

LOFAR Beamformed-Data Pipeline Cookbook - v1.2

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1 Observations

1.1 LOFAR System Overview: Observations

A general overview of the LOFAR system is provided by the figure 1. Observers and support scientist on duty can monitor the health of the system and system resources using SAS/OTB and Navigator GUIs. Management of Measurement-sets (MoM) is the astronomers' interface to specify different requirements of their observations; MoM interacts with the SAS/OTB database. Once an observation is specified by an astronomer, observer or support scientist checks if the observation can be carried out with the available resources, and uses SAS/OTB GUI in order to 'prepare' the specified observation.

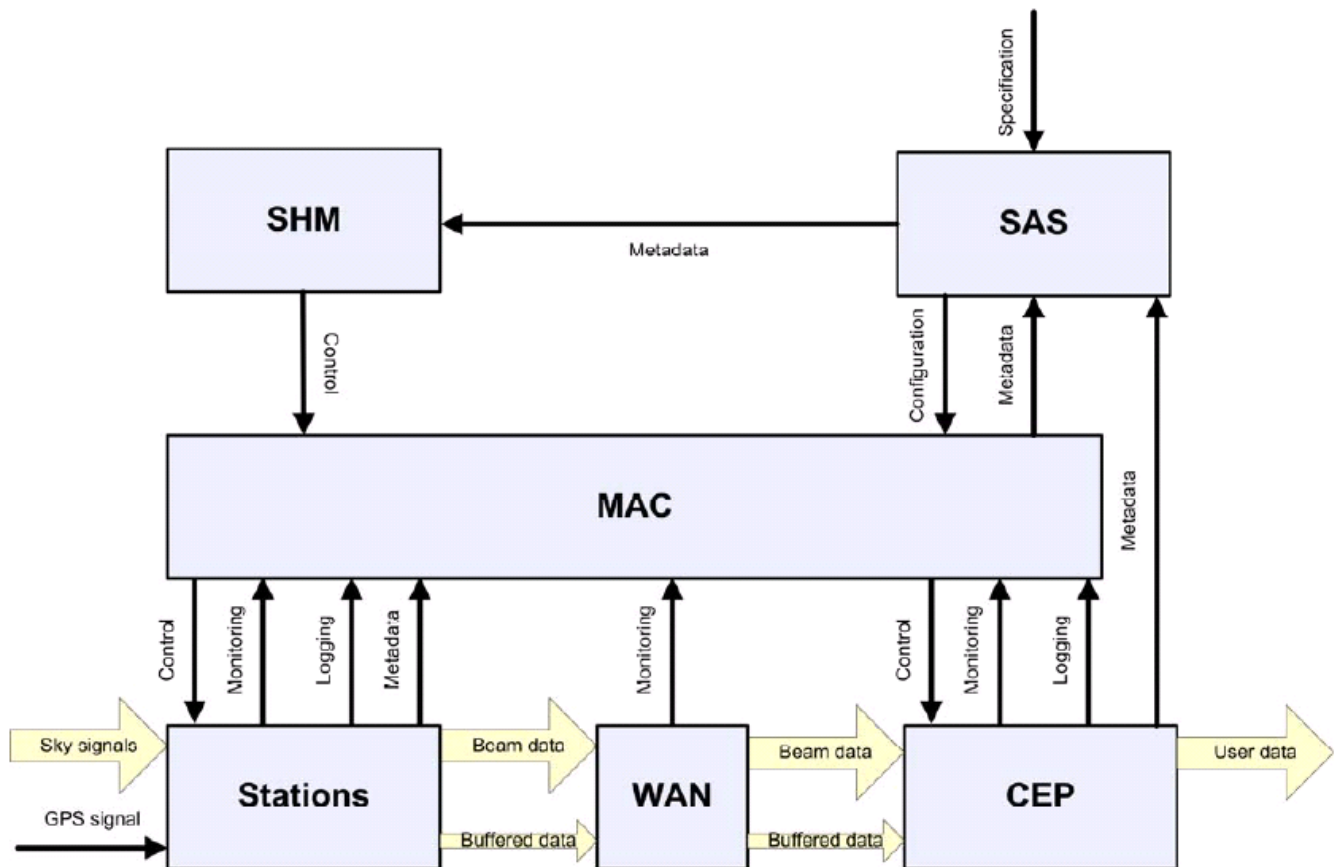


Figure 1: Overview of LOFAR hardware/software environment: astronomers 'specify' observations in MoM, a GUI (not shown above) which interacts with the SAS database. See S1.2 for details.

1.2 General scheme of operations

The general mode to observe with LOFAR is given below; these steps are discussed in more detail in the following sections.

1. Create a observation entry using the MoM interface³, by manual entry or importing an XML file.
2. Once you are satisfied about the description of the observation, change the status of the observation as “described”.
3. Requests should be routed through the operator to get approval of start time and end time. This will avoid overlap of different observations.
4. A support scientist and/or an observer will “specify” the system details with SAS/MAC tools and do a sanity check if the observation is possible with the available resources.
5. They can modify the observation settings (stations, data disks *etc.*) in coordination with astronomers.
6. As of Q2 2011, pipeline processing requests should also go through the support science team; so that processing resources do not clash.
7. Note that the system is not yet streamlined fully, so problems need to be reported to the developers. This feedback is crucial for system improvement. LOFAR issue tracker⁴ should used to report bugs; email is an additional resource to report them.
8. While an automatic recovery after failures is desirable, if an observation fails, we need to leave the system in the broken state so that the deveopers can track bugs (‘log’ files are no longer being written to /dev/null but being kept for debugging.)

1.3 Creating an Observation in MoM

1.3.1 MoM access of projects

This relates to item 1 in §1.2. The LOFAR MoM interface can be accessed from:

<http://lofar.astron.nl/mom3/>

If you have or had a previous login id on WSRT North Star system, the same should work for LOFAR MoM. If not, please contact your KSP group leader. In the currently-agreed scheme astronomers will create and specify observation(s) in MoM under the appropriate project. Some active projects for beamformed observations are: Pulsars: “Pulsars”; MSSS-test: “MSSS”; Radio Sky Monitor (simultaneous imaging & beamformed data): “LEA032”.

1.3.2 Specifying MoM Observations

The general scheme of creating an observation is as follows:

- The approved LOFAR projects have been created in the MoM already. If your projects do not appear there, please contact Science Support team (for contacts see §4.1).
- If a project exists, you can enter that project by clicking on its name. You can then add an observation using “add” tab under the project (see figure 2.)

³See webpage: <http://lofar.astron.nl/mom3> .

⁴<https://proxy.lofar.eu/redmine>.

