

# **GAMMA Portable Radar Interferometer II (GPRI-II)**



## **User Manual**

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# 1. Read First

First of all, thanks for buying this fascinating piece of hardware and software and we hope you can conduct many interesting and trouble free measurements. If you have feedback please do not hesitate to contact us (gamma@gamma-rs.ch or directly one of the staff). Feedback from our users is a strong element of our hardware and software evolution.

## 1.1 EMC Notice

This device complies with Part 15 of the FCC Rules and with RSS-210 of Industry Canada.

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.

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

This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance of 500 cm between the radiator (antenna in view direction) and your body. For proper radar imaging, no obstacle must be between the antennas and the target area during image acquisition at all (shadow effects). This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

## 1.2 Safety Guidelines

Follow these guidelines to ensure 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.
- Disconnect all power by turning off the power and unplugging the power cord before installing or removing a chassis or working near power supplies
- Do not work alone if potentially hazardous conditions exist.
- Never assume that power is disconnected from a circuit; always check the circuit.
- ***There are no user serviceable parts in the RF Assembly or the Instrument Controller Box. The Instrument Controller Box must not be opened with the power cable attached!***

## 1.3 Operating Safety

- Electrical equipment generates heat. Ambient air temperature may not be adequate to cool equipment to acceptable operating temperatures without additional measures.
- Ensure that the RF assembly and Instrument Controller cover is secure. The design allows

cooling air to circulate effectively.

## **1.4 Manual Outline**

This manual shall help the user to setup and use the instrument but also provides background information on the instrument. Section 2 gives a quick access on the instrument. Section 3 provides setup instructions and the basic commands needed to operate the instrument. Section 4 gives more detailed information on the instrument. Section 5 gives insight in the communication interfaces. Section 6 summarizes the instrument specifications and Section 7 a list of references and literature. Finally in the Appendix A in Section 8 a template for a measurement protocol is provided. While everything can be controlled digitally, nevertheless we recommend to keep a handwritten logbook.

## 2. Background

The GPRI-II is the second generation instrument of the Gamma Portable Radar Interferometer GPRI [1,2]. The GPRI-1 was developed as a proof of concept and later used on numerous scientific and commercial campaigns. The new second generation instrument GPRI-II has improved performance and is hardened for field measurements.

The GPRI development at Gamma was initiated based on the perceived 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 to landslides, pumping of oil and water, mining, glaciers, 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 length 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.

### 3. Quick Introduction

#### 3.1 Instrument Setup

The instrument setup needs to be stable (consider also wind!) and reproducible (if repeat measurements from a given position are foreseen). The standard setup of the GPRI-2 is on the supplied heavy duty Leica tripod. However it can also be mounted on permanent pier or other structure. In any case there must be sufficient room for the instrument to rotate (about 2.5 meters).

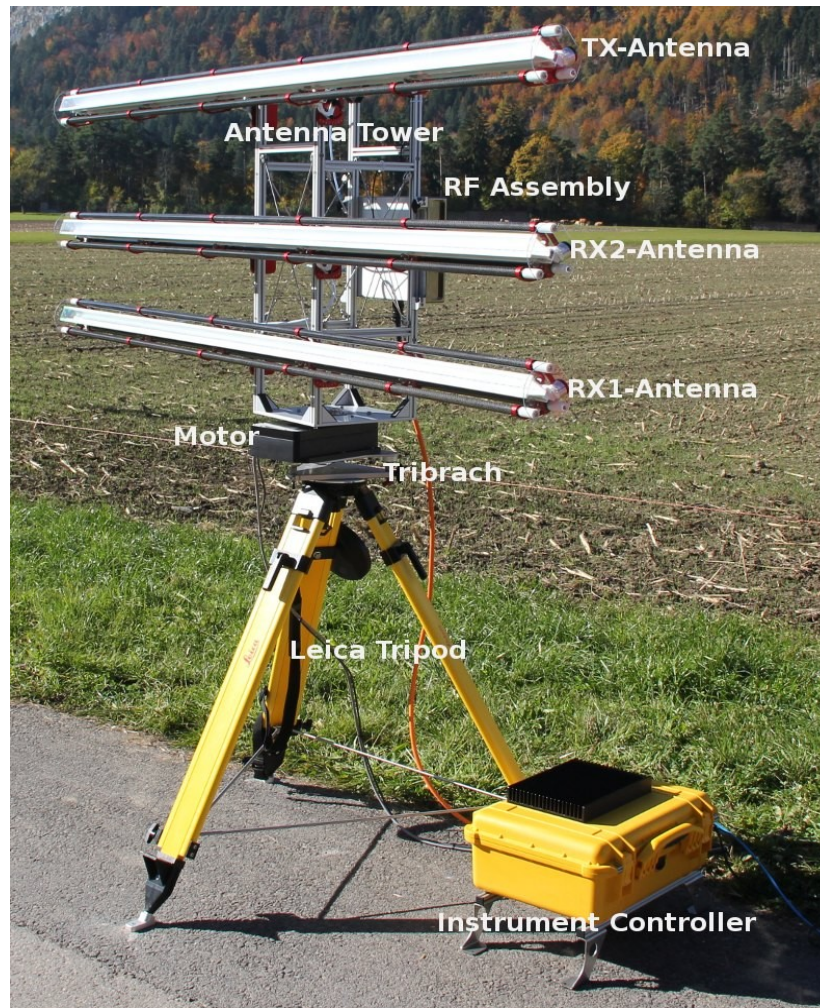


Figure 1: GPRI-II fully assembled. Instrument is aligned at 0 deg. azimuth position.

#### 3.1.1 Leica heavy-duty tripod

Installation of the tripod is the first step in setting up the GPRI2. The tripod legs should be initially fully retracted. 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 30 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 1.
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. 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.



*Figure 2: Fixture of rods to have tripod legs at fix distance.*



*Figure 3: Tripod foot with special tip that allows screwing to the ground.*



*Figure 4: Tripod leg extent documentation.*



*Figure 5: Interface Plate of the Leica Tripod with level and 5/8" screw.*

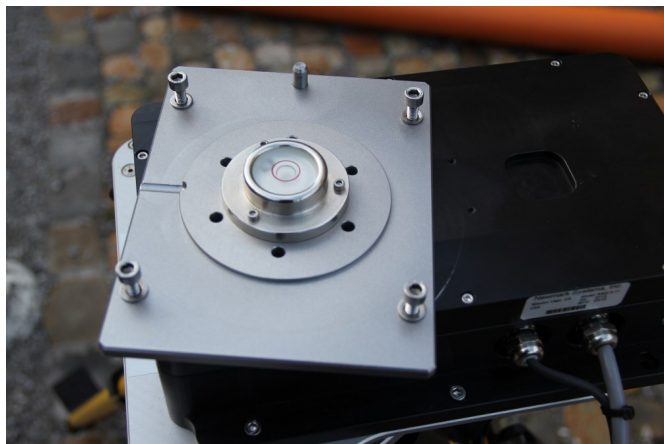
### **3.1.2 Motor with leveler and tower**

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.

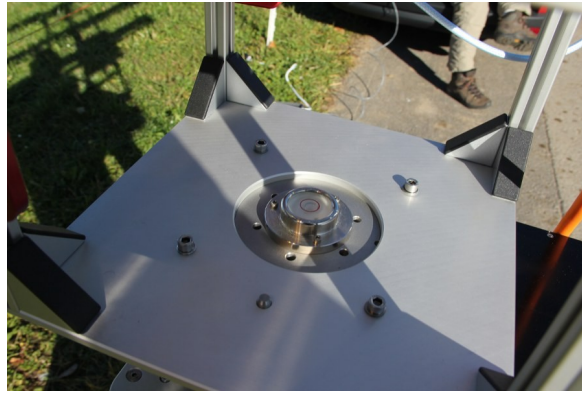
2. Make the antenna tower interface perfectly flat using the tribrach level adjustment screws. Note, the screw on side 1 is fixed and should never be change to not loose the absolute height reference. The large bubble level on the positioner should be used to determine if the tower mounting plate is level. Be sure to look down from directly above the level to make sure the bubble is centered.
3. 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 socket 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 6: Side view of the Tripod - leveler - positioner - Antenna Tower setup. The leveler is adjust by rotating the red knobs. The black screw is to fix the knob setting. At the bottom of the motor, the connector for the laser battery is indicated.*



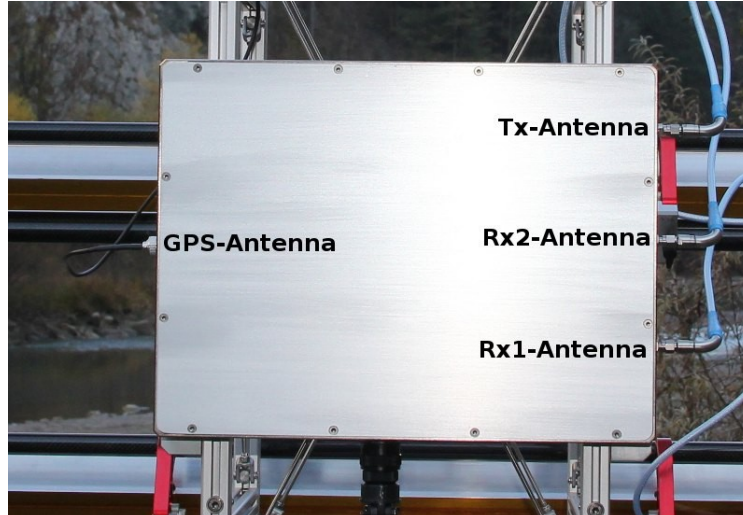
*Figure 7: Top view of the positioner. The 4 socket screws need to be removed before mounting the antenna tower.*



*Figure 8: Bottom of Antenna Tower mounted on the motor. Visible is the level, the 4 hexagon socket screws and the knob enforcing the defined tower orientation.*

### 3.1.3 RF Unit

1. Mount the RF Unit on mounting brackets at the back of the Antenna Tower. Use the 2 screws on the back to secure the RF unit
2. Plug in the GPS Antenna cable to the BNC connector. The GPS receiver is located on the rotation axis of the tower.



