LX200GPS & Autostar – Performs no function. Returns static string "0 - Objects found".

:LI# Get Object Information
Returns: <string>#
Returns a string containing the current target object's name and object type.
LX200GPS & Autostar – performs no operation. Returns static description of Andromeda Galaxy.

:LMNNNN#
Set current target object to Messier Object NNNN, an ASCII expressed decimal number.
Returns: Nothing.
LX200GPS and Autostar – Implemented in later versions.

:LN# Find next deep sky target object subject to the current constraints.
LX200GPS & AutoStar – Performs no function

:LoD# Select deep sky Library where D specifices
0 - Objects CNGC / NGC in Autostar & LX200GPS
1 - Objects IC
2 – UGC
3 – Caldwell (Autostar & LX200GPS)
4 – Arp (LX200 GPS)
5 – Abell (LX200 GPS)
Returns:
1 Catalog available
0 Catalog Not found
LX200GPS & AutoStar – Performs no function always returns "1"

:LsD# Select star catalog D, an ASCII integer where D specifies:
0 STAR library (Not supported on Autostar I & II)
1 SAO library
2 GCVS library

3	Hipparcos (Autostar I & 2)
4	HR (Autostar I & 2)
5	HD (Autostar I & 2)

Returns:

1	Catalog Available
2	Catalog Not Found

:LSNNNN#
Select star NNNN as the current target object from the currently selected catalog
Returns: Nothing
LX200GPS & AutoStar – Available in later firmwares

M – Telescope Movement Commands

:MA# Autostar, LX 16", LX200GPS – Slew to target Alt and Az
Returns:
0 - No fault
1 – Fault
LX200 – Not supported

:Me# Move Telescope East at current slew rate
Returns: Nothing

:Mn# Move Telescope North at current slew rate
Returns: Nothing

:Ms# Move Telescope South at current slew rate
Returns: Nothing

:Mw# Move Telescope West at current slew rate
Returns: Nothing

:MS# Slew to Target Object
Returns:

0	Slew is Possible
1<string>#	Object Below Horizon w/string message
2<string>#	Object Below Higher w/string message

P - High Precision Toggle

:P# Toggles High Precsion Pointing. When High precision pointing is enabled scope will first allow the operator to center a nearby bright star before moving to the actual taget.
Returns: <string>

"HIGH PRECISION"	Current setting after this command.
"LOW PRECISION"	Current setting after this command.

$Q – Smart Drive Control

$Q# Toggles Smart Drive PEC on and off for both axis
Returns: Nothing
Not supported on Autostar

:$QA+ Enable Dec/Alt PEC [LX200gps only]
Returns: Nothing

:$QA- Enable Dec/Alt PEC [LX200gps only]
Returns: Nothing

:$QZ+ Enable RA/AZ PEC compensation [LX200gps only]

Returns: Nothing

:$QZ- Disable RA/AZ PEC Compensation [LX200gpgs only]
Return: Nothing

Q – Movement Commands

:Q# Halt all current slewing
Returns:Nothing

:Qe# Halt eastward Slews
Returns: Nothing

:Qn# Halt northward Slews
Returns: Nothing

:Qs# Halt southward Slews
Returns: Nothing

:Qw# Halt westward Slews
Returns: Nothing

r – Field Derotator Commands

:r+# Turn on Field Derotator [LX 16" and LX200GPS]
Returns: Nothing

:r-# Turn off Field Derotator, halt slew in progress. [Lx 16" and LX200GPS]
Returns Nothing

R – Slew Rate Commands

:RC# Set Slew rate to Centering rate (2nd slowest)
Returns: Nothing

:RG# Set Slew rate to Guiding Rate (slowest)
Returns: Nothing

:RM# Set Slew rate to Find Rate (2nd Fastest)
Returns: Nothing

:RS# Set Slew rate to max (fastest)
Returns: Nothing

:RADD.D#
Set RA/Azimuth Slew rate to DD.D degrees per second [LX200GPS Only]
Returns: Nothing

:REDD.D#
Set Dec/Elevation Slew rate to DD.D degrees per second [LX200GPS only]
Returns: Nothing

:RgSS.S#
Set guide rate to +/- SS.S to arc seconds per second. This rate is added to or subtracted from the current tracking Rates when the CCD guider or handbox guider buttons are pressed when the guide rate is selected. Rate shall not exceed sidereal speed (approx 15.0417"/sec)[LX200GPS only]
Returns: Nothing

S – Telescope Set Commands

:SasDD*MM#

Set target object altitude to sDD*MM# or sDD*MM'SS# [LX 16", Autostar, LX200GPS]

Returns:

0 Object within slew range

1 Object out of slew range

:SbsMM.M#

Set Brighter limit to the ASCII decimal magnitude string. SMM.M

Returns:

0 - Valid

1 – invalid number

:SBn# Set Baud Rate n, where n is an ASCII digit (1..9) with the following interpertation

1	56.7K
2	38.4K
3	28.8K
4	19.2K
5	14.4K
6	9600
7	4800
8	2400
9	1200

Returns:

1 At the current baud rate and then changes to the new rate for further communication

:SCMM/DD/YY#

Change Handbox Date to MM/DD/YY

Returns: <D><string>

D = '0' if the date is invalid. The string is the null string.

D = '1' for valid dates and the string is "Updating Planetary Data# #"

Note: For LX200GPS this is the UTC data!