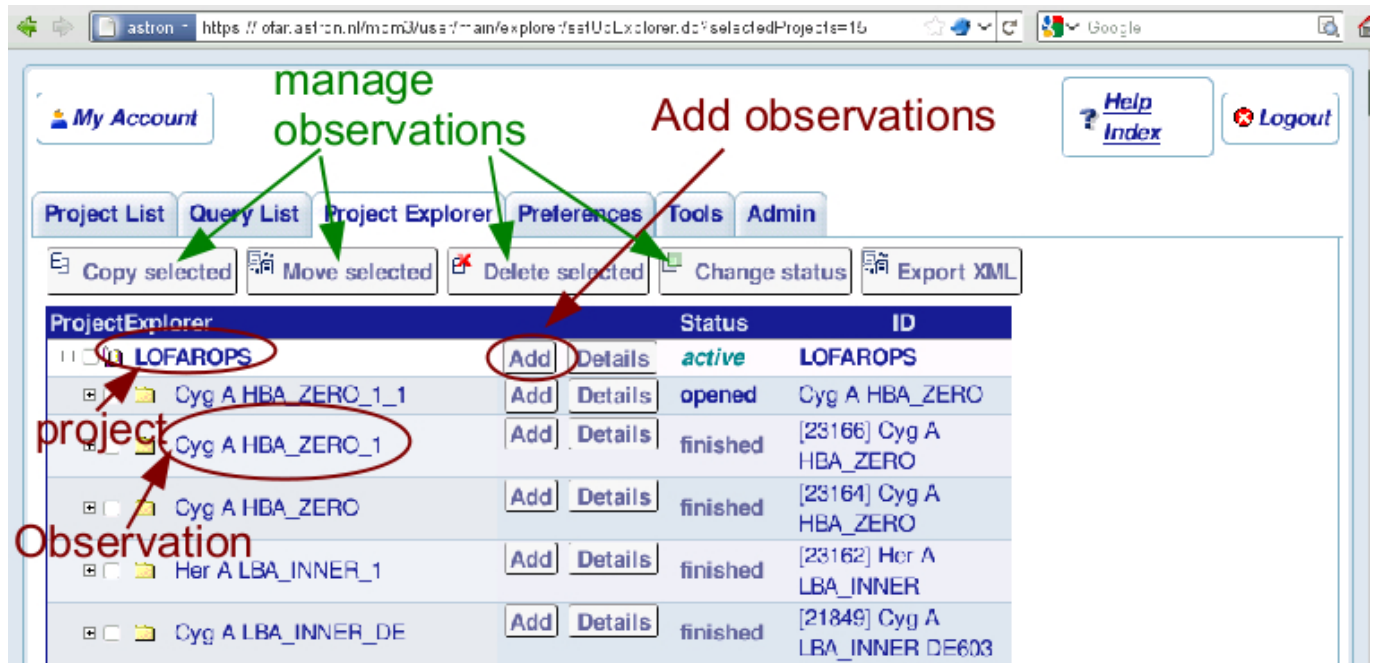


Figure 2: MoM project management.

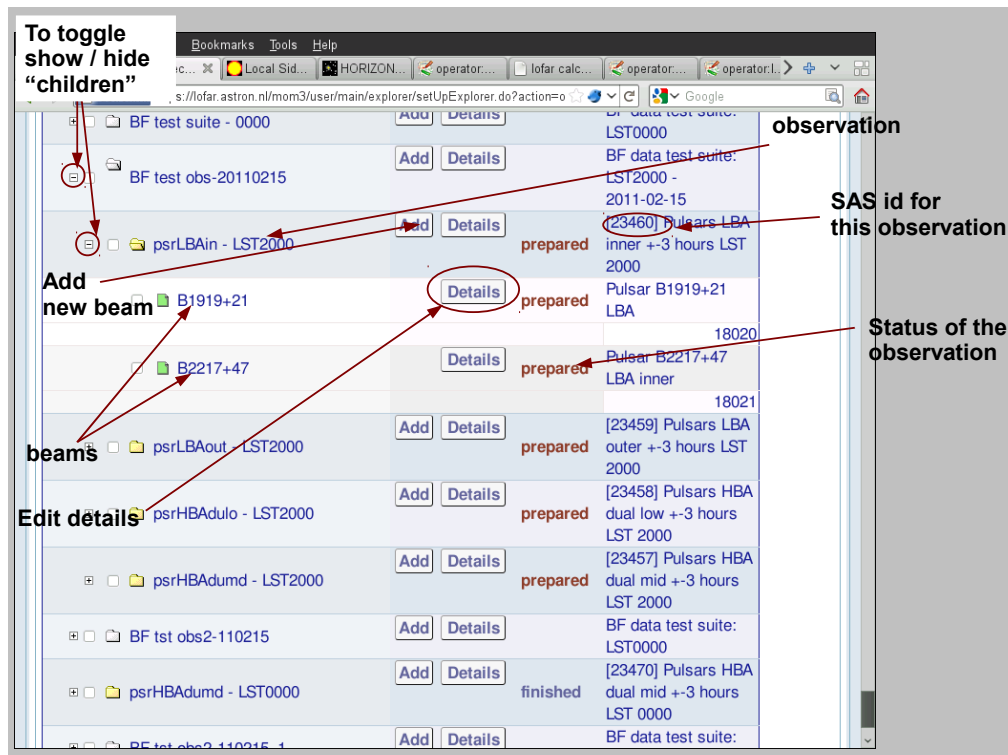


Figure 3: MoM observation details (under project LOFAROPS)

General info	Dataproducts	Reports and Remarks	Status history
Name:	B0329+54 IMG+PSR		
Description:	B0329+54 IMG+PSR to commission transients pipeline		
Current status:	finished(2010/10/16 07:30 UTC)		
Type:	Observation		
Project name:	LEA032		
Child of:	101015_Obs1		
ID	13145		
SAS MAC Observation ID	20901		
Instrument	Beam Observation		
Store Correlated Data	true		
Store Filtered Data	false		
Store raw Beamformed Data	false		
Store Coherent Stokes Data	false		
Store Incoherent Stokes Data	true		
Antenna	HBA Zero		
Clock	200 MHz		
Instrument Filter	110-190 MHz		
Correlator Integration Interval (s)	1.0		
Channels per Subband	16		
Correlator Integration Steps	12208		
Pencil Beam Flyseye	false		
Number of Pencil Rings	0		
Pencil Ring Size	0.0		
Pencil Beams (Custom)	(0.0,0.0)		
Stokes Selection	I		
Stokes Intergate Channels?	false		
Stokes Integration Steps	16		
Duration	43200.0		
Station Set	Custom		
Stations (Custom)	CS001,CS002,CS003,CS005,CS007,CS017,CS024,CS026,CS030,CS032,CS101,CS103,CS201,CS301,		
Time Reference	N/A		
Start time	2010/10/15 19:30:00		
End time	2010/10/16 07:30:00		

Figure 4: MoM observation details: note that some details at the bottom are not shown in this cropped image.

- If a previous observation of a certain type exists, you can copy it (select an observation and use “Copy selected” button at the top; see figure 2: top Green arrows.), and modify it. So, a beamformed observation can be copied for another beamformed observation. Note that you **can not copy** a synthesis-imaging observation **and modify** it to perform a ‘beamformed’ observation.
- Check for space on storage nodes to write raw data, usually pulsar data sets are stored on subclusters 5 & 6 (lse013–lse015 and lse016–lse018). See § 4.1 for a description of useful scripts and utilities, and § 4.3 constraints on different parameters for observation and beam specifications.
- Once you have an observation created or copied, it will appear within the chosen project as shown in figure 3. You can click on the ‘Details’ button next to the observation to open another window, where you can view various observation parameters, as shown in figure 4. You can specify relevant values by using the ‘Edit’ button at the bottom of the page. Note that Correlator Integration Interval (in seconds) is pertinent to imaging observations only.
- The total number of channels per subband depends on astronomers’ demand. See § 4.3 for a discussion about number of channels and effective time resolution of the observation.
- For a beamformed observation, if you choose both ‘Coherentstokes’ and ‘Incoherentstokes’ for observations, specify Number of Pencil Rings, ring sizes, beams’ locations⁵. All values are in radians.
- You request a list of stations and other resources via MoM, something which the observer or support scientist will check.
- Once you create an observation, you can add a beam under it using “add” tab under this ‘observation’ (see figure 2: Red arrow). Details of the specified beam will appear as shown in figure 4.
- One can ‘Edit’ the beam similar to observation window described earlier. One need not specify subbands, unless for special needs, MoM computes those based on the Central frequency and Bandwidth specifications. If an astronomer knows the frequencies of interest beforehand, and is choosy, s/he can set ‘Custom’ value for the subbands. § 4.3 gives expressions to compute subband frequencies.
- **Note:** in future, beams may have different durations. However, in the current scheme all beams under an observation must carry the same observation duration as entered in ‘observation details’. In MoM beam specification window, a user should a check-box, “Duration Equals Observation”.
- A newly-created observation will carry a status as ‘Opened’.
- Once the observation and beams are specified, the astronomer can select this observation by clicking on the its status (see figure 3: red mark). Now the status of the observation can be changed to ‘Described’ using the menu on the top of the page (see figure 2: menu on top row.)
- The support scientist or observer on duty will now see the observation in the SAS-OTB GUI, where the hardware resources can be allocated. For example, the data nodes/disk settings are set⁶. When the status is changed to ‘Prepared’ in OTB, this status will be reflected in the MoM interface.