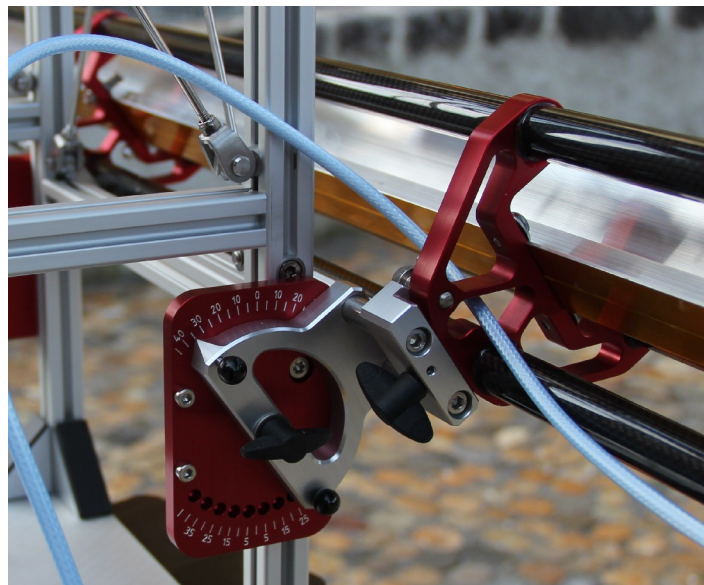
*Figure 9: RF Assembly mounted at the back of the Antenna Tower. On the left side the GPS Antenna mounted on top of the Antenna Tower is plugged, on the right side the Antenna cables, at the bottom the cable to the Instrument Controller and Power Unit.*

**There are no user serviceable parts in the RF Assembly or the Instrument Controller Box. The Instrument Controller Box must not be opened with the power cable attached!**

### 3.1.4 Antenna

1. Take each antenna out of the tube by loosening the 2 thumb screws. NOTE it is important that you push them out with the antenna cable plug in front to avoid damaging the antenna cable.
2. Mount the antennas one by one on the corresponding antenna holders. Make sure you use a fix order for the antennas (TX, RX1, RX2) to avoid phase effects due to slightly different antenna characteristics. It is recommended that you note the serial numbers of each antenna and if it is the top (TX), center (RX1), or bottom (RX2) of the tower. Each antenna has a slightly different pattern and phase and so it is strongly recommended to use the same antennas for TX, RX1, and RX2 for each measurement.
3. Plug in the 3 antennas to the appropriate port on the side of the RF assembly. The antenna cables have quick-connect SMA connectors. It is very important that these be pushed on gently and without being tilted relative to the connector axis or else they will be damaged. Inspect the connector before each use to make sure all the connector gold springs are not damaged or bent.

!! Never detach the antenna holders as you might loose the alignment precision of the antennas. These have been precisely positioned on the tower to insure that the antennas are parallel



*Figure 10: Closeup of the Antenna holder and Elevation Angle setting.*

### 3.1.5 Instrument Controller and Power Unit

1. Place the Pelican case close to the tripod at a dry and convenient place. The feet can be screwed to the ground if necessary.
2. Make sure the Instrument Controller is switched off.
3. Connect the Instrument Controller with the RF Unit (orange cable).
4. Connect the Instrument Controller with the motor (2 cables).
5. Connect the Instrument Controller to the network. The controller decides depending on the traffic which net configuration will be selected.

6. Switch Instrument Controller on.

**There are no user serviceable parts in the RF Assembly or the Instrument Controller Box. The Instrument Controller Box must not be opened with the power cable attached!**



*Figure 11: Instrument Controller and Power Unit in Pelican case. Connectors upper line from left to right: WLAN (not connected), Ethernet, RF Unit, Power. Lower line from left to right: Instrument Power Switch, USB, Motor Control, Motor Power.*

## **3.2 Operating the Instrument**

Communication with the instrument in the field is through TCP/IP. The easiest solution is to connect the instrument to an Ethernet Switch with attached laptop. In principle its also possible to use a crossed Ethernet cable but this has some disadvantages. In the lab it is also possible to connect screen and keyboard after opening the Pelican case.

The GPRI2 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.

### **3.2.1 Operating the instrument through SSH**

To control the instrument through SSH a SSH client software is necessary. Preferred is to access from a Linux system that also allows to export the window environment of the instrument. Though it is also possible to access the instrument purely through the shell using e.g. Putty. In the following we assume a Linux system accessing the instrument but the commands are the same for a pure shell connection.

Please refer to Section 5.4 for the detailed instrument software reference. Program parameters are provided for easier reading but needs to be adjusted to the individual case.

1. Login to instrument:  
`ssh -X -l gpri2 192.168.1.7x`
2. Check available disk space for data. The data are stored in their own disk partition called /data:  
`df /data`
3. Move to the data directory  
`cd data`
4. Initiate home run of the positioner (check first visually that the instrument can move freely and the cables have enough room!):  
`home_run.py`  
The instrument is now looking at 0 degrees instrument azimuth angle. Angles increase clockwise. Furthermore you may want to check system and gps status to make sure these components are well attached and working:  
`chupa_status.py`  
`tscg_status.py`  
`gps_message.py`  
Temperatures should be below 50° and 2 lines of GPS messages should be shown.
5. Determine the start and stop angles for the scan by moving the antenna around. Be aware that about 3 degrees are needed on both sides of the scan for rapid motion of 10 degrees/sec, otherwise motion is at .5 deg/sec  
`move_abs.py -30`
6. Create a directory for your site, e.g. the location name, and move into  
`mkdir Rosenlauri`  
`cd Rosenlauri`
7. 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 1 for the description. Depending on the maximum range you want to observe select the corresponding chirp rate in Section 6. (Table 2).  
You can copy a template preference file from /usr/share/gpri/profiles. Its a good idea to give it a descriptive name (site, name), especially if you do repeat measurements.  
`cp /usr/share/gpri/profiles/gpri_2ms.prf site_2ms.prf`
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. Description of the values is given in Section 6.6.1 .
9. Run listen only first to check for other transmissions.  
`gpri2_capture_utc.py gpri_2ms.prf raw/20110714 \  
1 now 1 -p slc/20110714 -m mli/20110714 \  
-d 5 -r 10 -s .3 -e .5`
10. Then display the processed data:  
`eog mli/20110714/20110714_083514*.ras`  
`gpri2_plot.py gpri_2ms.prf raw/20110714/20110714_083514.raw`
11. If no foreign signals are present start active measurement to derive gain settings (don't forget to set power on in the prf file!):  
`gpri2_capture_utc.py gpri_2ms.prf raw/20110714 \  
1 now 1 -p slc/20110714 -m mli/20110714 \  
-d 5 -r 10 -s .3 -e .5`

12. Then display the processed data:

```
eog mli/20110714/20110714_084014*1.ras
```

```
gpri2_plot.py gpri_2ms_ro.prf raw/20110714/20110714_084014.raw
```

Check signal levels in gpri2\_plot to make sure there is no saturation and that there is sufficient signal and adjust attenuation setting in the prf file. Redo step 11./12. until gain is ok

13. If attenuation setting is ok go for repeat measurements :

```
gpri2_capture_utc.py gpri_2ms.prf raw/20110714 \
```

```
1 now 180 -p slc/20110714 -m mli/20110714 \
```

```
-d 5 -r 10 -s .3 -e .5
```

14. Generate a differential interferogram from selected SLC files. It makes sense to check upper/lower antenna pairs and some succeeding pairs for data quality.

```
create_offset slc/20110714/20110714_084014l.slc.par \
```

```
slc/20110714/20110714_084014u.slc.par \
```

```
int/20110714_084014l_20110714_084014u.off 1
```

Parameters to provide: dummy\_create\_offset 0 0 48 48 256 256 7.0

```
SLC_intf slc/20110714/20110714_084014l.slc \
```

```
slc/20110714/20110714_084014u.slc \
```

```
slc/20110714/20110714_084014l.slc.par \
```

```
slc/20110714/20110714_084014u.slc.par \
```

```
int/20110714_084014l_20110714_084014u.off \
```

```
int/20110714_084014l_20110714_084014u.int 5 1 0 - 0 0
```

```
multi_look slc/20110714/20110714_084014l.slc \
```

```
slc/20110714/20110714_084014l.slc.par \
```

```
mli/20110714/20110714_084014l.mli \
```

```
mli/20110714/20110714_084014l.mli.par 5 1
```

```
rasmph_pwr int/20110714_084014l_20110714_084014u.int \
```

```
mli/20110714/20110714_084014l.mli 1016 1 1 0 1 1 0.4 0.35
```

```
eog int/20110714_084014l_20110714_084014u.int.ras
```

```
cc_wave int/20110714_084014l_20110714_084014u.int \
```

```
mli/20110714/20110714_084014l.mli - \
```

```
int/20110714_084014l_20110714_084014u.cc 1016 3 3 1
```

```
rascc int/20110714_084014l_20110714_084014u.cc \
```

```
mli/20110714/20110714_084014l.mli 1016 1 1 0 1 1 .1 .9 0.4 0.35
```

15. If applicable create interferograms with previous campaigns to check data consistency. Note that most likely the data need to be coregistered to correct for small offsets in the azimuth angle alignment. Use only linear offsets for the offset estimation. The following procedure is used to coregistered the second slc to the master (->rslc):

```
create_offset slc/20110714/20110714_084014l.slc.par \
```

```
slc/20110714/20110714_084014u.slc.par \
```

```
int/20110714_084014l_20110714_084014u.off 1
```

```
slc/20110714/20110714_084014l.slc \
```

```
slc/20110714/20110714_084014u.slc \
```

```
slc/20110714/20110714_084014l.slc.par \
```

```
slc/20110714/20110714_084014u.slc.par \
```

```
int/20110714_084014l_20110714_084014u.off
```

```
int/20110714_084014l_20110714_084014u.offsets
```

```
int/20110714_084014l_20110714_084014u.snr
```

```
offset_fit int/20110714_084014l_20110714_084014u.offsets
```

```

int/20110714_084014l_20110714_084014u.snr
int/20110714_084014l_20110714_084014u.off
int/20110714_084014l_20110714_084014u.coffs - - 1 0
SLC_interp slc/20110714/20110714_084014u.slc $slc1.par \
slc/20110714/20110714_084014u.slc.par \
int/20110714_084014l_20110714_084014u.off \
rslc/20110714/20110714_084014u.slc.rslc \
rslc/20110714/20110714_084014u.slc.rslc.par \

```

now that the interferogram is created using the master slc and the rslc as in Step 14 above.

16. Backup data. e.g. with secure copy or rsync to a network attached disk. Use ionice to avoid disk timeouts while acquiring data:

```

ionice -c2 n7 scp -r Rosenloui 192.168.1.1:backupdirectory/
ionice -c2 n7 rsync -av Rosenloui 192.168.1.1:backupdirectory/

```

or plug 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

```

or sometimes its just

```
[1295858.275046] sdb:
```

Mount the device on /mnt for user gpri2 with

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

The data can now be copied to and from /mnt.

