# LOFAR FPA Beamformer
## Using Command sets

| **Date:** 19 Sept 2016 | **Author:** Priya P. Hande, Kaushal D. Buch | |
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| **Rev:** 1.0 | **Title:** LOFAR FPA Beamformer- Using Command sets | NCRA • TIFR |

# Contents

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## Purpose of this document

This document provides information for running Remote Station Processing (RSP) boards control (rspctl) commands for carrying out various self tests, for monitoring and controlling the boards, for diagnostics and for configuring the boards.

## 1. INTRODUCTION
## LOFAR FPA BEAMFORMER SYSTEM
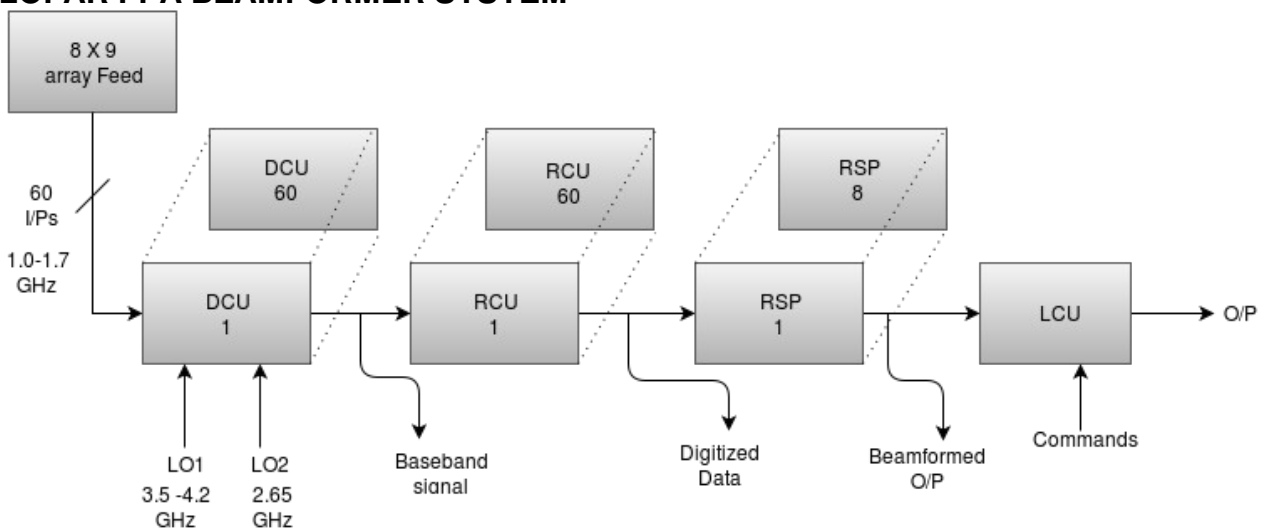


*Figure 1: Block Diagram of Focal Plane Array Beamformer system*

LOFAR, the Low Frequency Array, is a multi-purpose sensor array. Its main application is astronomy at low frequencies (10-240 MHz). One such system of LOFAR is the FPA Beamformer consisting of 8*9*2 Elements.

**There are two distinct receiver modes:**
The Low Band Antenna (LBA) mode operating between 10 and 90 MHz &
High Band Antenna (HBA) mode operating between 110 and 250 MHz

## 1.1 Signal Flow:

The Focal Plane Array feed consist of 8 * 9 dual polarized vivaldi elements. The feed is multi-pixel feed. Out of 72, only 60 inputs are connected to the Down Converter Unit (DCU).

The RF frequency ranges from 1.0 to 1.7 GHz. The down conversion of the signal takes place through the DCU blocks, where intermediate frequency (IF) is obtained with double down conversion. The IF is then provided to the Receiver Unit (RCU) where a 12-bit ADC converts the continous signal into discrete form. The digitized data is then fed to the Remote Station Processing Boards (RSP) where the correlation of the signal and beamforming operation are carried out.

The data then flows to the Local Control Unit (LCU) which is a computer server. Using LCU one can monitor and control various sub units of Digital Processing Board.