⁵ *e.g.*: Pencil Rings = 0, Pencil Ring Size = 0, Pencilbeams = ‘(0.0, 0.0)’, see §4.3

⁶ “Default Template” #8009 in OTB is used to create template using MoM, so default values of stations/ storage nodes *etc.* are picked up from its specifications. Note that we **never** write to lse019-021 (development subcluster).

- At this stage the astronomer(s) can view the changes and contact the support scientist and/or observer for any queries or modifications. Once satisfied, astronomer(s) can now change the status of the observation to ‘Approved’. This observation can now be scheduled by the observer, note that **no changes are possible in the observation settings after this stage.**⁷
- The observation status in MoM now will be shown as ‘Scheduled’, ‘Successful’ or ‘Aborted’, depending upon the outcome. The astronomer(s) can now find the data-id of the observation in MoM details, and check the data on the disks.

1.4 MoM observation setup: beamformed [+ (optional) imaging] observation

The following procedure describes how to set up a beam-formed observation in MoM with an option to add simultaneous imaging observation. See §4.3 for “default” values of various parameters, their possible ranges, and various constraints on them. While we set up this observation by hand, § 1.5 describes how to combine various modes using bash/XML scripts.

1. Create a “new folder” to keep all observations together using the ‘Add’ button in the project window (see figure 2: Green arrow). Either create a new or “copy” a previous beamformed observation entry to the new folder, as described in section 1.3.1.
2. Edit details of the observation: especially the name of the observation and its description (See § 4.3 for constraints on different parameters mentioned below):

Optional for imaging observation:

- “Correlated Data” = Yes
- Correlator Integration Interval = 1 s.
- Correlator Integration Steps is now computed by OLAP software, user need not specify it.

Other required parameters:

- “Incoherentstokes” = Yes
- Array = “HBA Zero”
- Channels per Subband = 16
- Fly’s Eye = “No” . NOTE: for Fly’s Eye observations, you have to specify Coherent Stokes = “Yes” as well.
- Number of Pencil Rings = “0” if only the central beam is needed, as is the case for most observations. [Set this to “1”, if you want to set up 6 surrounding beams automatically. However, before this logic is implemented (see §4.3), you still need to specify central beam as (0.0, 0.0) in the pencil Beams.]
- Ring Size = “0.00872663” radians for HBA (0.5° deg, approximate tied-array beam size when Superterp is added coherently. This value needs to be determined more carefully.). This is ignored if the Number of Pencil Rings = 0.
- Pencil Beams = “(0.0, 0.0)” - these are offsets in radians from beam direction. This is specified to record the center beam, and is ignored if the Number of Pencil Rings = 0

⁷In case of any error the ‘scheduled observation’ can be ‘Aborted’ by the observer using SAS/OTB GUI.

LOFAROPS > BF test suite_2 > psrLBAin - LST2000 > B1919+21 [? Help](#) [Close Window](#)

General info Dataproducts Reports and Remarks Status history

Name:	B1919+21
Description:	Pulsar B1919+21 LBA
Current status:	finished(2011/02/10 19:36 UTC)
Type:	UV Measurement
Project name:	LOFAROPS
Child of:	psrLBAin - LST2000
ID	17902
Measurement Type	UV Measurement
Type	Target
Ra	19:21:44.80
Dec	+21:53:02.2
Equinox	J2000
Duration	5M
Duration Equals Observation	false
Start time	2011/02/10 15:24:01
End time	2011/02/10 15:29:01
Central Frequency	42.089844 MHz
Bandwidth	24.023438 MHz
Subbands	154..276
Target name (Specification)	B1919+21
Ra (Specification)	19:21:44.80
Dec (Specification)	+21:53:02.2
Equinox (Specification)	J2000
Duration (Specification)	5M
Duration Equals Observation (Specification)	true
Central Frequency (Specification)	42 MHz
Bandwidth (Specification)	24 MHz
Contiguous (Specification)	true
Subbands (Specification)	154..276

Figure 5: MoM observation ‘beam’ details: note that some of details were cropped.

- Polarization = Stokes I
- Integrate Channels Online = No .
- Stokes Integration Steps = 16
- Central Frequency = 134 MHz and Bandwidth = 47.2 MHz, MoM will compute requisite values of subbands. We prefer to have custom-set subbands: “77...320”, without the quotes. This superceeds the Central Frequency/ Bandwidth settings above.
- Set stations: you may prefer to choose “Custom” stations over ‘Dutch’ or ‘Core’ stations⁸. An operator or support scientist can change these depending upon their availability & health, before changing the status to ‘Prepared’. If you desire specific stations, contact them.
- Add a Beam to specify where you’re pointing. If you choose start and end time of the observation, this may be over-ridden during the scheduling processing (manual or otherwise.) If you choose duration, end-time will be computed from start time and the duration. Set the following:
 - Type - UV measurement
 - Target Name - your favourite pulsar name
 - Right Ascension, Declination, J2000 ...
 - Duration = 12H. For our purpose beam duration should be the same as the duration of the observation (or at least longer, but not shorter than the duration of the observation.) **Note:** you can click on check box “Duration Equals Observation” to equal beam observing time to that of the observation. If you choose start and end time of the observation, this may be over-ridden during the scheduling processing (manual or otherwise.) If you choose duration, end-time will be computed from start time and the duration.
 - Central Frequency = 140 MHz & Bandwidth = 48 MHz.
 - Subbands Contiguous = “Yes” and specify default = 200...443.
- In current scheme, the duration mentioned in every Beam details must match those provided in Observation details. In future various beam durations may differ, however, in the current scheme this may lead future observations to fail. In MoM, one can now tick a option check-box, “Duration Equals Observation”, for this purpose.

3. Select the observation (or a group of observations) and change status to “described”
4. The observer will find a new “template” in SAS/MAC corresponding to the MoM entry.
5. The observer will add ‘clean’ stations to the template (Green mark on whiteboard entry); and set disk/node usage. ⁹
6. Note that this observation needed about ~ 90 GB/node (**for 12 hours**). Using LOFAR data calculator¹⁰ one can compute the total data rate, D , by computing the disk-space requirements for the whole observation. If one has N storage node disks at disposal, the data requirement is D/N , which must be $\leq 50\text{MB s}^{-1}$. At higher rates, system may drop significant fraction of data.

⁸“Dutch” or “Core” settings do not translate to meaningful settings in OTB as yet. So, needed stations should be chosen by clicking on them.

⁹To change storage nodes/disks for observations one can suitably modify OTB template #8009. After creating & scheduling observations one should revert settings in the OTB template back to more general disk/node values.