```
ionice -c2 -n7 cp -av Rosenloui /mnt
```

Make sure you unmount the device at the end

```
sudo umount /mnt
```

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

```
home_run.py
```

18. **and shut down the Instrument Controller properly**

```
sudo shutdown -P now
```

**and switch off the power at the yellow Pelican box.**

### 3.2.2 Operating the instrument through HTTPS

The Instrument Controller provides a web based user interface. It can be accessed through secure http (https) and needs authentication. Detailed description is given in Section 5.2 . Here we describe the minimal steps to run a measurement and check data quality.

1. Access instrument by browsing to the IP address of the instrument (Figure 12). Ignore the certificate complaint and provide username and password.
2. Check the entries in the Accordion Panel on the right (temperatures and GPS status) and finally do a homerun of the motor (Figure 13) to initialize the Home Position of the motor.
3. Determine the start and stop angles for the scan by moving the antenna around using the Motor Menu in the Accordion Panel on the right. Be aware that about additional 3 degrees are needed on both sides for the motor to accelerate and decelerate.
4. In the Measurement Control Tab, start the measurement setup (Figure 14). The measurement



form is setup setp-by-step when the corresponding data is provided (Figure 16)

- First you have to either select an existing Project Directory or create a new one. The directory is/will be allocated in the `data` directory.
  - Then you have to select an existing measurement profile or create a new one. Existing profiles can be edited (Figure 15). The profile will be store in the Project directory. Profile parameters are described in Section 6.6.1 .
  - Provide information on measurement timing. For initial tests single measurements conducted now are convenient.
  - It makes sense to process the data to SLC (single look complex data) and produce MLI (multi look intensity) images for quality control and check if the signal level is sufficient but not saturating (attenuation setting in the profile). Data will be stored in `slc/date/date_time.slc` and `mli/date/date_time.mli`.
  - Start the measurement.
  - The log of the measurement is shown in the tab below the Measurement Control Tab in the Data Capture Log and the images can be quickly accessed in the Images Tab.
  - Do an initial measurement with `TX_power` switched off to check for RFI (→ black image) and then check the attenuation level required for the scene.
  - When the images are satisfying repeat observation can be initiated preferably by adding the settings as a Repeat Task on the Scheduler (Click the corresponding link, Figure 16). So the number of measurements should in general be 1, if you want to do repeat measurements its generally better to use the Scheduler. The task scheduler provides access to the Cron Settings. The settings to measure every 10 minutes are shown in Figure 17.
5. To check quality it is worthwhile to compute interferograms of the acquired data, at least for an upper/lower antenna pair and two successive acquisitions at the same antenna. The processing can be initialized in the Compute Interferogram Tab (Figure 18). Again first the project directory needs to be selected, providing a list of all available SLC images for pair selection. If the data were not acquired during the same campaign its very likely that they have a slight offset in azimuth and need to be coregistered. Uncheck the checkbox in that case! The resulting interferogram images can again be found in the Image Tab below.
  6. Data can be retried from the directory browser or the file manager, accessible through the Main Menu option System Access (Figure 19).
  7. Make sure to do a home run before switching the instrument off from the comand line (`sudo shutdown -P now`) and finally the switch at the yellow Pelican case.

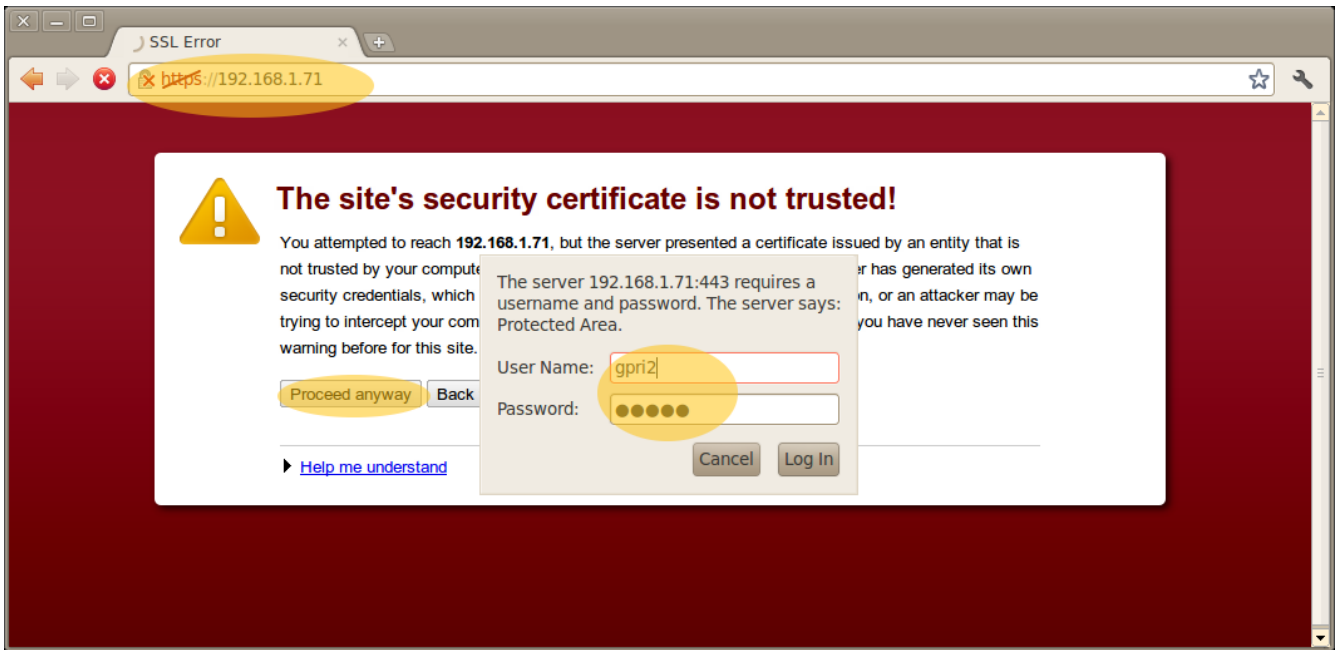


Figure 12: Instrument Web Access Login.

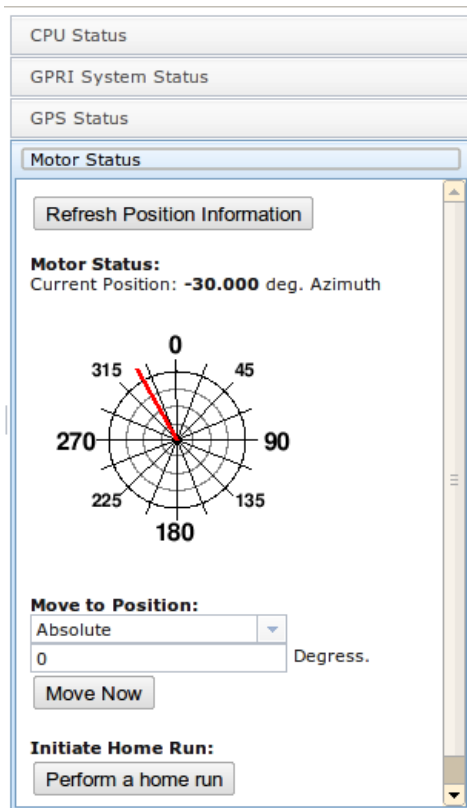


Figure 13: Motor Status Accordion Panel.

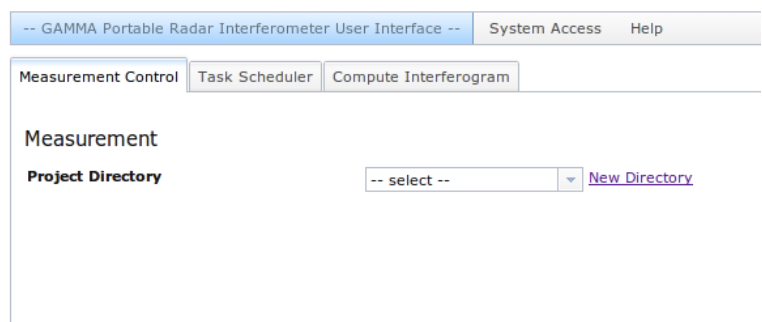


Figure 14: Initial Measurement Control Tab.

The screenshot displays the GPRI-II User Interface in a web browser. The main content area is titled "Measurement Control" and contains several configuration sections:

- Project Directory:** A dropdown menu set to "Lab" with a "New Directory" link.
- Profile:** A dropdown menu set to "Lab\_20110914\_4ms.prf" with an "Edit Profile" link and a list of profiles: "New 250us, 500us, 2ms, 4ms, 8ms Profile".
- Number of Measurements:** A text input field containing "1".
- Starting Time in UTC (YYYY-MM-DDTHH:MM:SS or now):** A text input field containing "now".
- Repeat interval in seconds:** A text input field containing "180".
- Create SLC:** A checked checkbox.
- RAW data decimation factor:** A text input field containing "5".
- Starting Slant Range in meters:** A text input field containing "50".
- Maximum Slant Range in meters:** A text input field containing "0".
- Antenna Center Azimuth Heading:** A text input field containing "0".
- Turn off azimuth interpolation:** An unchecked checkbox.
- Create MLI:** An unchecked checkbox.
- Delete RAW data:** An unchecked checkbox.

Below these settings are three buttons: "Start Measurement Now" (highlighted with a yellow circle), "As Repeat Task to Scheduler", "As 1-time Task to Scheduler", and "Show Commandline".

The right sidebar shows system status information:

- CPU Status:** Includes a "Refresh Content" button.
- GPRI System Status:** Shows "Current System Date: 23-09-2011" and "Current System Time: 00:31:00".
- TSCC Status:** Shows "Software Version: SW V1.07", "Voltage: 23.0 V", and "Temperature: 47.0 °C".
- CHUPA Status:** Shows "Software Version: SW V1.01" and six voltage readings (3.13 V to 22.75 V) with a temperature of 42.5 °C.

The bottom section of the interface shows a terminal window with the following text:

```

gprutils GPRI2 driver installed
data acquisition starting time (UTC): 2011-09-22 13:40:01.938076+00:00