## 1.2 Information to Remote Station processing Boards:



*Figure 2: Block highlighted shows Remote Station Processing Board in the FPA Block diagram*
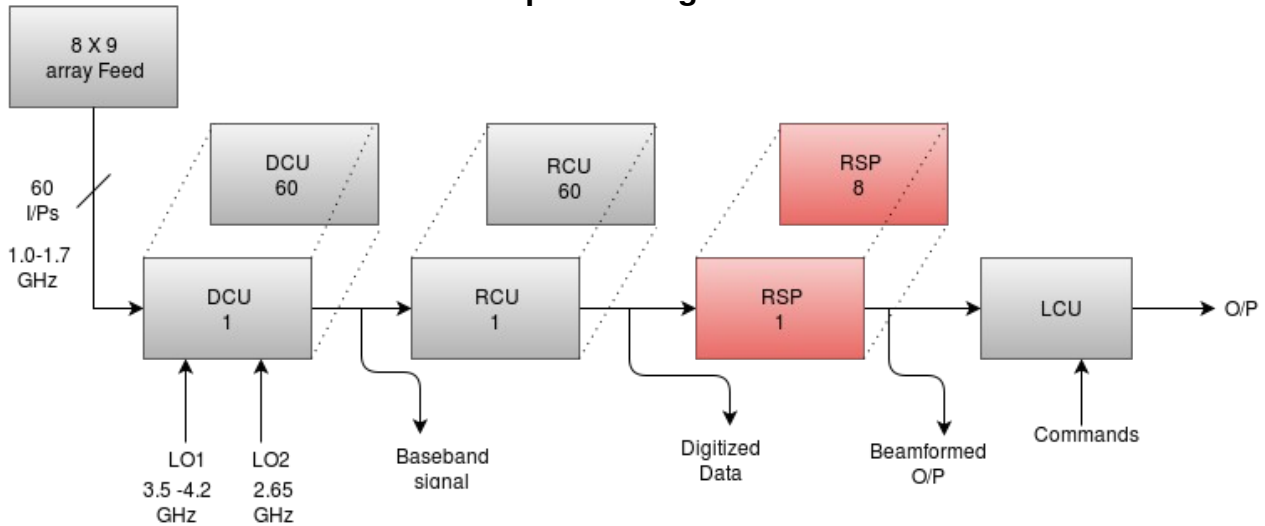
The main function of the RSP firmware is to process signal data that is received by the receiver unit (RCU). Because the processing function is distributed among several RSP boards, there is a data interface between RSP boards. The processed data is sent to the Central Processor (CEP). For transient recording, the RCU data is forwarded through RSP towards the Transient Buffer Board (TBB). A Timing Distribution board for Subrack (TDS) provides the system clock and synchronization signal. A local control unit (LCU) issues monitoring and control commands to RSP, and uses the RSP as a gateway for monitoring and controlling a Subrack Power Unit (SPU), and also RCU and TDS.

In general, the RSP performs a combination of data processing functions and control functions. For controlling special RSP control commands (rspctl) are used via LCU.

### 1.2.1 Using RSP Control Commands:

Using the RSP control (rspctl) commands allows the user to perform various tests like sinewave cancellation, noise test etc. Monitoring the on-board temperature for various sub-boards as well  as  for setting the receiver mode, receiver attenuation or HBA delays 'rspctl' commands are used.

For better undersanding of the command sets, classification of commands based on the usage has been made.
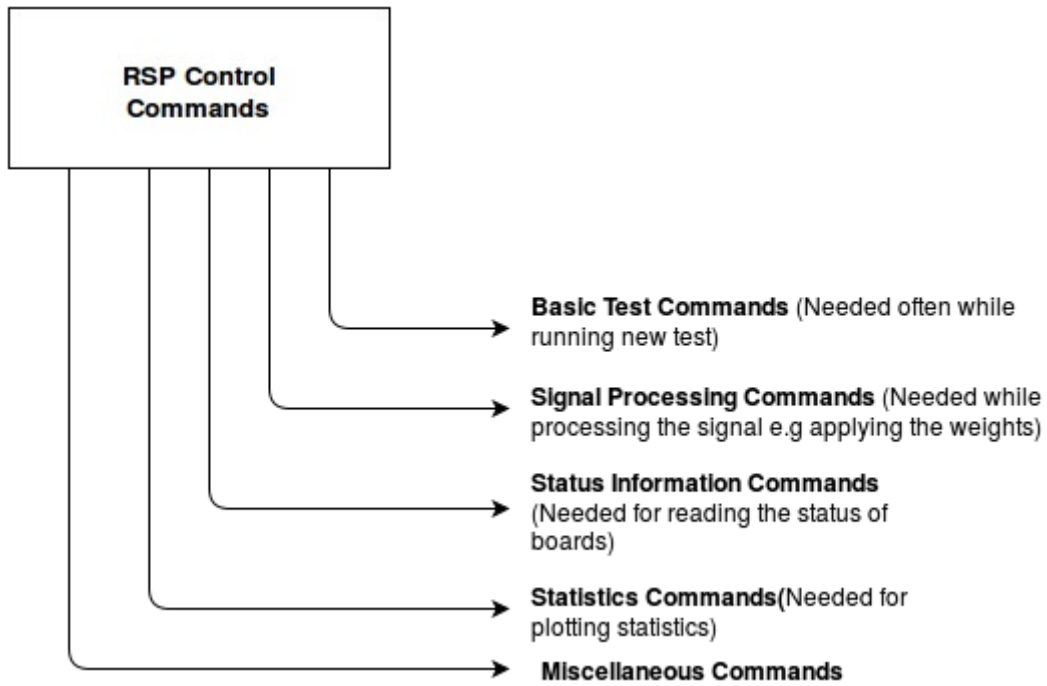