¹⁰<http://lofar.proposal.astron.nl/service/pages/storageCalculator/beamformed.jsp>

7. As outlined in §1.3.2, in MoM the observation status can be changed “prepared” through to “approved”. Observation status should change to “scheduled”, then to “running”. When the observation is completed, the status is automatically updated to “finished” or “aborted”.

1.5 Using XML files to schedule multiple observations

It is time-consuming to set up individual observations all by hand, and human error is likely. Therefore, to specify one or multiple observations in an automated fashion, one should create an XML file using a shell script developed by Anastasia Alexov. The resultant XML file can be imported into MoM and observations can be scheduled en-masse ¹¹. In order to use this shell script one needs to do the following:

1. Set up LUS Daily Build or local copy of USG software repository.

- To use daily build of the lofar software: set up your path with the following command
`$ use LUS (or $ source /opt/scripts/doLUS -today)`

OR

`$ use LUS Mon (or $ source /opt/scripts/doLUS Mon)`

- To build your own USG svn repository on your laptop/ dekstop (Mac / Ubuntu Linux)¹² or on lfe001: the instructions for download and install are here

http://www.lofar.org/operations/doku.php?id=tkp:general_pwg_info#code_repository_ies

If you use BASH, include these lines in your `.bashrc` file in your home directory on lfe001:

```
export LOFARSOFT=$HOME/lofarsoft
$LOFARSOFT/devel_common/scripts/init.sh
```

If you use CSH, include these lines in your `.cshrc` file in your home directory on lfe001:

```
setenv LOFARSOFT=$HOME/lofarsoft
source $LOFARSOFT/devel_common/scripts/init.sh
```

The Pulsar and 3C catalogs are in

```
$LOFARSOFT/release/share/pulsar/data
```

2. Create an ASCII observing file, there are various file formats for different kinds of observations: imaging, beam-formed, multi-beam observations *etc.* Use template-creation script, called

```
multi-templatesNbeams.sh
```

3. The appendix 4.4 lists various examples, with different switches (for IM, BF, piggybacking, multi-beam, *etc.*)

4. Invoke the script without any option to see help menu, with description of all the options. For help to configure imaging observations, use

```
multi-templatesNbeams.sh -h IM
```

¹¹RO can see all MoM projects and mostly have ADMIN status and can import an XML observation file. Soon a group of ‘power users’ will be created, its group members will have similar privileges.

¹²Versions for other flavors of Linux are not available at the moment.

and for help regarding beam-formed observations, use

```
multi-templatesNbeams.sh -h BF
```

5. The section 4.4 lists various examples to show some of the ways to execute the script. This script will read a template XML script, modify the relevant details using specified options, and create a new output XML file.
6. Import the output XML file from the previous step into MoM¹³ and check the MoM observation settings¹⁴. Contact Science Support if you need to use this “XML import” feature.
7. Check for space on storage nodes to write raw data from observations. Usually pulsar data sets are stored on subclusters 5 & 6 (1se013-1se015 and 1se016-1se018). Appendix 4.1 lists various useful scripts and utilities to aid observation specifications.

1.6 Monitoring System Resources and Health

You should consult with the LOFAR operator at +31-521-595-701 or via email to observer@astron.nl

- The data size calculator for LOFAR observations can be found here <http://lofar.proposal.astron.nl/service/pages/storageCalculator/beamformed.jsp>
- The state of stations can be viewed online on the ROCR White Board http://www.lofar.org/operations/doku.php?id=operator:current_station_overview
- See `/globalhome/asgekar/bin` for the following scripts: `show_data1.sh`, `show_data1_sorted.sh`, `show_data_all.sh` and `show_data_allsorted.sh`. Their obvious names indicate their function: they display available space on storage nodes in percentage points; note that each storage node disk has 2 TB space.
- The telescope observations should first be specified in MoM early in the week, and RO will decide the observation list for the remaining week by Wednesday morning.
- Request the science-support team to suspend the NFS mount of lse disks on compute nodes during the most resource-intensive observations.
- Observation logs are stored in `/globalhome/lofarsystem/logs/Lxxxxx`, where “xxxxx” is the observation id, for example 20589.
- Methods to verify if observational data looks OK (initial tests):
 - When an observation is set, MoM provides you with the data id set in hardware. Check if a parset has been written. Find `/globalhome/lofarsystem/log/Lxxxxx/Lxxxxx.parset*`, where xxxxx is the observation id.

¹³To Import the output XML file from the previous step into MoM: Click on “Admin” tab, which opens administrator page. This page provides a link to “Import XML” file.

¹⁴RO can see the all MoM projects and mostly have ADMIN status and can import an XML observation file. Soon a group of ‘power users’ will be created, its group members will have similar privileges.

- Check data sizes on the storage nodes: 1) data rate for an un-smoothed beam-formed data (48 MHz bandwidth, IQUV) is 1400 GB per hour. 2) data rate for an imaging observation (10 stations, 48 MHz bandwidth, 1-second integration) is 400 GB per hour.
- Note that in the SAS001 login window, log files are read to `STDOUT` (observers set this up every day to tail the log). In case of an error there will be stack trace in that `STDOUT` window. In case of a crash, this window will show the command prompt.

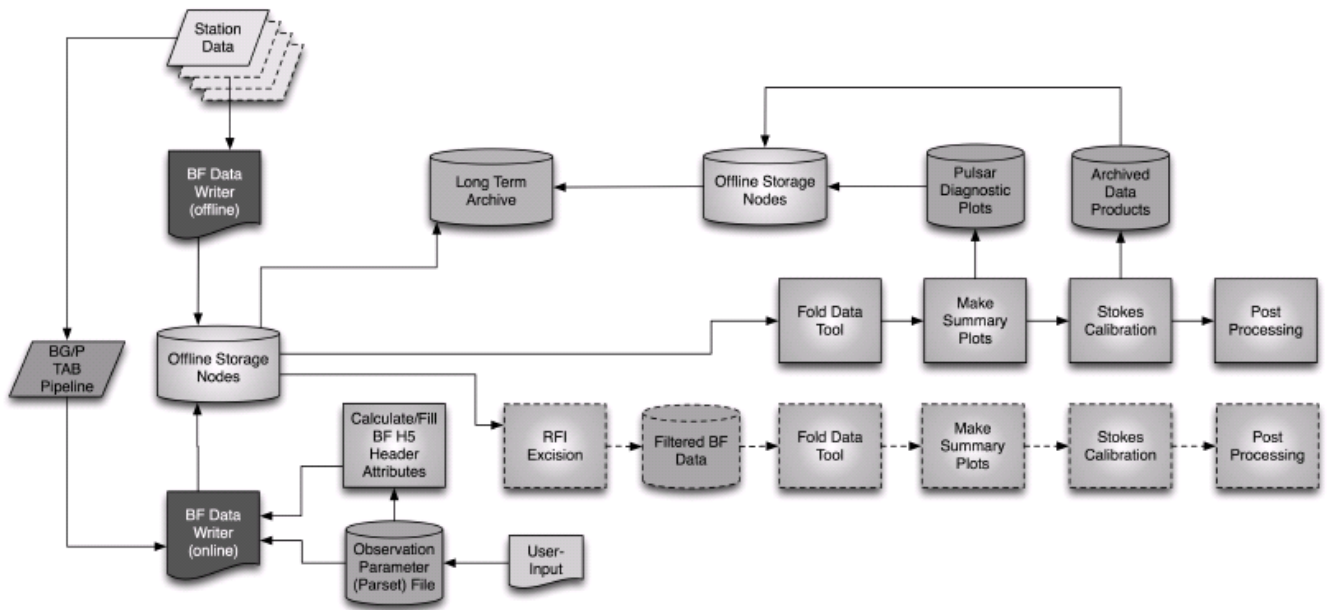


Figure 6: Schematic of known pulsar pipeline with “online” and “offline” elements. Note that this is how the pipeline will appear with HDF5 data and long-term archive in place.