:SdsDD*MM#

Set target object declination to sDD*MM or sDD*MM:SS depending on the current precision setting

Returns:

1 - Dec Accepted

0 – Dec invalid

:SEsDD*MM#

Sets target object to the specificed selenographic latitude on the Moon.

Returns 1- If moon is up and coordinates are accepted.

0 – If the coordinates are invalid

:SesDDD*MM#

Sets the target object to the specified selenogrphic longitude on the Moon

Returns 1 – If the Moon is up and coordinates are accepted.

0 – If the coordinates are invalid for any reason.

:SfsMM.M#

Set faint magnitude limit to sMM.M

Returns:

0 – Invalid

1 - Valid

:SFNNN#

Set FIELD/IDENTIFY field diamter to NNNN arc minutes.

Returns:
0 – Invalid
1 - Valid

:SgDDD*MM#
Set current site's longitude to DDD*MM an ASCII position string
Returns:
0 – Invalid
1 - Valid

:SGsHH.H#
Set the number of hours added to local time to yield UTC
Returns:
0 – Invalid
1 - Valid

:ShDD#
Set the minimum object elevation limit to DD#
Returns:
0 – Invalid
1 - Valid

:SlNNN#
Set the size of the smallest object returned by FIND/BROWSE to NNNN arc minutes
Returns:
0 – Invalid
1 - Valid

:SLHH:MM:SS#
Set the local Time
Returns:
0 – Invalid
1 - Valid

:SM<string>#
Set site 1's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SN<string>#
Set site 2's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SO<string>#
Set site 3's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SP<string>#
Set site 4's name to be <string>. LX200s only accept 3 character strings. Other scopes accept up to 15 characters.
Returns:
0 – Invalid
1 - Valid

:SoDD*#
Set highest elevation to which the telescope will slew
Returns:
0 – Invalid
1 - Valid

:Sq#
Step the quality of limit used in FIND/BROWSE through its cycle of VP … SU. Current setting can be queried with :Gq#
Returns: Nothing

:SrHH:MM.T#
:SrHH:MM:SS#
Set target object RA to HH:MM.T or HH:MM:SS depending on the current precision setting.
Returns:
0 – Invalid
1 - Valid

:SsNNN#
Set the size of the largest object the FIND/BROWSE command will return to NNNN arc minutes
Returns:
0 – Invalid
1 - Valid

:SSHH:MM:SS#
Sets the local sideral time to HH:MM:SS
Returns:
0 – Invalid
1 - Valid

:StsDD*MM#
Sets the current site latitdue to sDD*MM#
Returns:
0 – Invalid
1 - Valid

:STTT.T#
Sets the current tracking rate to TTT.T hertz, assuming a model where a 60.0 Hertz synchronous motor will cause the RA axis to make exactly one revolution in 24 hours.
Returns:
0 – Invalid
1 - Valid

:SwN#
Set maximum slew rate to N degrees per second. N is the range (2..8)
Returns:
0 – Invalid
1 - Valid

:SyGPDCO#
Sets the object selection string used by the FIND/BROWSE command.
Returns:
0 – Invalid
1 - Valid

:SzDDD*MM#
Sets the target Object Azimuth [LX 16” and LX200GPS only]
Returns:

0 – Invalid
1 - Valid

T – Tracking Commands

:T+# Increment Manual rate by 0.1 Hz
Returns: Nothing

:T-# Decrement Manual rate by 0.1 Hz
Returns: Nothing

:TL# Set Lunar Tracking Rage
Returns: Nothing

:TM# Select custom tracking rate
Returns: Nothing

:TQ# Select default tracking rate
Returns: Nothing

:TDDD.DDD#
Set Manual rate do the ASCII expressed decimal DDD.DD
Returns: '1'

U - Precision Toggle

:U# Toggle between low/hi precision positions
Low - RA displays and messages HH:MM.T sDD*MM
High - Dec/Az/El displays and messages HH:MM:SS sDD*MM:SS
Returns Nothing

W – Site Select

:W<n>#
Set current site to <n>, an ASCII digit in the range 0..3
Returns: Nothing

? – Help Text Retrieval

:??# Set help text cursor to the start of the first line.
Returns: <string>#
The <string> contains first string of the general handbox help file.

:?+# Retrieve the next line of help text
Returns: <string>#
The <string> contains the next string of general handbox help file

:?-# Retreive previos line of the handbox help text file.
Returns: <string>#
The <string> contains the next string of general handbox help file

Appendix A: LX200GPS Command Extensions

:Aa#	Automatically align scope
:$BAdd#	Set Altitude/Dec Antibacklash
:$BZdd#	Set Azimuth/RA Antibacklash
:BD<n>#	Programmable Reticule Duty Cycle
:F<n>#	Set Focuer Speed
:g+#	Turn on GPS power
:g-#	Turn off GPS power
:gps#	Stream GPS data
:gT#	Updates Time of Day from GPS
:I#	Initialize Telescope
:$QZ+#	RA PEC Enable
:$QZ-#	RA PEC Disable
:$QA+#	Dec PEC Enable
:$QA-#	Dec PEC Disable
:RADD.D#	Programmable Slew Rates
:REDD.D#	Programmable Slew Rates
:RgSS.S#	Programmable Guiding Rates
:SBn#	Set Baud Rate