*Figure 3: Classification of RSP Control Commands*

**1.3 RSP Control Commands**
In this chapter the most important rspctl commands are explained. It is not a very detailed description of all software but a guide line through the system. Following are the commands used with rspctl instruction:
**1.3.1. Basic test commands**

1. **swlevel**
Defines the software level for the beamformer.
Before the measurement can start the status of the software need to be checked. This can be done with the *swlevel* command.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ swlevel
Currently set level is 2

Status of all software level:
1 : ServiceBroker          DOWN
---
2 : RSPDriver             DOWN
---
3 : AMCServer             DOWN
3 : CalServer             DOWN
3 : BeamServer            DOWN
---
4 : SoftwareMonitor       DOWN
4 : HardwareMonitor       DOWN
---
5 : SHMInfoServer         DOWN
---
6 : StationControl        DOWN
6 : ClockControl          DOWN
6 : CalibrationControl    DOWN
6 : BeamControl           DOWN
6 : TBBControl            DOWN
---
Missing : ServiceBroker[1] RSPDriver[2]
[lofarsys@IN001C ~]$
```

Screenshot 1: swlevel command

This gives the current status of the drivers. The level can be set by entering a number behind swlevel (example: swlevel 5). The maximum level is 5 for manual setting. Level 2 is sufficient for a RSP measurement. Use swlevel 0 to stop all the processes.

## 2. swlevel 2

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ swlevel 2
Going to level 2
Starting ServiceBroker
lofarsys  9724  9712  0 10:23 pts/0    00:00:00 /opt/lofar/bin/ServiceBroker
Starting RSPDriver
Loading image 1 on RSPboard 0 ...
Loading image 1 on RSPboard 1 ...
Loading image 1 on RSPboard 2 ...
Loading image 1 on RSPboard 3 ...
Loading image 1 on RSPboard 4 ...
Loading image 1 on RSPboard 5 ...
Loading image 1 on RSPboard 6 ...
Loading image 1 on RSPboard 7 ...
root      9833     1  1 10:23 pts/0    00:00:00 /opt/lofar/bin/RSPDriver

Status of all software level:
1 : ServiceBroker          9724
---
2 : RSPDriver              9833
---
3 : AMCServer              DOWN
3 : CalServer              DOWN
3 : BeamServer             DOWN
---
4 : SoftwareMonitor        DOWN
4 : HardwareMonitor        DOWN
---
5 : SHMInfoServer          DOWN
---
6 : StationControl         DOWN
6 : ClockControl           DOWN
6 : CalibrationControl     DOWN
6 : BeamControl            DOWN
6 : TBBControl             DOWN
---
[lofarsys@IN001C ~]$
```

Screenshot 2: swlevel 2 command

It starts the Service Broker and RSP Driver which are important for executing the rspctl commands.

## 3. rspctl –-reg
This command is used for monitoring by Remote Station Processing (RSP) Board to verify all registers.

```
registerstate update at 1468538656 - Fri, 15 Jul 2016 04:54:16  +0000

System Status        * * * * * * * $
BF                   * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * $
Subband Selection    * * * * * * * * * * * * * * * * * * * * * * * * * * * *
RCUSettings          . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
RCUProtocol          . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
RCU Read             . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
HBAProtocol          . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
RSUClear             . . . . . . . . $
DIAGWGSettings       . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . $
SubbandStats         * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * $
BeamletStats         * * * * * * * * $
XCorrelationStats    * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *
CDO                  . . . . . . . . . . . . . . . . . . $
BS                   . . . . . . . . . . . . . . . . . . . . . .
TDSClear             . . . . . . . . . $
TDSWrite             . . . . . . . . . $
TDSRead              . . . . . . . . . $
RAD                  . . . . . . . . . $
Timestamp            * * * * * * * * $
TDS Status (write)   * * * * * * * * $
TDS Status (read)    * * * * * * * * $
TBBSettings          . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
TBBBandsel           . . . . . . . . . . . . . . . . . . . . . . . . . . .
. . . . . . $
DIAGBypassSettings   . . . . . . . . . . . . . . . . . . . . . . . . . . .
RawDataBlock(write)  . . . . . . . . . $
RawDataBlock(read)   . . . . . . . . . $
SerdesWrite          . . . . . . . . . $
SerdesRead           . . . . . . . . . $
```

Screenshot 3: RSP Boards register update command

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It takes about 40 seconds for the TDS to stabilize the clock and for the RSP board to read and verify all registers. When the rspdriver is ready (only **** and ....) send the following command to select the correct mode.