2 Processing

2.1 Standard Pulsar Pipeline

Figure 6 shows a schematic of known pulsar pipeline as it is envisioned with HDF5 data format and the long-term archive (LTA). The offline processing pipeline can process data from the BlueGene or data after RFI excision (*rfifind*). The data sets are first converted to PRESTO format, *.sub for each channel, using with BF2presto. The channel data are corrected for dispersion coherently or incoherently. After correction, one can obtain time series data after combining all channels (*prepfold*), create dynamic spectra or obtain folded profiles. The pulsar pipeline shell scripts, defined below, automate many of these tasks after reading the observation metadata from the PARSET file.

There are two ways to start the pipeline currently: processing one observation at a time, using `pulp.sh` (§ 2.1.1) or processing multiple observations from MoM, using `xml_pipeline_kickoff.sh` (§ 2.1.2).

2.1.1 `pulp.sh`

Run the beamformed pipeline using `pulp.sh` (acronym for Pulsar Pipeline) script. Invoking `pulp.sh` will list all the command-line options. Invoking `pulp.sh -help` will list the options along with examples and more text explanations as shown below. The script reads the parset file from `/globalhome/lofarsystem/logs/` and extracts different parameters of the observation, before processing it with given options. Some examples are provided at the bottom of this section.

```
$ pulp.sh ↵
```

```
This is the help page for the LOFAR Known Pulsar Pipeline (shell-script), also known as "pulp.sh".
The command line options and examples are listed below. The executable is a link to the most recent
```

version of the pipeline (make_subs_SAS_Ncore_Mmodes.sh).

By default, the pipeline needs the LOFAR OBSID in the form of L<year>_OBSID where OBSID is 5-digits padded by zero's; the output directory location is also required; lastly, you must specify either the Pulsar name or a list of Pulsars or the word "position" in order for the pipeline to fold the data for the pulsar(s) in the FOV. Additional optional switches are described below. The pipeline uses 8 cores on a machine by default, splitting up the data into 8 sets of subbands (generally, 240 subbands are split into 8 groups of 31 subbands each); the split is adjustable using the "-core" argument; however, the split must be even, else an even split if found closest to the user-requested number of cores.

Also see the examples section below.

```
usage : make_subs_SAS_Ncore_Mmodes.sh -id OBS_ID -p Pulsar_names -o Output_Processing_Location
[-core N] [-all] [-all_pproc] [-rfi] [-rfi_pproc] [-C] [-del] [-incoh_only] [-coh_only] [-incoh_redo]
[-coh_redo] [-transpose] [-help] [-test]
```

```
-id OBS_ID ==> Specify the Observation ID (i.e. L2010_06296)
-p Pulsar_names ==> Specify the Pulsar Name or comma-separated list of Pulsars for folding
  (w/o spaces) or specify the word 'position' (lower case) find associated known Pulsars in
  the FOV of observation (i.e. single Pulsar: B2111+46) (i.e. multiple pulsars to fold:
  B2111+46,B2106+44) (i.e. up to 3 brights pulsars to fold at location of FOV: position
-o Output_Processing_Location ==> Specify the Output Processing Location
  (i.e. /net/sub5/lse013/data4/LOFAR_PULSAR_ARCHIVE_lse013/L2010_06296_red)
[-all] ==> optional parameter perform folding on entire subband set in addition to N-splits
  (takes 11 extra min)
[-all_pproc] ==> Post-Processing optional parameter to ONLY perform folding on entire subband
  set based on already-processed N-splits
[-rfi] ==> optional parameter perform Vlad's RFI checker and only use clean results (takes 7 extra min)
[-rfi_pproc] ==> Post-Processing optional parameter to perform Vlad's RFI checker on
  already-processed N-splits
[-C | -c] ==> optional parameter to switch on bf2presto COLLAPSE (Collapse all channels in MS
  to a single .sub file)
[-del] ==> optional parameter to delete the previous ENTIRE Output_Processing_Location if it
  exists (override previous results!)
[-core N] ==> optional parameter to change the number of cores (splits) used for processing (default = 8)
[-incoh_only] ==> optional parameter to process ONLY Incoherentstokes (even though coherentstokes data exist)
[-coh_only] ==> optional parameter to process ONLY Coherentstokes (even though incoherentstokes data exist)
[-incoh_redo] ==> optional parameter to redo processing for Incoherentstokes (deletes previous incoh results!)
[-coh_redo] ==> optional parameter to redo processing for Coherentstokes (deletes previous coh results!)
[-transpose] ==> optional parameter to indicate the input data were run through the TAB 2nd transpose
[-help] ==> optional parameter which prints the usage and examples of how to run the pipeline
[-test] ==> optional parameter for testing: runs bf2presto and bypasses prepfold and rfi processing but echo's
  all commands
```

Examples:

```
$ pulp.sh -id L2010_06296 -p B0329+54,B0320+39 -o /net/sub5/lse013/data4/LOFAR_PULSAR_ARCHIVE_lse013/L2010_06296_red
  -core 4 -all -rfi -incoh_only -transpose

$ pulp.sh -id L2010_06296 -p B0320+39 -o /net/sub5/lse013/data4/LOFAR_PULSAR_ARCHIVE_lse013/L2010_06296_red
  -core 4 -all -rfi -coh_only -incoh_redo -transpose

$ pulp.sh -id L2010_06296 -p position -o /net/sub5/lse013/data4/LOFAR_PULSAR_ARCHIVE_lse013/L2010_06296_red
  -core 4 -all -rfi -transpose
```

2.1.2 xml_pipeline_kickoff.sh

Use `xml_pipeline_kickoff.sh` script to process multiple completed observations scheduled through MoM. To do this, follow these steps:

The item below is optional for good organization.

1. Export the XML template of observation(s):
 - Create a folder under the project, with ‘Add’ button, as you did for adding a new observation under the project. All observations to be processed can be copied inside this folder. This will allow for serial processing of many observations using a single command.
 - Observations must be “Finished” in order to be processed this way.
 - Select this folder or select all observations you wish to export and choose “Export” tab in the project management window. This will allow you to save the output as an XML file on your local disk.
2. Decide if you want to split the pipeline processing onto N nodes/splits.
3. For BF observations we use the observation XML script to run the pipeline using shell scripts. The shell script has many switches to include various options incorporated in the observation description (XML) file.
4. Use the shell script for processing: `xml_pipeline_kickoff.sh`

Example:

- The exported XML file: `Obs_B1254-10_HBA.xml`
- Number of lce machines to run the pipeline: 4.
- Run the script:

```
$ xml_pipeline_kickoff.sh -infile Obs_B1254-10_HBA.xml\  
-prefix Obs_20100730 -splits 4
```

This results in 4 executable files, with file name-prefix such as `Obs_20100730_PipeExec*.sh` which contain shell commands to run the pipeline.