File Number: 1 start time: 2011-09-22 13:40:01.938076+00:00 raw: /data/Lab/raw/20110922//20110922_134001.raw log: /data/L
ionice -c2 -n0 gpri2_capture.py --nosemaphore -e eth1 -f 0.0 -M -P -S 1 -s -k 1.0 -v -p /data/Lab/Lab_20110914_4ms.prf -o /data/Lab/
gpri2_proc.py /data/Lab/raw/20110922//20110922_134001.raw /data/Lab/raw/20110922//20110922_134001.raw_par /data/Lab/slc/2
multi_look /data/Lab/slc/20110922//20110922_134001u.sic /data/Lab/slc/20110922//20110922_134001u.sic.par /data/Lab/ml/201109
raspwr /data/Lab/ml/20110922//20110922_134001u.mli 11184 1 0 1 1 0.400 0.350
raspwr /data/Lab/ml/20110922//20110922_134001u.mli 11184 1 0 1 1 0.400 0.350
convert /data/Lab/ml/20110922//20110922_134001u.mli.ras /data/Lab/ml/20110922//20110922_134001u.mli.png
convert /data/Lab/ml/20110922//20110922_134001u.mli.ras /data/Lab/ml/20110922//20110922_134001u.mli.png
move_abs.py 30.000 10.0

```

At the bottom, there are tabs for "Data Capture Log", "Processing Log", and "Images". The bottom right corner shows "GPS Status" and "Motor Status".

Figure 16: Measurement Settings. The button starts the measurement as a single task, the links allow to transfer the settings to the Repeat task Scheduler.

Measurement Control Task Scheduler Compute Interferogram

### Recurrent Tasks

**Active** On

**Command** /usr/bin/gpri2\_capture\_utc.1

**Minutes** \*/10

**Hours** \*

**Days** \*

**Months** \*

**Weekdays** \*

**Comment**

[Add Recurrent Task](#)

### One time Tasks

ID	Execution Date	Command
<a href="#">Add New One-Time Task</a>		

### Recurrent Tasks

Run at

Figure 17: Recurrent Task Menu (Cron Interface).

Measurement Control Task Scheduler Compute Interferogram

### Interferogram

**Project Directory** Lab

**SLC 1** 20110922\_134001l.slrc

**SLC 2** 20110922\_134001u.slrc

**Number of Looks in Range** 5

**Number of Looks in Azimuth** 1

**Selected SLC are already coregistered**

Compute Interferogram

Figure 18: Compute Interferogram Tab.

-- GAMMA Portable Radar Interferometer User Interface --

Measurement Control Task Scheduler Compute Interferogram

Measurement

- System Access
- Data Directory
- File Manager
- Shell Access
- Help

Figure 19: Main Menu.

## 4. Detailed Instrument Description

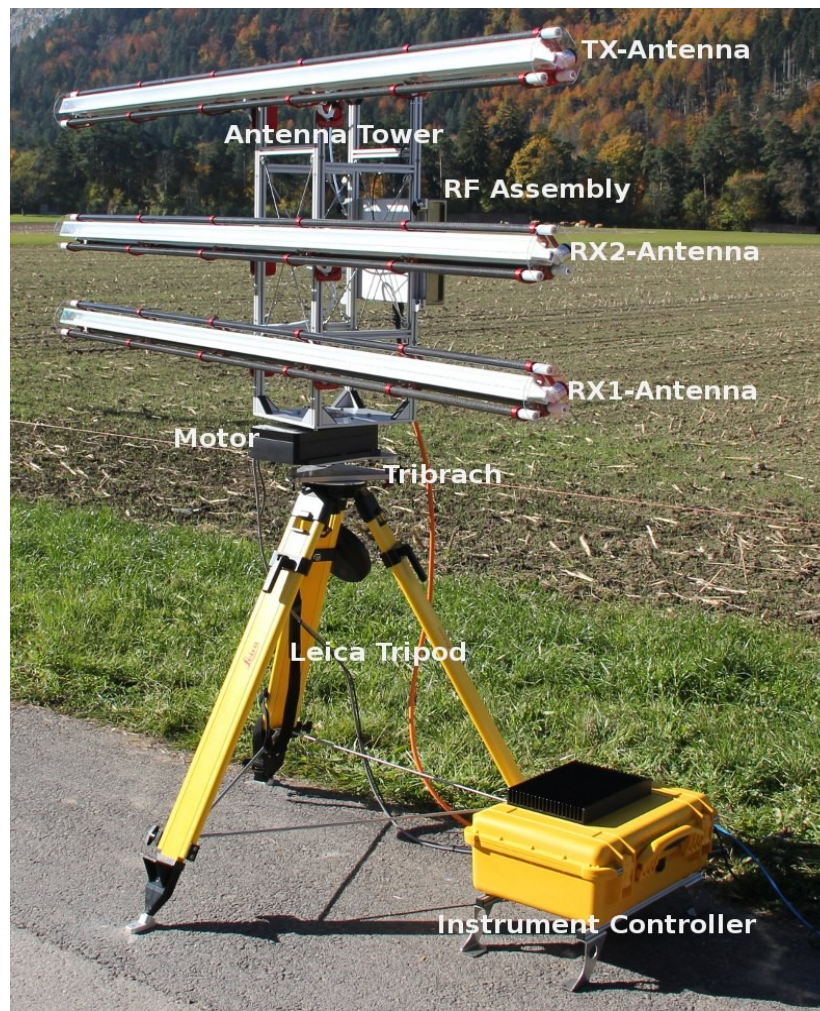


Figure 20: GPRI-II fully assembled. Instrument is aligned at 0 deg. azimuth position.

### 4.1 Instrument Components / Package List

The instrument consists of the following components:

- 3 Fan-Beam Antennas
- 1 RF Assembly (Aluminum case)
- 1 Instrument Computer (yellow Pelican case)
- 1 Power Cord (black)
- 1 Instrument Cord (orange)
- 1 Antenna tower with attached GPS antenna
- 1 Leica tripod with 3 aluminum rods (orange bag)

- 1 Positioner with tribach leveler
- 1 Laser Plummet Battery Pack

Additional items necessary for field work

- Power generator with spare fuel
- Network Switch and 2 Ethernet cables
- Laptop computer
- Backup disk
- Drill and screws, washers, anchors to fix the tripod to the ground (6mm screws should be fine)
- socket screw key (socket screw key) 5mm

## **4.2 Instrument Hardware**

The GPRI-II instrument benefits from the experience of the GPRI-1 in the mechanical and electronic design.

The GPRI-II has the following enhancements with respect to the GPRI-1:

1. Improved tower support based on the industry standard Leica mount system with a custom designed tribach for leveling and repositioning.
2. Azimuth scanner based on Newmark RMS-5S (IP67) rotary stage. Continuous scanning with a single sweep acquisition 10 deg/sec.
3. Slotted-waveguide antennas 2.06m long, beam 0.4 azimuth beam. 37.5 deg. elevation pattern
4. DDS controlled chirp generator design with improved phase noise and negligible spurs (AD-9910)
5. Self-contained Linux-based computer for scheduling, data acquisition, processing, and display. Linux OS (Ubuntu 10.04 LTS) with web and scheduling services and supports the security required for autonomous operation.
6. ETTUS USRP2 Software Defined Radio (SDR) dual-channel 14-bit streaming Analog to Digital Converters (ADC).
7. Improved cabling with a single cable from the RF enclosure to the Peli-Case containing the instrument controller, power-supply, and SDR.
8. Power input of 110-240 VAC and +24VDC. Weather sealed enclosures (IP65) with cooling via heat-sinks and internal fan. Operation over temperature range -20 to +40C.

## 4.2.1 GPRI-II Electronics

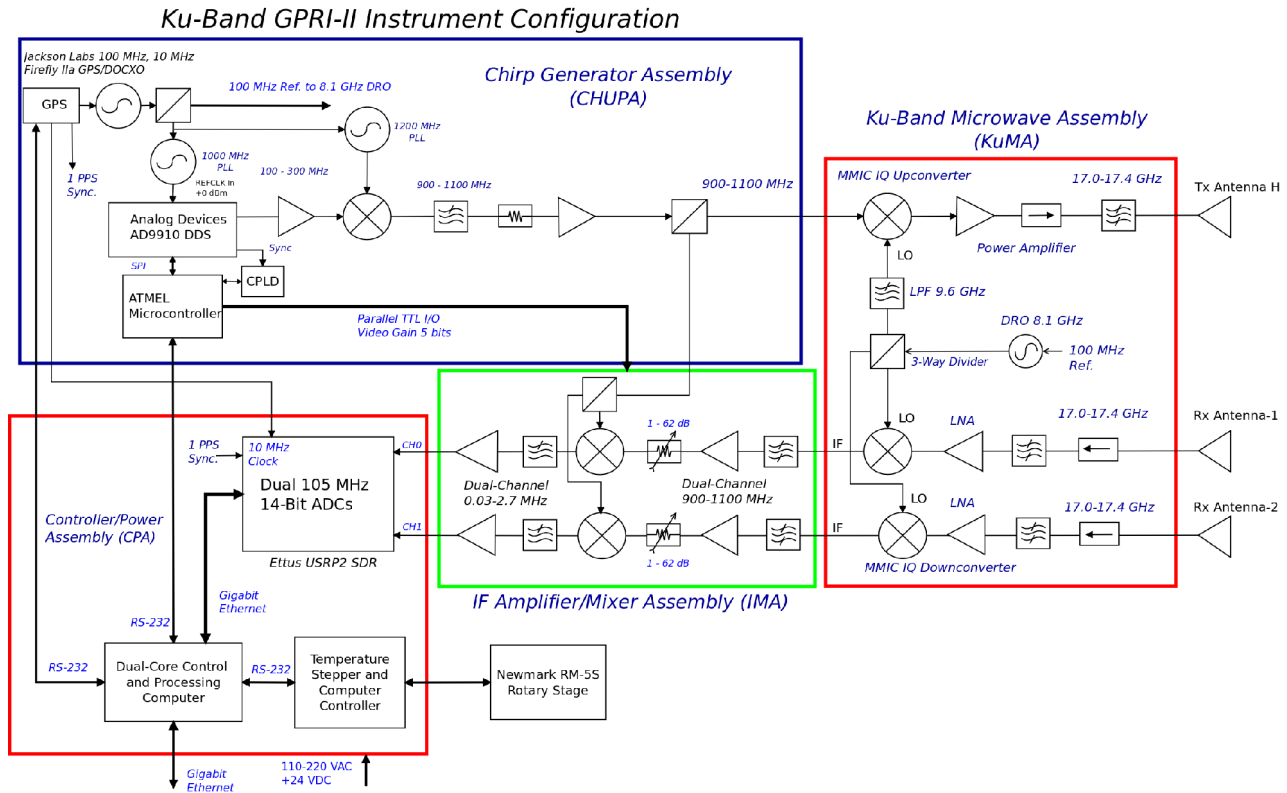


Figure 21: GPRI-II System Level Design

The high-level block design of the GPRI-II is shown in Figure 21. The main elements in the electronics are the Chirp Generator Assembly (CHUPA), IF Amplifier/Mixer Assembly (IMA), Ku-Band Microwave Assembly (KuMA), and the Computer and Power Assembly (CPA). We retain the dual receive channel design of the GPRI-1 to support recording interferograms with a spatial baseline defined by the antenna separation on the tower. The GPRI acquires data with a few milliseconds minimizing the effects of temporal decorrelation.

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, ADC and stepper motor controller are all within the controller/power assembly enclosure. Temperature and power regulation are steered by a micro-controller on the TSCC (Temperature, Stepper, Computer Controller) board. It is responsible for ensuring that the temperature within the enclosure is within operational limits.

### Chirp Generator

The chirp generator module generates a linear FM pulse over the 900-1100 MHz frequency range. The most critical component in the chirp generator is the Direct Digital Synthesizer (Analog Devices AD9910). This DDS has substantially better phase noise characteristics relative to the AD9858 used in the GPRI-1 instrument. This is due primarily to the 14-bit ADC (the AD9858 uses a 10-bit ADC). The linear ramp generator in the DDS can be set to produce a continuous series of pulses.

The system reference signal is provided by a GPS disciplined 100 MHz crystal oscillator (Jackson

Firefly-II). The DDS 1 GHz clock signal is generated using a Phase-Locked Loop (PLL) oscillator that uses the 100 MHz system clock as reference. All GPRI-II timing and reference signals are derived from the 100 MHz reference oscillator such that the radar is fully synchronous.

Programming of the DDS is via a 3-wire serial protocol. A small micro-controller handles this protocol and communicates with the Instrument Computer over an RS-232 serial line. The DDS produces a chirp in the frequency range 100 to 300 MHz. This chirp is first heterodyned to the frequency range 900 to 1100 MHz. The first local oscillator (LO) is a 1200 MHz Phase-Locked Loop operating above the desired 900-1100 MHz sideband.

The microwave LO is a phase-locked Dielectric Resonator Oscillator (DRO) operating at 8.1 GHz. The output chirp spanning 17.1 to 17.3 GHz is then filtered, then amplified and then feed to the antenna. An isolator in the output path provides a constant load for the input and output RF amplifiers. In the receiver, the signals from the 2 receiver antennas are amplified, filtered, and mixed down to 900-1100 MHz using the DRO LO signal. We use an MMIC active mixer with integral LO amplifier (Hittite HMC570LC5) for this function.

The IF signal is then further amplified and mixed with the original transmitted chirp (FM-CW). A portion of the chirp signal spanning 900 to 1100 MHz is amplified and used to demodulate the received signal. Digitally programmable attenuators are used to set the receiver gain. The second mixer is a high-level MMIC active mixer with integral LO amplifier (Hittite HMC686LP4). The baseband demodulated signals lie in the range 0.30 to 2.5 MHz. The frequency of the demodulated signals is proportional to distance from the radar.

These two baseband channels are amplified and digitized at 6.25 MHz by 14-bit analog-to-digital converters (ADC). These ADCs are in the front-end of the ETTUS USRP-2 Software Defined Radio (SDR) that streams data samples over raw Ethernet to the system instrument computer.

One of the significant advantages of the GPRI-II design is the ability to change the output operating frequency by changing the LO frequency. Another important feature is the use of gain modules with constant gain over the passband in the IF module.

The microwave electronics use MMIC modules on co-planar-waveguide boards rather than connectorized modules as in the GPRI-1. This major advantages including

1. Elimination of connectors and cabling, leading to reduction in losses, less connectors and shorter transmission lines
2. Approximately 3 times less power consumption leading to substantially less heat generation
3. Lower cost, typical MMIC components cost a fraction of the connectorized component but require a custom microwave coplanar waveguide circuit board and custom enclosure.
4. Simpler mechanical construction, parts are integrated on the circuit board. Reduced size and mass elimination of heat-sinks.
5. Better performance, amplifier efficiency is about 2.5 times better than connectorized versions. Better noise figure due to lower losses.

Microwave components from Hittite are the basis of the GPRI-II up- and down converters. The HMC710LC5 is an IQ frequency up-converter and the HMC570LC5 is the matching receiver IQ down-converter. These chips contain a 2 local oscillator (LO) amplifiers, a X2 frequency multiplier, a 90 degree splitter, 2 balanced mixers, and an RF amplifier packed within a 5x5 mm square package. The up-converter is used to heterodyne the 0.9 to 1.1 GHz chirp to 17.1 to 17.3 GHz. The down-converter is used in the receiver to amplify and translate the receiver input signal down to 0.9 to 1.1 GHz. The



transmit signal for the up-converter is then filtered and amplified using a HMC498LC4 amplifier chip that can produce up to 150 mW of output power. The receiver has a low-noise amplifier input (HMC516LC5) with a noise figure of 2.2 dB followed by a bandpass filter. The up and down-converters utilize IQ mixers that have the advantage of suppressing noise from the image spectrum of the input signal. The local oscillator for both the up- and down-converters is a dielectric resonator oscillator operating at 8.1 GHz and phase locked to the 100 MHz reference signal.