## 4. rspctl --ver

This command is used to read the RSP Boards version. It also provides information to Antenna Processor (AP) and Board Processor (BP) FPGA versions.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --ver
160715 102508,921 [9989] TRACE  TRC [:] - TRACE module activated
RSP[ 0] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 1] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 2] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 3] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 4] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 5] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 6] RSP version = 5, BP version = 6.0, AP version = 6.0
RSP[ 7] RSP version = 5, BP version = 6.0, AP version = 6.0
[lofarsys@IN001C ~]$
```

Screenshot 4: Information to RSP and its FPGA versions

## 5. rspctl --rcumode=5

This command is used to set the reciver mode. There are 7 different receiver modes.
To set the RCU's and the TDS in the correct mode use Table 1. We would like to measure HBA antenna in the 110...190 MHz mode. This means that we have to set the clock at 200MHz and RCUMODE=5.

| RCU mode | Input mode | Sampling clock (MHz) |
|---|---|---|
| 0 | Only control RCU on | 200 |
| 1 | LBL input 10...90 MHz | 200 |
| 2 | LBL input 30...90 MHz | 200 |
| 3 | LBH input 10...90 MHz | 200 |
| 4 | LBH input 30...90 MHz | 200 |
| 5 | HB input 110...190 MHz | 200 |
| 6 | HB input 170...230 MHz | 160 |
| 7 | HB input 210...270 MHz | 200 |

Table 1: Receiver modes and corresponding sampling clock

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --rcumode=5
160715 102556,602 [9991] TRACE  TRC [:] - TRACE module activated
control(0) =0x0007a400
modified(0)=0x0007ff00
[lofarsys@IN001C ~]$
```
Screenshot 5: Setting receiver mode

### 6. rspctl --rcuenable=1
This command enables the selected receiver mode.
```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --rcuenable=1
160715 102653,740 [9993] TRACE  TRC [:] - TRACE module activated
control(0) =0x00000080
modified(0)=0x00000080
[lofarsys@IN001C ~]$
```
Screenshot 6: Enabling the selected receiver mode

### 7. rspctl --specinv=1
This command enables the spectral inversion which is needed specifically for the receiver mode 5.
```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --specinv=1
160715 102746,941 [9994] TRACE  TRC [:] - TRACE module activated
bypassSetting  =31
setSIack.timestamp=-19800 - Thu, 01 Jan 1970 00:00:00  +0000
[lofarsys@IN001C ~]$
```
Screenshot 7: Enabling the spectral inversion

### 8. rspctl --statistics
This command plots the statistics for all the 64 RCU's. To see the autocorrelation spectrum of the selected antenna's *rspctl --statistics --sel=RCU's* command can be used.
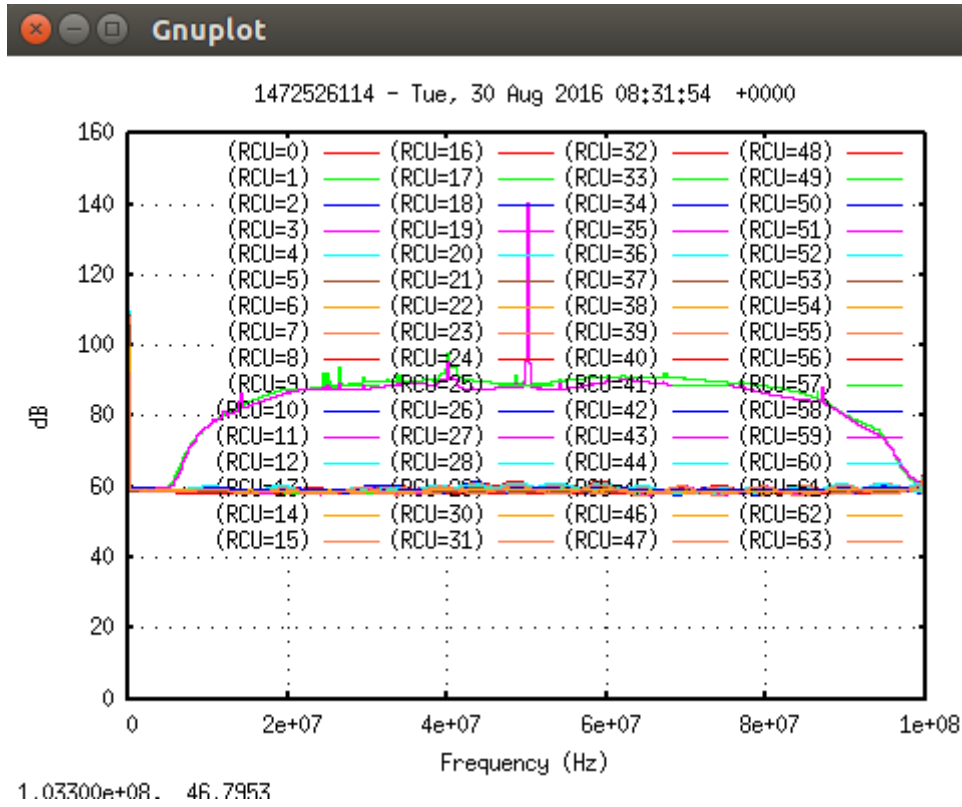
Screenshot 8: Output plot for Statistics spectrum