5. Log on to a compute node (`lce037-lce054`) and create a new (or change to an existing) directory for processing: use `sub5:/data4` and `sub6:/data4` disks for your processing.
6. Executing the script by using command : `./Obs_20100730_PipeExec1`.
7. Use `nice -n 10 <command>` to get higher priority for processing.
8. Use “`kill-STOP <PID>`” or “`kill CONT <PID>`” when you need to stop/start major tasks on the cluster, where `<PID>` is the process id provided by command “`ps -ax |grep your-user-id`” .
9. Pipeline processing sends commands to the background. If you want to bail out of (stop) pipeline processing, check for `bf2presto` or `prepfold` runaway commands and use command “`killall`” .
10. Avoid running more than 2 sets of pipelines which would access (read/write) the same storage nodes, especially if there is an ongoing observation, since this may result in dropped data during the observation, especially when reading or writing data on storage node `lse014`.

2.1.3 Data storage, archival and error detection

1. Generally for BF data, the pipeline products are stored in `sub5:/data4/<dir>/DATE` and `sub6:/data4/<dir>/DATE`. For example:

```
/net/sub5/lse015/data4/LOFAR_PULSAR_ARCHIVE_lse015/20100817
/net/sub5/lse013/data4/LOFAR_PULSAR_ARCHIVE_lse013/20101029
/net/sub6/lse018/data4/LOFAR_PULSAR_ARCHIVE_lse018/20101102
```

`/data/scratch` can also be used. **Note** that this is a temporary area and **old files may be deleted routinely**. For long-term storage, use the above selected method.

2. Look at pipeline results: the TAR.GZ file contains all important files. Use `epdfview` or `display` or `gv` or just `konqueror` to look at pdf and ps plots in resultant directory:
 - Summary of all plots is in `output_dir/combined.png`
 - Single beam incoherentstokes `output_dir/incoherentstokes/RSP?/*.pdf`
 - Single beam coherentstokes `output_dir/stokes/RSP?/*.pdf`
 - Multiple beam incoherentstokes `output_dir/incoherentstokes/*/RSP?/*.pdf`
 - Multiple beam coherentstokes `output_dir/stokes/*/RSP?/*.pdf`
3. If pipeline was run with “-all” option, then an “RSPA” directory under Incoherentstokes directory contains all the subbands and has the best cumulative plot.
4. Check pulsar observations summary web page :
<http://www.astron.nl/~kondratiev/lofar/megapulsars-time.html>
One can sort this list by OBSID, date, object name, and the page is updated nightly.
5. If results are not as expected, you may use the following steps to check the raw and processed files for intermediate results:
(Raw) `$readfile -f incoherentstokes | less` : The starting lines contain numbers are the same, it should not contain a lot of zero's
(Processed) `$grep "null" bf2presto*out` : in the output sub-directories named RSP0-RSP7.

2.2 Standard imaging pipeline

An extensive cookbook has been created to use LOFAR imaging pipeline to make images, interested reader is asked to follow steps outlined in it. It can be accessed from the following link:

<http://www.astron.nl/radio-observatory/lofar/lofar-imaging-cookbook>

2.3 Clean up and data management

Every few months the pulsar group goes through the data id's listed on internal wiki pages to identify datasets that can be removed (old, redundant, bad, *etc.*) The raw (and processed) data corresponding to these data id's are deleted. This process currently can only be done by hand.

Always move processing results from `/data/scratch` to an archive or delete them if not needed.

NOTE: never exceed 98% disk capacity, which can affect NFS mounted disk access speed (and observations in progress / to follow). Always check disk space before processing.

To check the data size of top processes, you can run commands such as `sub5command.sh` or `cexec1` or `cexec2`. See `~alexov/.myalias` for details.

3 Analysis

The processed data from LOFAR are in PRESTO “.sub” format. Most of the PRESTO software analysis tools can be used to further analyse these data sets. The “.sub” files can be found in the LOCATION (in the data processing directory), and different files are for individual channels. Most standard LOFAR observations contain $244 \times 16 = 3904$ or $240 \times 16 = 3840$ channels (files). Interested readers are directed to PRESTO documentation for relevant details.

Users can access raw data through pipeline programs, such as `bf2presto` and `bf2fits`. There are a number of pulsar software packages available: `TEMPO`, `PRESTO`, `PSRCHIVE`, `DSPSR`, *etc.*

A number of utilities were written by users of LOFAR data:

`subdyn.py`, `subhist.py`, `subtime.py`, `spectrum.py`, `pdf_reader.py`, `obsinfo.py`, *etc.*

3.1 BFDataReader: Python class

Sander ter Veen¹⁵ has created a Python class to read BF Raw data, which can currently read Coherentstokes and Incoherentstokes format from single beam instance. One can read data in Numpy array format, and then process them in any way desired. To use this class one has set the following in file `.mysetenv` on the `lfe001`.

```
export PYTHONPATH='/home/veen/usg/src/CRTTools/implement/Pypline/modules/:$PYTHONPATH'
```

Example below shows how to invoke this class for Incoherentstokes data:

```
dptr=bfd.BFDataReader('L22889')
```

Various metadata are read from the PARSET file and are available for use.

<code>dptr.channels</code>	<code>dptr.datatype</code>	<code>dptr.__init__</code>	<code>dptr.nrtypes</code>	<code>dptr.samples</code>
<code>dptr.__class__</code>	<code>dptr.__doc__</code>	<code>dptr.__module__</code>	<code>dptr.par</code>	<code>dptr.setDatatype</code>
<code>dptr.data</code>	<code>dptr.files</code>	<code>dptr.nrsubbands</code>	<code>dptr.read</code>	

Shown below are commands to read the data in an Numpy array.

```
data=[]
for block in range(dat.par['nrblocks']):
    d=dptr.read(block)
    data.append(d)

data=array(data).reshape(dptr.par['nrblocks']*dptr.samples,\
    len(dptr.files)*dptr.channels)
```

The Numpy array “data” now holds an array of floats.

```
shape(data) = (76288, 2304)
```

¹⁵s.terveen @ astro . ru . nl

3.2 Dynamic Spectra: scintillation/Solar studies

If one wanted to study interplanetary scintillation, one would run only 'rfireport' and produce the dynamic spectrum produced by "subdyn.py" for a **single** RSP group (core=1). Dynamic spectrum pipeline is under construction.

4 Appendix

4.1 A: Useful Contacts, webpages and shell scripts

- You can contact observer on duty via telephone on 0521 595 701, or via email: observer@astron.nl
- You can reach support science team via email on: sciencesupport@astron.nl
- The state of stations can be viewed online on the ROCR White Board
http://www.lofar.org/operations/doku.php?id=operator:current_station_overview
- The data size calculator for LOFAR observations can be found here
<http://lofar.proposal.astron.nl/service/pages/storageCalculator/beamformed.jsp>
- See `/globalhome/asgekar/bin` for the following scripts: “`show_data1.sh`”, “`show_data1_sorted.sh`”, “`show_data_all.sh`” and “`show_data_allsorted.sh`”. Their obvious names indicate their function: they display available space on storage nodes in percentage points; note that each storage node disk has 4.6 TB space.
- Pulsar Observations Summary web page¹⁶ by Vlad Kondratiev:
<http://www.astron.nl/~kondratiev/lofar/megapulsars-time.html>
You can sort entries by OBSID, date, object name; this page is updated nightly.
- To build your own USG svn repository on your laptop/ dekstop (Mac / Ubuntu Linux) or on lfe001: the instructions for download and install are here:
http://www.lofar.org/operations/doku.php?id=tkp:general_pwg_info#code_repository_ies
- Resource wiki page from pulsar working group:
[http://www.lofar.org/operations/doku.php?id=tkp:general_pwg_info&s\[\]=anastasia](http://www.lofar.org/operations/doku.php?id=tkp:general_pwg_info&s[]=anastasia)
- LOFAR wiki is password protected. Please register on this page <http://www.lofar.org/operations/doku.php?id=wiki> to gain access.