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. All signals are relatively low frequency ( $\leq 10$  MHz). The receiver uses output buffer amplifiers with the capability to drive capacitive loads such as a coaxial line. The receiver output goes directly to the input of the ADCs in the CPA enclosure.

## 4.2.2 Antenna

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 (-15 dB). The predicted antenna pattern, shown in Figure 22, illustrate how the antenna squints approximately a total of 1 degree when sweep from 17.1 to 17.3 GHz. This squint effect can be compensated in the data processing as long as the scene remains coherent for the time period of the observations that cover the scene. Assuming that data are oversampled in azimuth ( $< 0.1$  degree spacing) the data can be readily interpolated as a function of frequency to create a data set that is equivalent to an antenna with a fixed beam in one direction. What is important is that the scene remains coherent during all observations that cover a specific direction.

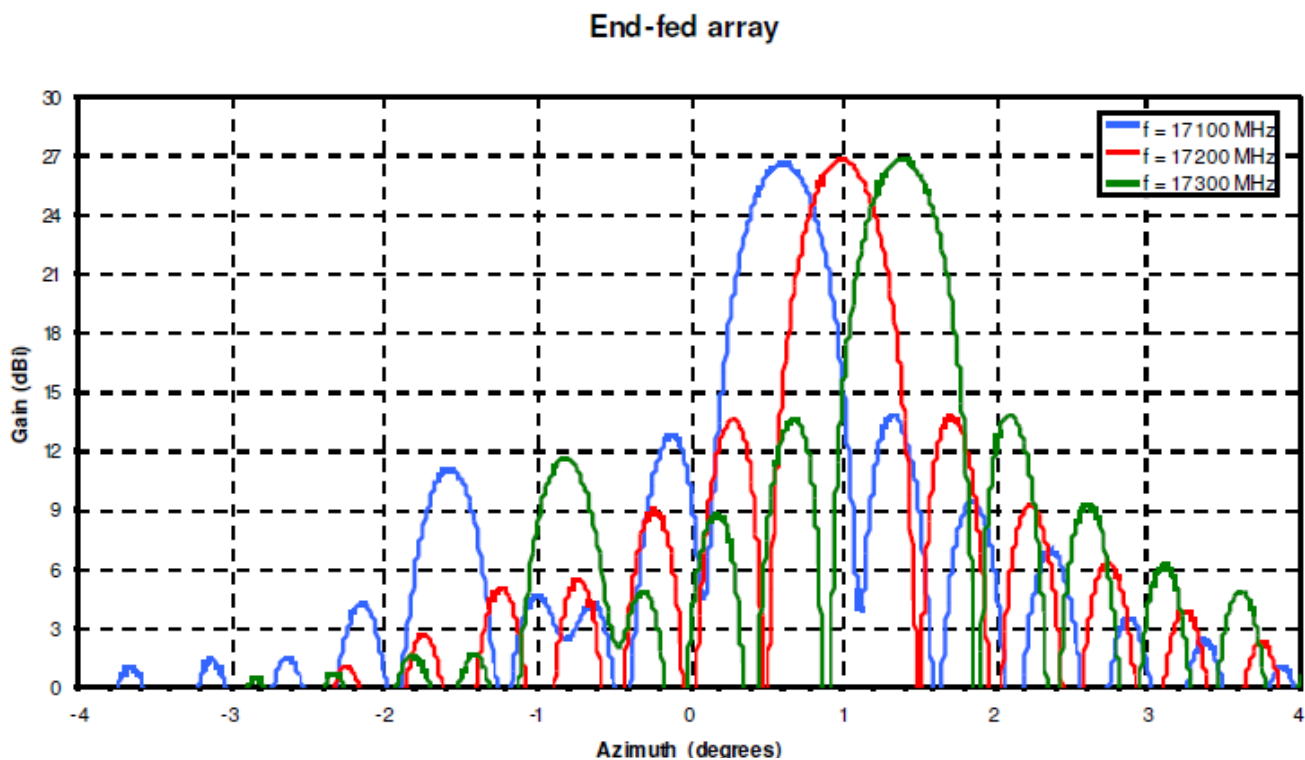


Figure 22: End-fed Array performance for GPRI-II antenna

The new antenna is designed with an aluminum flare that determines the elevation beamwidth of 37.5

deg. There is a thin plastic sheet over the flare opening to seal the antenna against moisture. The GPRI-II antennas and support is designed to fit in a 125 mm PVC shipping tube.

The antennas are supported on a carbon-fiber truss structure as shown in Figure 23. The carbon tubes are symmetrically positioned about the waveguide so there is access from -45 degrees to +45 degrees in elevation.

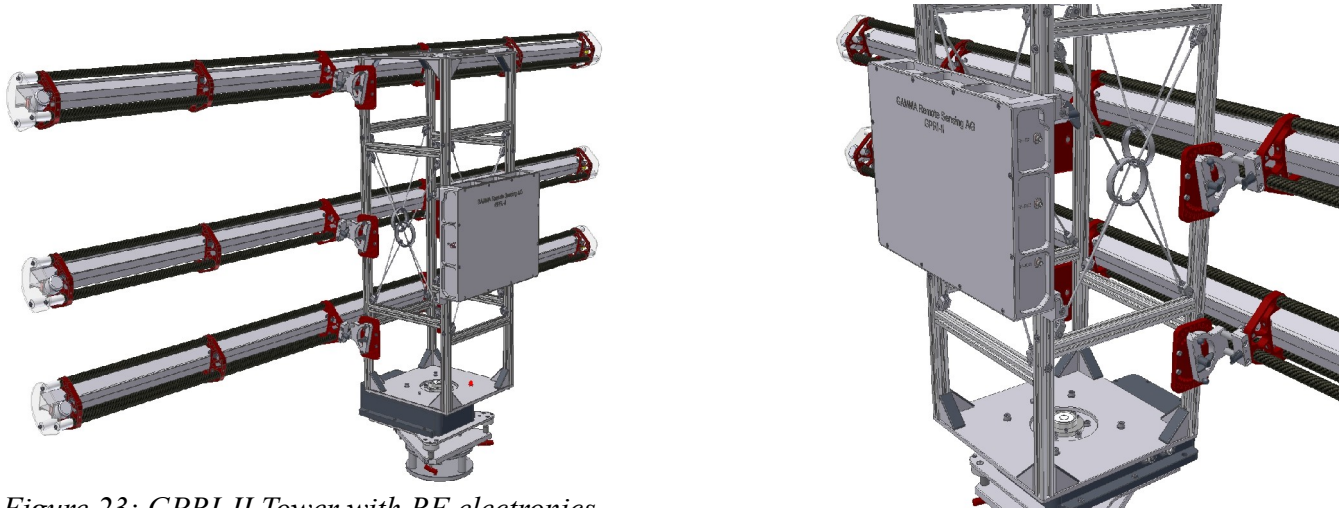
## 4.2.3 Mechanics

### ***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 10. These cross-struts stiffen the tower to reduce torsional deformation.

### ***Tripod, Positioner and Tribach Leveler***

The tripod supporting the scanner and antenna tower is a Heavy-Duty Leica 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 is used to ensure that the tripod itself is level within a few tenths of a degree. The tripod can be leveled approximately by moving out the legs. The feet of the tripod have been modified so that there is an aluminum bracket that can be fixed to the ground using a screw in an anchors (Figure 24). This arrangement permits accurate repositioning of the GPRI-II for later data acquisitions. A small laser on the tribrach rotational axis can be used to see the rotation axis as projected 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.

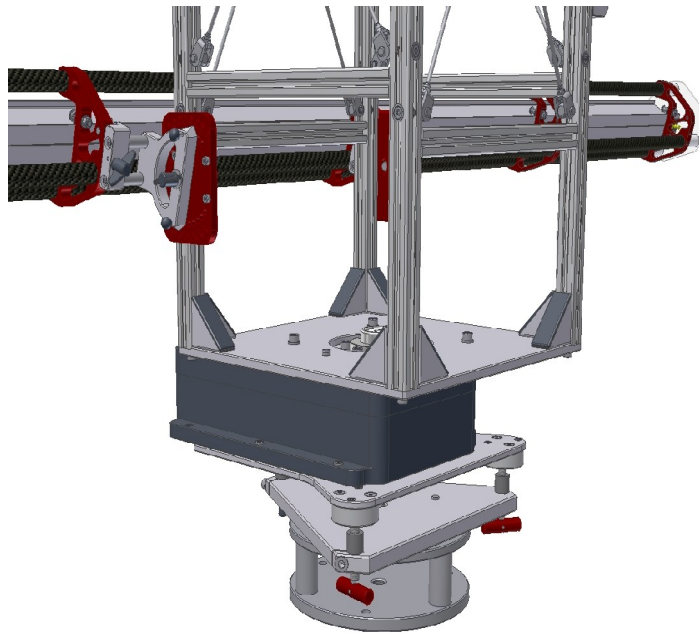


*Figure 23: GPRI-II Tower with RF electronics.*

A rugged custom tribrach supports the tower and is used to adjust the axis of rotation to be vertical. The tribrach incorporates a small laser for centering the tower axis of rotation about a benchmark. In addition a heavy-duty adapter is provided to mount the tribrach on geodetic monuments or other structures (Figure 25).



*Figure 24: Tripod mounting adapter for screw anchor mounting.*



*Figure 25: Tribrach with azimuthal scanner and tower. Adapter for fixed mounting is shown attached to the tribrach. Red knobs adjust the tilt of the tribrach motor mounting plate.*

### **Azimuthal Scanner**

The GPRI-II uses the Newmark RMS-5S azimuthal scanner. This scanner uses a stepper motor with a 72:1 gear reduction. This positioner has a repeatability of 5 arc-sec, and a resolution of 0.36 arc-seconds. The maximum load for the RMS-5S is 36.4 kg and it has a mass of 5 kg. The TSCC micro-

controller and stepper driver support smooth ramp-up and ramp-down of the rotational velocity to permit stable rotation without vibration. Nominal rotational scan velocity is in the range of 5 to 10 deg./sec.

### ***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. (see Figure 26). A gasket for the top and bottom plates makes the RF enclosure waterproof. The top and bottom covers are 3 mm thick aluminum plates. A single 19-pin MIL C26582 connector is used for signals and power to the Radio Frequency Assembly (RFA). SMA microwave connectors for the TX output and RX inputs are mounted on the side of the RFA.

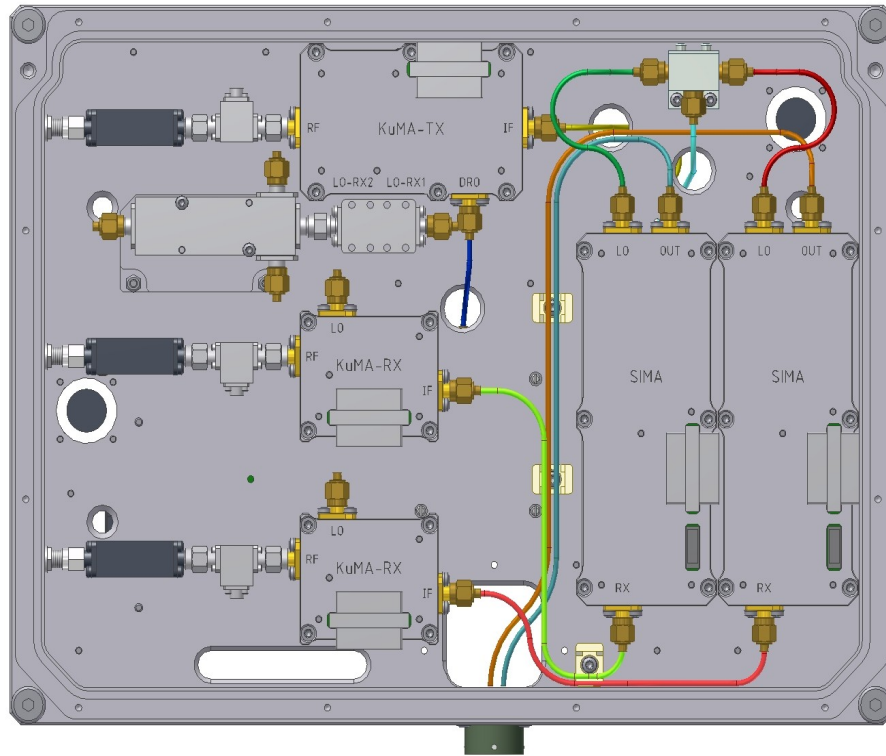
The cable connecting the RFA and Instrument Computer carries power, serial communication, and the analog receiver output. The RFA is powered by +24 volt DC that is then converted to the various voltages used by the RFA modules in the DISTRI module inside the RFA enclosure.

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

The Ku-Band Microwave Assembly (KuMA) contains a Transmitter (TX) and two Receiver modules (RX). The TX module accepts as input the chirp signal with a frequency range between 900 and 1100 MHz. This signal is up-converted, using a quadrature mixer to the 17.1 to 17.3 GHz frequency range and then amplified. The TX RF output power level is approximately 100 mW at the TX output connector.

The RX modules accept an microwave RF signal in the covering 17.1 to 17.3 GHz and down-converts this signal to the 900-1100 MHz band using a quadrature (IQ) mixer. The output signal level of the RX module is approximately -60 dBm. The input local oscillator for both the TX and RX mixers has a frequency of 8.1 GHz. The quadrature mixers have an internal x2 frequency multiplier to generate an internal LO at 16.2 GHz that is used in the up or down conversion. An external 3-way power splitter is used for the distribution of the 8.1 GHz local oscillator signal to the KuMa TX and RX modules.

The receiver IF amplifier assemblies (SIMA) amplify the output of the KuMA RX down-converters and deramp the echo to obtain an echo in slant range geometry. Communication and control of the RFA is via a micro-processor located in the CHUPA. The CHUPA can configure the chirp parameters, receiver gain, and control power to the different modules. Thermally-controlled fans in the enclosure circulate air to promote cooling and thermal stability.



*Figure 26: RF Electronics Assembly Interior showing KuMA-TX and KuMA-RX modules along with the SIMA.*

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

### **Controller and Power Unit**

The control and power unit (Figure 27) contains the power supplies that convert 100-240 VAC or 18-32 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. LED lights indicate that power is available and that the computer communication has been established. Output connectors are provided for the RF electronics and the azimuthal scanner. Additional ports for Ethernet and USB interfaces are also available.

The instrument controller and power unit contains a 2.8 GHz Intel Core 2 Duo Processor T9600 on a Kontron KTGM45 mini-ITX form-factor CPU board with 4 GB RAM and 500 GB SATA disk. An ATMEL micro-controller switches the PC, GPS, and RF assembly power, monitors temperatures, and drives the stepper motor controller. The micro-controller is integrated on a single board along with the power supplies for the Linux computer, azimuthal scanner, internal fans, and USRP2 SDR. Input to the power supply is 100-240 VAC, or +18 to +32 VDC.

Two internal fans circulate the air inside the Pelican case and transfer heat to 2 external heat sinks, one on the under-side of the Pelican case and the top cover. The internal fan speed is regulated to provide some control of the internal temperature. A goal for temperature regulation is that the internal temperature is in the range of 0-45 C. The heat transfer out of the case is about 4-5 W/deg. Given the maximum electronics thermal load, the interior temperature of the case is 15-20 deg C higher than the external temperature.



*Figure 27: Computer and Power Assembly*

### **4.3 Instrument Software**

The instrument has different levels of software. The instrument controller is running Ubuntu Linux 10.0.4 (Long Term Stable) as Operating System. On top of that different system services such as *openssh* and *lighttpd* and tools that are provided through the Ubuntu software repository are running. Additional instrument specific software is provided through the GAMMA gpri2 Debian software repository (deb [http://apt.gamma-rs.ch/lucid\\_gpri2\\_stable/](http://apt.gamma-rs.ch/lucid_gpri2_stable/)). It covers the GPRI-II instrument software, and the GPRI-II data post-processing software. Not included is the standard GAMMA software packages for InSAR data analysis.

## **5. 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 Pelican 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 Access**

To have local access on the Instrument Controller the Pelican case needs to be opened and a computer screen (VGA) and a Keyboard and Mouse (USB) can be attached. After booting up the instrument the Ubuntu login screen shows up. The user to login is gpri2. After logging in the standard gnome user interface is shown. It allows full access on system settings, in particular also the network settings.

### **5.2 Graphical User Interface**

The graphical user interface can be accessed with any recent (Javascript enabled) web browser by requesting <https://192.168.1.73/> (the IP needs to reflect your setting). After logging in as user gpri2, you have access on system status information, instrument settings etc. The graphical user interface gives you only access on the most important instrument functions. For full system access use the terminal access or the local access.

### **5.3 Terminal Access**

The instrument terminal can be accessed through secure shell (ssh). The export of the X11 windows is supported. You can initiate this feature by logging in with the option `-X` (`ssh -X gpri2@192.168.1.73`). The terminal access gives you full access on the system.

## 6. Software Reference

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.

### 6.1 Acquire data

The basic program to acquire data is `gpri2_capture.py`. However, usually it is much more convenient to use `gpri2_capture_utc.py` or `gpri2_capture_all.py`. These two scripts are wrapping around `gpri2_capture.py`. The main difference among them is that `gpri2_capture_utc.py` names output files with timestamps while `gpri2_capture_all.py` uses a sequential numbering. Furthermore `gpri2_capture_utc.py` allows to have the data processed to SLC or MLI format on-the-fly. So using `gpri2_capture_utc.py` is the recommended way to acquire data.

#### 6.1.1 gpri2\_capture\_utc.py

Script to capture a series of raw data sets at fixed time intervals starting at a specific UTC time-stamp, or immediately:

```
$ gpri2_capture_utc.py
*** 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      GPRI2 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 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
  -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 GPRI2 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) or type now to start the first scan right away.

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

## 6.1.2 gpri2\_capture.py

This program acquires a single GPRI2 raw data set. 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 6.6.1 . There are template profiles (\*.prf) for different duration chirps (250us, 500us, 1ms, 2ms, 4ms, and 8ms).

```
*** GPRI-II data capture program v2.0 12-Jul-2011
Usage: gpri2_capture.py: [options] -p profile -o output_filename
```

### Options:

```
-h, --help                show this help message and exit
-e INTERFACE, --interface=INTERFACE
                          use specified Ethernet interface [default=eth0]
-m MAC_ADDR, --mac-addr=MAC_ADDR
                          use USRP2 at specified MAC address [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 USRP2 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]
--rx-bufsize=RX_BUFSIZE  set rx buffer size to RX_BUFSIZE [default=0]
-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-II acquisition profile [default=None]

```

## 6.2 Quality control field analysis of data

Here we group the programs that are needed to check data quality. That includes range profile analysis, (gpri2\_plot.py) conversion of raw data to SLC (gpri2\_proc.py and gpri2\_proc\_all.py) and MLI (multi\_look) and visualisation (raspwr), and computation of an interferogram of two co-registered images (create\_offset, SLC\_intf) and visualisation rasmph\_pwr. The tools shall allow to get an idea about data quality in the field.