### 1.3.2. Signal Processing Commands:

In order to carry out the beamforming test following rspctl commands are used for providing weights and observing the results.

### 1. rspctl --weights

This command displays the default weights for all the 248 beamlets.

```
RCU[63].weights=248
[ (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
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  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
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  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
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  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
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  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
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  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)  (8000,0)
  (8000,0)  (8000,0)  (8000,0)  ]
[lofarsys@IN001C ~]$
```

Screenshot 9: Default weights for beamlets

**2. rspctl --weights=0,0 --beamlets=0:243**
This command makes all the beamlet weights zero.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --weights=0,0 --beamlets=0:243
160715 103414,783 [10002] TRACE   TRC [:] - TRACE module activated
rcumask.count()=64
[lofarsys@IN001C ~]$
```

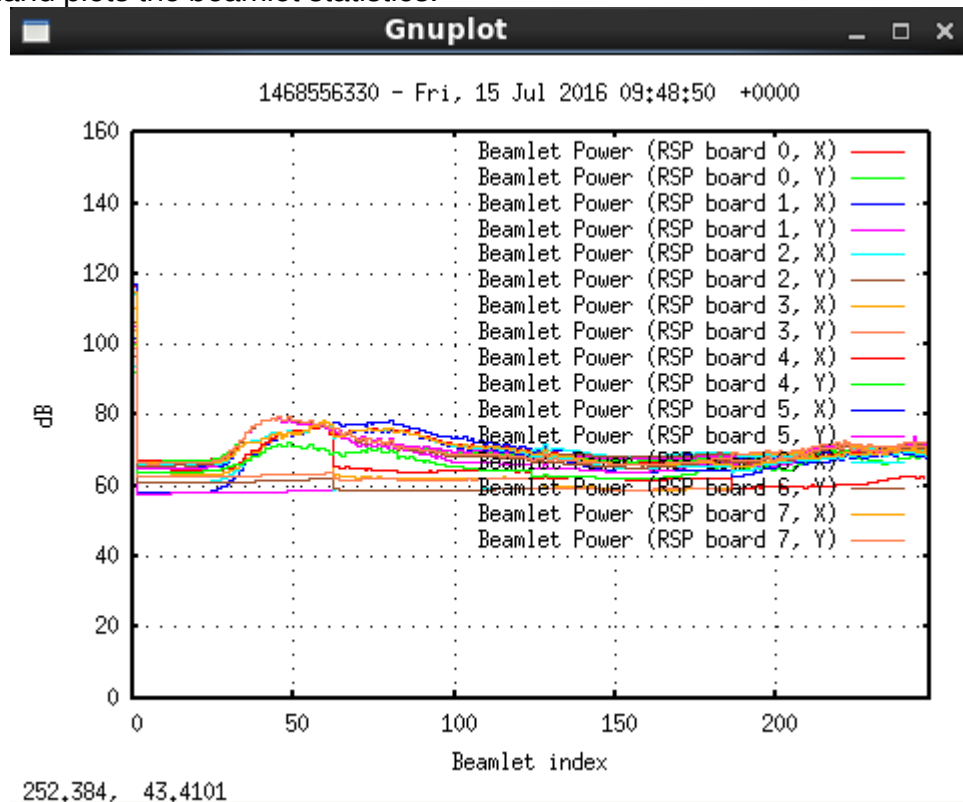Screenshot 10: Making all the beamlet weights equal to zero

3. **rspctl --weights=1,0 --beamlets=0:9 --sel=5,15**
This command adds the signal on selected receiver unit. The *weights* argument specifies amplitude and phase for the receiver units.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --weights=1,0 --beamlets=0:9 --sel=5,15
160715 103522,633 [10003] TRACE   TRC [:] - TRACE module activated
rcumask.count()=2
[lofarsys@IN001C ~]$
```

Screenshot 11: Snap for RSP weights command showing beamlets selection and phase input in-phase

4. **rspctl --weights=-1,0 --beamlets=0:9 --sel=5**
This command cancels the signals for selected receiver units. The *weights* argument specifies amplitude and phase for the receiver units.

```
[lofarsys@IN001C ~]$ rspctl --weights=-1,0 --beamlets=0:9 --sel=5
160715 103737,877 [10007] TRACE   TRC [:] - TRACE module activated
rcumask.count()=1
[lofarsys@IN001C ~]$
```

Screenshot 12: Snap for RSP weights command showing beamlets selection and phase input out of-phase

## 5. rspctl –statistics=beamlet

This command plots the beamlet statistics.