¹⁶These pages are password protected. Please contact Jason Hessels or Ben Stappers for access.

4.2 B: Various possible Modes of Beam-formed Observations

This list is copied from http://www.lofar.org/wiki/doku.php?id=operator:observing_modes_mom, which maintains a more updated version.

Also check constraints in software imposed on various observation parameters set in MoM:
http://www.lofar.org/operations/doku.php?id=operator:observation_parameters_constraints
stokes I from incoherently added stations

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	no
Coherent Stokes data	no
Incoherent Stokes data	yes
Pencilbeam flyseye	no
Select Stokes	I

Stokes IQUV from coherently added stations. Note: `pulp.sh` can not process IQUV data.

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	no
Coherent Stokes data	yes
Incoherent Stokes data	no
Pencilbeam flyseye	no
Select Stokes	IQUV

Stokes IQUV from incoherently added stations. Note: `pulp.sh` can not process IQUV data.

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	no
Coherent Stokes data	no
Incoherent Stokes data	yes
Pencilbeam flyseye	no
Select Stokes	IQUV

Stokes I from individual stations

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	no
Coherent Stokes data	yes
Incoherent Stokes data	no
Pencilbeam flyseye	yes
Select Stokes	I

Stokes IQUV from individual stations. Note: pulp.sh can not process IQUV data.

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	no
Coherent Stokes data	yes
Incoherent Stokes data	no
Pencilbeam flyseye	yes
Select Stokes	IQUV

Complex voltages from individual stations (after poly-phase filter on BG/P). Note: pulp.sh can not process complex-voltage data.

Instrument	Beam Observation
Correlated data	no
Filtered data	no
Beamformed data	yes
Coherent Stokes data	no
Incoherent Stokes data	no
Pencilbeam flyseye	yes
Select Stokes	IQUV

Complex voltages from individual stations (before poly-phase filter on BG/P). Note: pulp.sh can not process complex-voltage data.

Instrument	Beam Observation
Correlated data	no
Filtered data	yes
Beamformed data	no
Coherent Stokes data	no
Incoherent Stokes data	no
Pencilbeam flyseye	yes
Select Stokes	IQUV

4.3 C: Beamformed observation parameters.

4.3.1 Typical values and range of values for various observation parameters

- Array = “High-Band Antennas” (HBA low).
 - **For HBA observations** (frequency 110 – 230 MHz): choose one among “HBA Zero”, “HBA One”, “HBA Dual”, or “HBA Joined”.
 - In mode HBA Dual , both HBA sub-stations, HBA0 and HBA1, are recorded separately.
 - One can also choose also just HBA0 or HBA1 to observe with just only one sub-station.
 - Use HBA Joined when signals from HBA0 and HBA1 are joined at station level, with undesirable beam shape.
 - **For LBA observations** (10 – 90 MHz): choose one between “LBA Outer” or “LBA Inner”.
When using international stations in LBA, one must choose Array=“LBA Inner”.
- Clock = “200 MHz” almost always ¹⁷.
- “Filter” = 110 – 230 MHz (for HBA observations), 30 – 90 MHz or 10 – 90 MHz (both for LBA observations)
- Channels per Subband = 16
- Correlator Integration Steps (how many samples in a second) = 12288. We should set it, but system re-calculates it now automatically.
- Fly’s Eye = “No” . **Note:** for Fly’s Eye observations, you have to specify Coherent Stokes = “Yes” as well.
- Polarization = Stokes I (or IQUV)
- Integrate Channels Online = “No”. This integrates over all the channels, **not** desirable.
- Stokes Integration Steps = 16.
- You may prefer to have custom-set subbands: “200..447”, without the quotes. This overwrites the Central Frequency/ Bandwidth settings.
- Set stations: you may prefer to choose “Custom” stations over ‘Dutch’ or ‘Core’ stations¹⁸. Operator can change these depending upon their availability & health, before changing the status to ‘Prepared’.
- Add a Beam to specify where you’re pointing. If you choose start and end time of the observation, this may be over-ridden during the scheduling processing (manual or otherwise.) If you choose duration, end-time will be computed from start time and the duration.
- Duration mentioned in the Beam details must match those provided in Observation details. One can choose to select “Duration Equals Observation” option for individual beams to enforce this.

¹⁷For observations in 170-230 MHz band one has to use 160 MHz clock; see ASTRON webpage for details.

¹⁸“Dutch” or “Core” settings do not translate to meaningful settings in OTB as yet. So, needed stations should be chosen by clicking on them.

- Correlator Integration Interval = “2 s”. This is only important for imaging observations, but you still need to specify it. Default values for imaging observations are: 2 seconds for HBA, and 3 seconds for LBA.
- Incoherentstokes and/or Coherent Stokes.
- If you choose both ‘Coherent Stokes’ and ‘Incoherent Stokes’ for observations, set the following:
 - Number of Pencil Rings = “0” if only the central beam is needed (or “1”, one wants to set up 6 surrounding beams automatically) However, before this logic is implemented (see below), you still need to specify central beam as (0.0,0.0) in the pencil Beams.
 - Ring Size = “0.00872663” radians for HBA (0.5° deg, approximate tied-array beam size when Superterp is added coherently. This value needs to be determined more carefully.). This is ignored if the Number of Pencil Rings = 0.
 - Pencil Beams = “(0.0,0.0)” - these are offsets in radians from beam direction. This is specified to record the center beam, and is ignored if the Number of Pencil Rings = 0

NOTE: rings are introduced as help to have hexagonal pointings around the center beam. If you want arbitrary beams, than just specify them all in Pencil Beams. Currently, by default the central beam is not recorded, and you always have to specify it in Pencil Beams as (0.0,0.0). But this will change this soon, so that you will always get the central beam. For now, number of rings=1 means only 6 pointings around the central beams without the central, and one has to add (0.0,0.0) by hand in Pencil Beams to record central beam as well. In future we will not have to worry about manually specifying the central beam, it will be always recorded.

- Filtered data = No (for raw data before 2nd polyphase filter in BG/P)
- Beamformed data = No (for complex voltage data after 2nd polyphase filter)
- Channels per Subband: values 4, 8, 16, 32, 64, ... 512 have been used in the past. Typical pulsar observations use 16 channels. In principle the system can provide upto 2048 channels, although that has never been tested.
- Effective time resolution for the beamformed data: $\tau > (\text{channel_width})^{-1}$. For 16 channels, one has a resolution of $\sim 80 \mu\text{-s}$. If less resolution is desirable, then one must use “Stokes Integration Steps” option, discussed below.
- Correlator Integration Steps (how many samples in a second): 12288. See discussion in the next subsection.
- Fly’s Eye = False. NOTE: for Fly’s Eye observations, you have to specify Coherent Stokes = “Yes” as well.
- Integrate Channels Online = No
- Stokes Integration Steps = 16. If one does not need high resolution, one can use this option to average over time-series in a given channel, further reducing time resolution. For channels = 16 and Stokes Integration Steps =16, time resolution is $16 * 16 * (1/\text{subband width}) \sim 256 * 5 \mu\text{s} \approx 1.28\text{ms}$.