### 6.2.1 gpri2\_plot.py

Usage: gpri2\_plot.py v1.2 30-Nov-2010: [options] profile raw\_data

Takes a gpri2 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 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=0]
-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=1]
-y YMAX, --ymax=YMAX  maximum value for range-profile magnitude:
                        [default=20.0]

```

## 6.2.2 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
--png                    generate PNG output image
```

## 6.2.3 gpri2\_proc.py

Takes a GPRI2 echo data and process to SLCs for channel-1 and channel-2. In the case that the data are acquired with alternating transmit polarization (C-Band only) then the user can specify the transmit polarization. The two SLCs are then obtained with from the data where the specified transmit polarization was used. The names of the SLC will include either H or V prior to the extension eg. 20110707\_115716Hu.slc was acquired with H transmit polarization from the upper receiver channel. Upper and lower refer to the RX channels on the side of the RFA.

Usage: gpri2\_proc.py: [raw\_data] [raw\_par] [slc1] [slc2] options

Process GPRI-2 raw data to SLCs v2.1 27-July-2011 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 about 5 meters, **-r 5**

The maximum slant range in the SLC is given by the **-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 2ms 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 GPRI2 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** 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 kaiser is 3.0 that results in range sidelobes < -35 dB

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 then generated from the data with the selected transmit channel.

## 6.2.4 gpri2\_proc\_all.pl

Script to process a series of SLC images using gpri2\_proc.py:

```
*** ./gpri2_proc_all.pl
*** GPRI2 ground-based radar image processing for raw data ***
*** Copyright 2011, Gamma Remote Sensing, v1.7 28-Jul-2011 clw ***

usage: ./gpri2_proc_all.pl <RAW_list> <SLC_dir> <min_range> <max_range> <dec>
<SLC_tab> <log>
  RAW_list      (input) list of raw data files (2 columns):
                  1. GPRI2 raw data file (*.raw)
                  2. GPRI2 raw data parameter file (*.raw_par)
  SLC_dir       directory to store output SLC images and SLC parameter files
  max_range     maximum slant range (enter - for default)
  dec           azimuth decimation factor (1 --> 64)
  SLC_tab       output file containing list of SLC and SLC_par files
  log           processing log file
  -a           (option) along-track interferometry processing: turn off azimuth
interpolation
  -t TX_ant     (option) transmit antenna (H or V) when using HV alternating TX mode
(default: V)
  -z NSAMP      (option) number samples to weight at the start of the echo (default:
300)
  -k beta      (option) set Kaiser window beta parameter (default: 3.84)
  -r rmin      (option) set starting slant range (default: 50)
  -h head      (option) set heading at the center of the scan (default: 0)
```

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  $\mathbf{\delta_r = 0.75m}$ . The maximum possible range  $\mathbf{R_{MAX}}$  for a particular chirp duration  $\mathbf{t_c}$  is given by:

$$\mathbf{R_{MAX} = 0.9 * t_c * 3.125e6 * \delta_r}$$

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 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.

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 then generated from the data with the selected transmit channel.

## 6.2.5 multi\_look

Creates multi-look intensity (MLI) image from an SLC image.

```
*** ISP Calculate a Multi-Look Intensity (MLI) image from an SLC image ***
*** Copyright 2010, Gamma Remote Sensing, v3.7 17-Nov-2010 clw/uw ***
```

```
usage: /home/andreas/grs_soft/20110521/ISP/bin/multi_look <SLC> <SLC_par> <MLI>
<MLI_par> <rlks> <azlks> [loff] [nlines] [scale] [exp]
```

input parameters:

```
SLC      (input) single-look complex image
SLC_par  (input) SLC ISP image parameter file
MLI      (output) multi-look intensity image
MLI_par  (output) MLI ISP image parameter file
rlks     number of range looks
azlks    number of azimuth looks
loff     offset to starting line (default: 0)
nlines   number of SLC lines to process (enter - for default: entire file)
scale    scale factor for output MLI (default: 1.0)
exp      exponent for the output MLI (default: 1.0)
```

## 6.2.6 create\_offset

Create offset parameter file.

```
*** ISP offset/interferogram parameter file creation/update ***
*** Copyright 2006 Gamma Remote Sensing v4.8 clw/uw 14-Feb-2008 ***
```

```
usage: /home/andreas/grs_soft/20110521/ISP/bin/create_offset <SLC1_par> <SLC2_par>
<OFF_par> [offset_algorithm] [rlks] [azlks]
```

```

input parameters:
  SLC1_par      (input) SLC-1/MLI-1 ISP image parameter filename (reference)
  SLC2_par      (input) SLC-2/MLI-2 ISP image parameter filename
  OFF_par       (output) ISP offset/interferogram parameter file
  offset_algorithm  offset estimation algorithm:
                    1: intensity cross-correlation (default)
                    2: fringe visibility
  rlks          number of interferogram range looks (default: 1)
  azlks         number of interferogram azimuth looks (default: 1)

```

## 6.2.7 SLC\_intf

Compute an interferogram from an SLC pair and the corresponding offset parameter file.

```
*** Interferogram generation from co-registered SLC data ***
```

```
*** Copyright 2010, Gamma Remote Sensing, v4.3 clw/uw 15-Jul-2010 ***
```

```
usage: /home/andreas/grs_soft/20110521/ISP/bin/SLC_intf <SLC-1> <SLC-2R> <SLC1_par>
<SLC2R_par> <OFF_par> <interf> <rlks> <azlks> [loff] [nlines] [sps_flg] [azf_flg]
[rp1_flg] [rp2_flg] [SLC-1s] SLC-2Rs][SLC-1s_par] SLC-2Rs_par]

```

```

input parameters:
  SLC-1         (input) single-look complex image 1 (reference)
  SLC-2R        (input) single-look complex image 2 coregistered to SLC-1
  SLC1_par      (input) SLC-1 ISP image parameter file
  SLC2R_par     (input) SLC-2R ISP image parameter file for the co-registered image
  OFF_par       (input) ISP offset/interferogram parameter file
  interf        (output) interferogram from SLC-1 and SLC-2R
  rlks          number of range looks
  azlks         number of azimuth looks
  loff          offset to starting line relative to SLC-1 for interferogram
(default=0)
  nlines        number of SLC lines to process (enter - for default: to end of file)
  sps_flg       range spectral shift flag:
                    1: apply spectral shift filter (default)
                    0: do not apply spectral shift filter
  azf_flg       azimuth common band filter flag:
                    1: apply azimuth common-band filter (default)
                    0: do not apply azimuth common band filter
  rp1_flg       SLC-1 range phase mode
                    0: nearest approach (zero-Doppler) phase
                    1: ref. function center (Doppler centroid) (default)
  rp2_flg       SLC-2 range phase mode
                    0: nearest approach (zero-Doppler) phase
                    1: ref. function center (Doppler centroid) (default)
  SLC-1s        SLC-1 after range spectral shift and azimuth common-band filtering
(FCOMPLEX format)
  SLC-2Rs        SLC-2R after range spectral shift and azimuth common-band filtering
(FCOMPLEX format)
  SLC1s_par     SLC-1s ISP image parameter file
  SLC2Rs_par    SLC-2Rs ISP image parameter file

```

## 6.2.8 rasmph\_pwr

Compute an image of the interferometric phase and the intensity image.

```
*** DISP rasmph_pwr: generate raster image of interferogram phase + intensity data
```



\*\*\*

\*\*\* Copyright 2005, Gamma Remote Sensing, v2.5 10-Oct-2005 clw \*\*\*

usage: rasmph\_pwr <cpx> <pwr> <width> [start\_cpx] [start\_pwr] [nlines] [pixavr]  
[pixavaz] [scale] [exp] [LR] [rasf] [cc] [start\_cc] [cc\_min]

input parameters:

cpx (input) complex image (fcomplex, e.g. interferogram)  
pwr (input) intensity image  
width samples per row of cpx and pwr  
start\_cpx starting line of cpx (default=1)  
start\_pwr starting line of pwr (default=1)  
nlines number of lines to display (default=0: to end of file)  
pixavr number of pixels to average in range (default=1)  
pixavaz number of pixels to average in azimuth (default=1)  
scale pwr display scale factor (default=1.)  
exp pwr display exponent (default=.35)  
LR left/right flipping flag, (default=1: normal, -1: mirror image)  
rasf (output) raster image (enter - for default=\*.ras: SUN raster format,  
\*.bmp: BMP format)  
cc (input) display threshold data file (float): e.g. correlation  
start\_cc starting line of cc data file (default = 1)  
cc\_min pixels with cc values below cc\_min are displayed using greyscale  
(default=.2)

## 6.2.9 raspwr

Compute image from MLI data

\*\*\* DISP raspwr: generate raster image of intensity image (power-law scale) \*\*\*

\*\*\* Copyright 2008, Gamma Remote Sensing, v2.5 11-Sep-2008 clw \*\*\*

usage: /home/andreas/grs\_soft/20110521/DISP/bin/raspwr <pwr> <width> [start]  
[nlines] [pixavr] [pixavaz] [scale] [exp] [LR] [rasf] [data\_type] [hdrsz]

input parameters:

pwr (input) intensity image (FLOAT or SHORT INTEGER data type)  
width samples per row  
start starting line to display (default=1)  
nlines number of lines to display (default=0: to end of file)  
pixavr number of pixels to average in range (default=1)  
pixavaz number of pixels to average in azimuth (default=1)  
scale display scale factor (default=1.)  
exp display exponent (default=.35)  
LR left/right flipping flag, (default=1: normal, -1: mirror image)  
rasf (output) raster image (enter - for default = \*.ras: SUN raster format,  
\*.bmp: BMP format)  
data\_type input data type (default=0)  
0: FLOAT  
1: SHORT INTEGER  
hdrsz line header size in bytes (default=0, ESA PAF for PRI products=12)

## 6.2.10 mk\_tab

Creates a text file containing 2 columns with data and meta data files.

```
*** Copyright 2011, Gamma Remote Sensing, v1.2 29-Apr-2011 clw ***
*** Generate SLC_tab, MLI_tab, or RAW_list for processing ***
```

```
usage: ./mk_tab <dir> <ext-1> <ext-2> <tab>
  dir      (input) directory including paths that contain the data files
  ext-1    (input) pattern to select data files (examples: slc, raw...)
  ext-2    (input) pattern to select parameter files that match the data
           (enter - for none, examples: slc.par, raw_par, raw.par)
  tab      (output) list of data filenames and associated parameter files (including
           paths) (text format)
```

NOTE: The current directory is denoted using .