Screenshot 13: Output plot for Beamlet statistics

## 6. rspctl --subbands=250:259

This command is used for selecting the specifiic subbands out of 512 subbands. Those selected subbands are mapped one to one with the selected beamlets for further processing.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --subbands=250:259
160715 110253,502 [10852] TRACE  TRC [:] - TRACE module activated
rcumask.count()=64
setsubbandsack.timestamp=-19800 - Thu, 01 Jan 1970 00:00:00  +0000
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
```

Screenshot 14: Selection of specific subbands

### 7. rspctl --xcsubband=256

This command is used for selecting the specific cross-correlation subband.
E.g. For 150 MHz, the cross-correlation subband equals to 256.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --xcsubband=256
160715 110355,615 [10854] TRACE  TRC [:] - TRACE module activated
rcumask.count()=64
setsubbandsack.timestamp=-19800 - Thu, 01 Jan 1970 00:00:00  +0000
[lofarsys@IN001C ~]$
```
Screenshot 15: Selection of specific cross-correlation subbands

### 8. rspctl --wg=150e6 --sel=0,2

This command is used for initializing the waveform generator by selecting the frequency and receiver units.

```
[lofarsys@IN001C ~]$ rspctl --wg=150e6 --sel=0,2
160715 110458,058 [10856] TRACE  TRC [:] - TRACE module activated
Getting the clockvalue
Current clockvalue is 200 Mhz
[lofarsys@IN001C ~]$
```
Screenshot 16: Initialization of inbuilt waveform generator

### 1.3.3. Status Information Commands

This particular set of commands are used for reading the status information related to different sub units of Digital Processing Boards (DPB).

### 1. rspctl --status

This command displays the RSP board's status.

```
RSP[ 7] RAD Status        Align    Sync    CRC    Frame cnt
RSP[ 7]              ri:      _      OK     OK      195312
RSP[ 7] lane0 crosslets:    OK      OK     OK      195312
RSP[ 7] lane0  beamlets:    OK      OK     OK      195312
RSP[ 7] lane1 crosslets:    OK      OK     OK      195312
RSP[ 7] lane1  beamlets:    OK      OK     OK      195312
RSP[ 7] lane2 crosslets:    OK      OK     OK      195312
RSP[ 7] lane2  beamlets:    OK      OK     OK      195312
RSP[ 7] lane3 crosslets:    OK      OK     OK      195312
RSP[ 7] lane3  beamlets:    OK      OK     OK      195312
[lofarsys@IN001C ~]$
```

Screenshot 17: RSP Board's status information

### 2. rspctl --tdstatus

This command is used for displaying Time Distribution System (TDS) Board status information.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --tdstatus
160715 110632,091 [10859] TRACE  TRC [:] - TRACE module activated
RSP |   10MHz input | output clock | PPS input | PLL 160MHZ | PLL 200MHz | V3.3 | V5.0 | Temperature
  0 |      SMA      |     200      |    SMA    | not locked |   LOCKED   | 3.2  | 4.3  | 25
  1 | Not controlling the TD board
  2 | Not controlling the TD board
  3 | Not controlling the TD board
  4 |      SMA      |     200      |    SMA    | not locked |   LOCKED   | 3.0  | 4.3  | 26
  5 | Not controlling the TD board
  6 | Not controlling the TD board
  7 | Not controlling the TD board
[lofarsys@IN001C ~]$
```

Screenshot 18: TDS Board's status information

### 3. rspctl --spustatus

This command is used for displaying Station Power Unit's (SPU) status information.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --spustatus
160715 113251,079 [10884] TRACE  TRC [:] - TRACE module activated
Subrack | RCU 5.0V | LBA 8.0V | HBA 48V | SPU 3.3V | Temperature
    0   |    4.7   |    7.6   |   45.4  |    3.4   | 23
    1   |    4.7   |    7.5   |   45.1  |    3.4   | 28
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
```
Screenshot 19: SPU Board's status information

### 1.3.4. Statistics Commands

This particular set of commands are used for plotting the statistics of the FPA Beamformer system. The statistics can be for beamlets or subbands.