### Example:

```
mk_tab raw_20110606 raw raw_par RAW_list_20110606
```

#### Generates the 2 column list input:

```
raw_20110606/20110606_001.raw raw_20110606/20110606_001.raw_par
raw_20110606/20110606_002.raw raw_20110606/20110606_002.raw_par
raw_20110606/20110606_003.raw raw_20110606/20110606_003.raw_par
raw_20110606/20110606_004.raw raw_20110606/20110606_004.raw_par
raw_20110606/20110606_005.raw raw_20110606/20110606_005.raw_par
raw_20110606/20110606_006.raw raw_20110606/20110606_006.raw_par
raw_20110606/20110606_007.raw raw_20110606/20110606_007.raw_par
raw_20110606/20110606_008.raw raw_20110606/20110606_008.raw_par
raw_20110606/20110606_009.raw raw_20110606/20110606_009.raw_par
raw_20110606/20110606_010.raw raw_20110606/20110606_010.raw_par
```

## 6.3 Postprocess data

In this section we present the tools used for post processing of GPRI data that are not part of the standard GAMMA Software packages.

### 6.3.1 SLC\_stack.py

```
*** Calculate average of complex SLC images after subtraction of reference phase
***
```

```
*** Copyright 2011, Gamma Remote Sensing, v1.0 clw 13-Oct-2011 ***
```

```
Usage: SLC_stack.py [SLC_tab] [SLC_ave] [SLC_cc] <-r rpix azpix> <-w rwin azwin>
```

```
  SLC_tab  two-column list of SLC file  SLC_parameter_file
  SLC_ave  output SLC average after subtraction of average phase of the reference
  region
  SLC_cct  SLC temporal coherence
```

#### Options:

```
-h, --help  show this help message and exit
-r REF_POS  ref. center position REF_POS: rpos azpos [default=none]
-w REF_WIN  ref. window size REF_WIN: rwin azwin [default=none]
```

### 6.3.2 ts\_plot\_cpx.py

```
*** Plot time-series of SLC phases 14-Oct-2011 clw ***
```

Usage: ts\_plot\_cpx.py [SLC\_tab] [image] [-r rpix azpix]

SLC\_tab (input) two column list of SLC filenames and SLC parameter filenames (including paths)

1. SLC filename (includes path)
2. SLC parameter filename (includes path)

image display image of deformation used to select point for time series plot (PNG or JPEG format)

Options:

-h, --help show this help message and exit  
-r REF\_POS point position: rpos azpos [default=none]

### 6.3.3 ts\_plot\_diff.py

\*\*\* Plot time-series of deformation derived from unwrapped phase v1.1 31-Oct-2011 clw \*\*\*

Usage: ts\_plot\_diff.py [DIFF\_tab] [itab] [MLI\_tab] [image]

DIFF\_tab single-column list of the differential unwrapped phase, each line in the DIFF\_tab corresponds to the same line in the itab

itab (input) table associating interferograms with pairs of MLI files listed in the MLI\_tab

1. row number in SLC\_tab of the reference SLC
2. row number in SLC\_tab of SLC-2 of the interferogram
3. line number in the itab
4. flag used to indicate if this interferogram is used for IPTA processing (0:not used 1:used)

MLI\_tab (input) two column list of MLI filenames and MLI parameter filenames (including paths)

1. MLI filename (includes path)
2. MLI parameter filename (includes path)

image image used to select point for time series plot, same dimensions as the DIFF\_tab files (PNG format)

enter "w" to save the plot and write a file ts\_range\_azimuth.dat, where range and azimuth are the range and azimuth pixel coordinates

"q" to exit

Options:

-h, --help show this help message and exit  
-s SCALE scale: min, max deformation [default=auto]

## 6.4 Move the instrument

### 6.4.1 get\_pos.py

Get current positioner angle in degrees

### 6.4.2 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.

### 6.4.3 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 measurment semaphore before moving
```

### 6.4.4 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.)
```

### 6.4.5 stop\_scan.py

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

## 6.5 Maintenance

A collection of tools is available for instrument status monitoring and maintenance.

### 6.5.1 chupa\_status.py

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

### 6.5.2 chupa\_test.py

Test Chupa components.,

```
*** set DDS chirp parameters and transmit ***
Usage: chupa_test.py <f_start> <f_end> <steps>'
f_start  chirp minimum (range 100e6 to 300e6)
f_end    chirp maximum frequency (range 100e6 to 300e6)
steps    number of frequency steps (3125, 6250, 12500, 25000)
```

### 6.5.3 ff\_init.py

Sets the GPS to GPRI default values.

### 6.5.4 gps\_poweron.py

Turn on power to GPS receiver located in the RFA

### 6.5.5 gps\_poweroff.py

Turn off power to GPS receiver located in the RFA

### **6.5.6 ima\_poweron.py**

Turn on power to IMA located in the RFA

### **6.5.7 ima\_poweroff.py**

Turn off power to IMA located in the RFA

### **6.5.8 rfa\_poweron.py**

Turn on RFA power supplied by the DISTR II to the chirp generator (CHUPA), IF amplifiers (IMA), and microwave electronics (except for the transmitter)

### **6.5.9 rfa\_poweroff.py**

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

### **6.5.10 rx\_poweron.py**

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

### **6.5.11 rx\_poweroff.py**

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

### **6.5.12 tsc\_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']
```

### **6.5.13 tx\_poweron.py**

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

### **6.5.14 tx\_poweroff.py**

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

### **6.5.15 usrp\_poweron.py**

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

### **6.5.16 usrp\_poweroff.py**

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

## **6.6 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.

## 6.6.1 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 1: Measurement preference file*

The keywords identify the chirp generator (CHP), transmitter (TX), Intermediate Frequency Amplifiers (IMA), 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. If the RFA is C-Band this should be  $5.4e9$  while if it is the KU-band radar the center frequency is 17.2 GHz.

The IF amplifier attenuation can be set between 2 and 60 dB. Nominal system values are between 30 and 36 dB. Increasing the attenuation decreases the signal level at the input to the Software Defined Radio (Ettus USRP2 or UN210) digitizer. It is important that the digitizer ADCs do not saturate. A test data acquisition followed by examining the data with `gpri2_plot.py` can confirm if saturation is occurring. Saturation in the plot of the ADC output is observed as clipping of the input level at approximately  $\pm 0.7$  volts. Adjust the `IMA_atten_dB` parameter in steps of 2 dB (always even) to attenuate the signal. Increasing the attenuation by 6 dB will cut the signal level in half.

The start and stop frequency of the baseband chirp generated by the Direct Digital Synthesizer (DDS) are specified by the `CHP_freq_min` and `CHP_freq_max` parameters. These values are approximate and should not be changed. The number of samples in the chirp determine the chirp duration. The ADC sampling rate is 6.25 MHz. Hence a chirp with 12500 samples is a 2ms chirp. The radar uses chirps between 250us 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:

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

*Table 2: Recommended Chirp Duration and Rotation Rates*

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. On the C-Band system, the transmitter has 3 mode values: **H** transmit, **V** transmit, and **HV** alternating. In the case of alternating polarization, The first pulse of the acquisition is always H. pol, as marked on the RFA case. For Ku-band data the mode is **None**.

In the case where the antenna will be scanned in azimuth, the start and stop azimuth angles can be specified with the ST\_antenna\_start and ST\_antenna\_end keywords. The start and end angles of the SLC produced from the data set are within these bounds because only the data segment with constant azimuth velocity is used to produce an SLC.

The rotational velocity specified in the profile is only approximate, since it is programmed in steps of approximately 0.5 degrees. The exact value for the velocity in deg/sec is stored in the metadata file (\*.raw\_par) that is associated with the raw data file and created by gpri2\_capture.py. The \*.raw\_par files are also organized by keyword:value.

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 is a fixed value in the profile and should not be changed since it is related to the analog filters in the IMA.

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.

## 6.6.2 Raw data

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: 1.720000000000e+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

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 GPRI2 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. For C-band operation, 3 modes are supported including **H**: horizontal polarization transmit, **V**: vertical polarization transmit, and **HV**: alternating H and V polarization, starting with H.

The IMA\_atten\_dB value is value using for IMA attenuation an is copied from the GPRI2 profile.

The ADC\_capture\_time 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.

### 6.6.3 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.

## 7. Instrument Specifications

The GPRI-II instrument specifications are as follows:

Frequency Range	17.1 to 17.3 GHz
Antenna Pattern	0.5 deg 3 dB azimuth beamwidth 35 deg. 3 dB beamwidth Elevation Peak sidelobes: -15 dB sidelobes (1-way)
Radar type	FM-CW, chirps between 0.25 and 8 milliseconds
Radar operational range	10 m →10 km
System Clock	100 MHz low phase-noise temperature-controlled crystal oscillator DOXCO (Jackson Firefly IIa)
Transmit Power at the antenna	<100 mW (+20 dBm)
Chirp Bandwidth	200 MHz maximum (programmable)
Range resolution	1.0 meters with 200 MHz chirp and Kaiser window weighting
Azimuth resolution (-3 dB)	8m @1 km, proportional to slant range
Analog to Digital conversion	14-bits, dual channel, 6.25 MHz sample clock
Estimated Power Consumption	Max: 65 W, 110 – 220VAC , or 24 VDC
Computer type and OS	Kontron KTGM45/mITX Computer, Intel T9600 Dual-Core CPU, 4 GB RAM, 500 GB Disk, Linux Ubuntu LTS OS.
Azimuth Scan time	20 sec for a 180 deg sweep
Radar Mass	Tower ~8kg, RF electronics ~4 kg, scanner 10 kg, Controller/Power ~14 kg, Antennas 2.7 kg each.
Radar Dimensions	Tower: 80x28x28 cm RF assembly: ~ 30x26x6cm Controller/Power: ~52x42x30cm Antennas: 210x12.5x12.5 cm

## 8. References

- [1] Werner C., T. Strozzi, A. Wiesmann, and U. Wegmüller, "GAMMA's Portable Radar Interferometer", Procs. IAG – FIG Symposium Lisbon, Portugal, 12 – 15 May 2008.
- [2] Wiesmann A., C. Werner, T. Strozzi, and U. Wegmüller, "Measuring deformation and topography with a portable Radar interferometer", Procs. IAG – FIG Symposium Lisbon, Portugal, 12 – 15 May 2008.

## 9. Appendix A

### Measurement Protocol

Campaign Name	
Customer	
Site Name and Coordinates	
Date	
Weather (Temp, Wind)	
Antenna elevation	
Tripod legs etc.	
GPS Position	
Power Source	
Chirps	
TX_mode (C-Band)	
RX IMA Attenuation	
Start Azimuth	
Stop Azimuth	
Start/End Time	
Time Intervals	
Dataset Names	
Pictures	
Remarks	

## **10. Demo Data Processing**

### **10.1 *Continuous Measurements***

### **10.2 *Repeat Measurements***