### 1. rspctl --statistics=subband
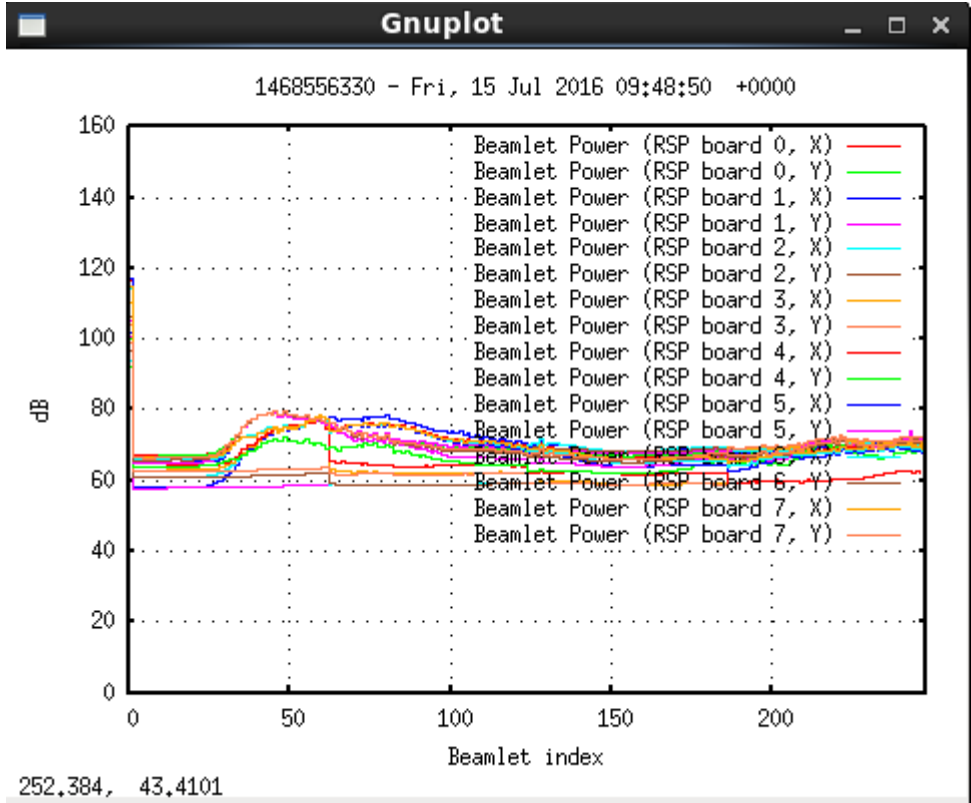
This command plots the subband statistics for all the 64 receiver units.
Following command can be used for specific receiver units with 'select' argument.
For E.g. *rspctl --stati=subband --sel=3,4,15,17:50*
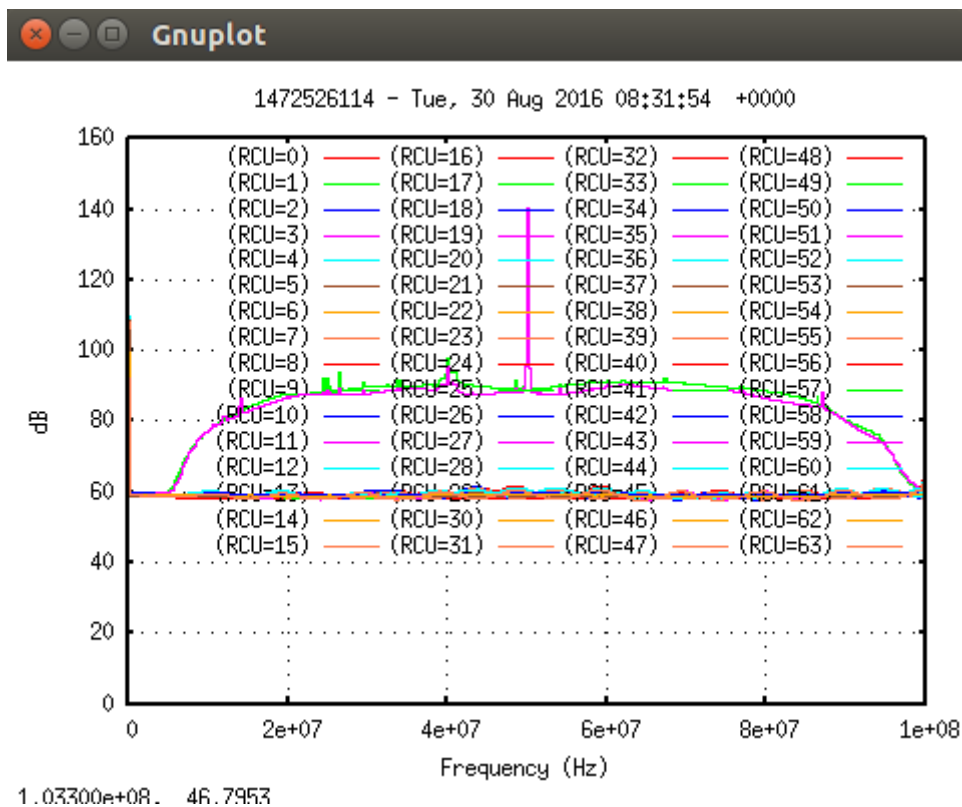


Screenshot 20: Subband statistic output plot

### 2. rspctl --statistics=beamlet

This command plots the beamlet statistics.
Following command can be used for specific receiver units with 'select' argument.
For E.g.
*rspctl --statistics=beamlet --select=4,6,28,32:47*

| **Date:** 19 Sept 2016 | **Author:** Priya P. Hande, Kaushal D. Buch | |
|---|---|---|
| **Rev:** 1.0 | **Title:** LOFAR FPA Beamformer- Using Command sets | |



Screenshot 21: Beamlet statistic output plot

## 3. rspctl --xcangle --xcstatistics
This command plots the cross-correlation statistics.
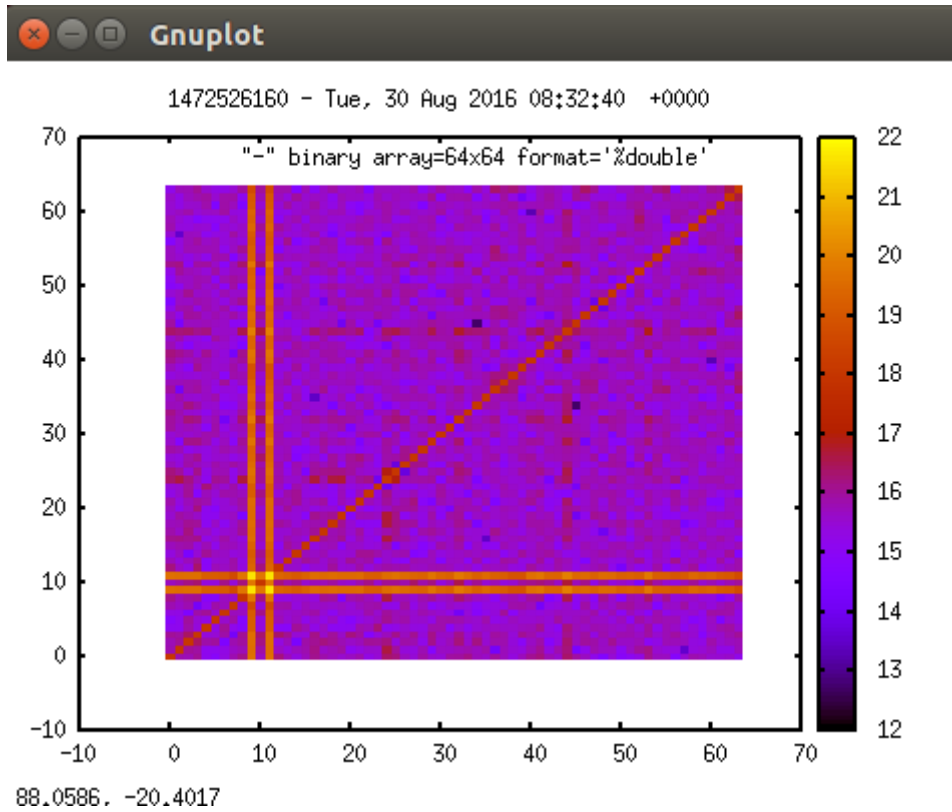


Screenshot 22: Cross-correlation statistic output plot

### 1.3.5. Miscellaneous

### 1. rspctl --clock
This command is used to get the clock information for the RSP borads.
The clock settings can be changed using this command.
For E.g. rspctl --clock=200

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --clock
160715 114403,769 [10955] TRACE   TRC [:] - TRACE module activated
Sample frequency: clock=200MHz
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
```

Screenshot 23: RSP board clock output

### 2. rspctl --rspclear
This command is used to clear the RSP boards.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --rspclear
160715 114457,034 [10957] TRACE   TRC [:] - TRACE module activated
control(0)=0x00000002
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$
```

Screenshot 24: Command to clear RSP Board

### 3. rspctl --hbadelays --sel=26
This command is used for providing delays for the High Band antenna inputs.

```
[lofarsys@IN001C ~]$
[lofarsys@IN001C ~]$ rspctl --hbadelays --sel=26
160715 114548,980 [10959] TRACE   TRC [:] - TRACE module activated
settings().shape()=2 [          1         16 ]
HBA[26].delays=   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0
[lofarsys@IN001C ~]$
```

Screenshot 25: High Band Antenna delay output