- Central Frequency = 134 MHz and Bandwidth = 47.2 MHz, MoM will compute requisite values of subbands. The central frequency depends on the science goals:
 - for **LBA** $10 \text{ MHz} \leq \nu \leq 90 \text{ MHz}$
 - for **HBA Low** $110 \text{ MHz} \leq \nu \leq 190 \text{ MHz}$
 - for **HBA High** $210 \text{ MHz} \leq \nu \leq 240 \text{ MHz}$
- Bandwidth: LOFAR is now operated with a reduced bandwidth, due to 244 beamlets being used instead of earlier 248. This is due to some firmware issues.
- Subbands : “77...320”, without the quotes. This overwrites the Central Frequency/ Bandwidth settings in MoM.
 - LBA: subbands = 154...397 (band of 31 – 79 MHz)
 - HBA low: subbands = 77...320 (band of 140 – 188 MHz)
 - HBA mid: subbands = 66...309 (band of 174 – 210 MHz) — **not** available currently in MoM.
 - HBA high: subbands = 52...255 (band of 210 – 250 MHz)
- Number of rings = “0” (if only central beam is needed. If you need to include more number of rings surrounding the central beam, use ‘1’ or ‘2’. The beam locations are set by default. JD will soon change the logic— see NOTE below, you still need to specify central beam as (0.0,0.0) in the Pencil Beams)
- Ring Size = “0.00872663” for HBA (in radians, it is 0.5° , this is the approximate tied-array beam size when Superterp is added coherently. This value is ignored for Number of rings = 0, and should be determined more carefully though)
- Pencil Beams = “(0.0,0.0)” - these are offsets in radians from beam direction.

4.3.2 Time and Spectral Resolution

Correlator.Integration.Interval applies for UV synthesis data alone. Please see the subsection below for more details. The time resolution for BF data is set by the inverse of the channel width and Stokes.Integration.Steps¹⁹.

The time resolution is limited by how many channels the data processing chain can handle, and one’s scientific goals. When using the correlator software (in general any soft/hardware using Fourier transform) it is advised to use number of channels an order of 2, so 64/128/256 channels, and so on. One needs higher spectral resolution for better interference rejection and reduce bandwidth smearing. The default number of channels for imaging observations is 64.

On the other hand, we have 16 channels in BF mode, since pulsar pipeline can not currently handle more than 244×16 channels in the pipeline. At the same time, this reduces data rate, while not many of scientific goals are not compromised by the lower time resolution.

For beam-formed data with N channels per subband, the ‘channel’ time resolution, τ , is given by

$$\tau = \frac{N}{195312.5} \text{ seconds}$$

¹⁹This does not take into account smearing due to dispersion or scattering in the interstellar plasma.

If you want to lower the resolution further (*e.g.* to reduce data rate), one should use "Stokes.Integration.Steps" parameter. The name 'Stokes Integration steps' is a slight misnomer, it is an integration carried over subsequent stokes time samples in each channel. So, it is averaging the time-series data further, contributing to the BF time resolution given by,

$$\tau = \frac{N \times \text{Stokes.Integration.Steps}}{195312.5} \text{ seconds}$$

For example, if one uses 64 channels, the time resolution is about 320 μ -sec. For 16 channels, the channel resolution is about $\sim 80 \mu$ -s. If one desires reduced time sampling, to ~ 1 ms (1000 μ -s), one can use Stokes.Integration.Steps = 4, for example. For 16 channels we use Stokes.Integration.Steps parameter value = 128, to reduce the time resolution to about 1 ms.

Note: see below for constraints on Stokes.Integration.Steps and Correlator.Integration.Steps.

4.3.3 Subband frequencies

For LOFAR, we use the following default subband list (with 61 beamlets):

Frequency Range	Subband list
30 – 78 MHz	154..397
115 – 163 MHz	77..320
180 – 220 MHz	128..371

For a clock with clock rate R , the subband width in frequency is given by,

$$\delta\nu_{\text{subband}} = \frac{R}{2 \times 512}$$

The observing frequency for a subband with number S is given by

$$\nu_{\text{subband}} = \left(\frac{N \times R}{2} \right) + \delta\nu_{\text{subband}} \times S,$$

where N is the Nyquist zone, tabulated below for various clock rates and frequency ranges.

Nyquist Zone (N) \rightarrow	0	1	2
Clock: 200 MHz	0 – 100 MHz	100 – 200 MHz	200 – 300 MHz
Clock: 160 MHz	0 – 80 MHz	80 – 160 MHz	160 – 240 MHz

4.3.4 Sanity check for the following

- Number of data products > 0
- Number of subbands > 0
- Number of stations > 0
- Observation End Time $>$ Observation Start Time $>$ Time Now
- Do not specify both Beamformed and Coherent Stokes as True.

4.3.5 Correlator Integration Steps

This parameter sets the total number of (sample*channel) integrations carried out in the correlator over a time period of 1.007 second.

1. For a sample interval of τ seconds and N channels per subband, constraint is:
Correlation.Integration.Steps * τ * N \sim 1.007

Examples

- N = 16, $\tau = 1.0/195312.5$ (clock of 200 MHz): Correlation.Integration.Steps = 12288
 - N = 256, $\tau = 1.0/195312.5$ (clock of 200 MHz): Correlation.Integration.Steps = 768
2. Correlation.Integration.Steps must be divisible by 16
 3. Correlation.Integration.Steps/16 = integer \geq 1

4.3.6 Correlator Integration Steps and Stokes Integration Steps

The Correlation.Integration.Step should be divisible by Stokes.Integration.Step.

Examples

- If the calculation in the first item sets Correlation.Integration.Steps = 12288, then Stokes.Integration.Step = 16 or 256 will work, but Stokes.Integration.Step = 100 or 25 will fail.
- If the calculation in the first item sets Correlation.Integration.Steps = 768, then Stokes.Integration.Step = 16 or 48 will work, but Stokes.Integration.Step = 40 will fail.

4.4 D: Shell script to generate XML template file

To generate an XML file for one or multiple observations, use the generator shell script (on lfe001):

```
$ use LUS ↵
```

Usage for Imaging:

```
multi-templatesNbeams.sh [[-help IM]]
-in observation_list_file -inswitch IM -intype source_or_position
-out template_output_file -project project_name [-stations stations_list]
[-start obs_start] [-time duration] [-gap duration] [-lst|-LST]
[-subsHBAHigh subband_range] [-subsHBALow subband_range] [-subsLBA subband_range]
[-integHBA integration_interval_HBA] [-integLBA integration_interval_LBA]
[-antenna antenna_setup] [-modeHBA antenna_submode] [-modeLBA antenna_submode]
[-chansubsHBA channels_per_subband_HBA] [-chansubsLBA channels_per_subband_LBA]
[+multi] [+IS|+CS|+FD|+BF list_or_ALL] [-namecol]
```

Usage for BeamFormed:

```
multi-templatesNbeams.sh [[-help BF]]
-in observation_list_file -inswitch BF -intype source_or_position
-out template_output_file -project project_name [-st stations_list]
[-start obs_start] [-time duration] [-gap duration] [-lst|-LST] [-IS list_or_ALL]
[+IS|+CS|+FD|+BF list_or_ALL] [-subsHBA subband_range] [-subsLBA subband_range]
[-integHBA integration_interval_HBA] [-integLBA integration_interval_LBA]
[-antenna antenna_setup] [-modeHBA antenna_submode] [-modeLBA antenna_submode] [+multi]
[+IM list_or_ALL] [-chansubsHBA channels_per_subband_HBA] [-chansubsLBA channels_per_subband_LBA]
[-integstepsHBA integration_steps_HBA] [-integstepsLBA integration_steps_LBA] [-namecol]
```

Options:

```
-in observation_list_file ==> Specify the ascii file with observation listing (i.e. in.txt)
-inswitch BF_or_IM ==> Switch between 'BF' (Beam-Formed) or 'IM' (IMAGING) type of default obs
-intype source_or_position ==> Input file contains 'source'-based or 'position'-based input
-project project_name ==> Name of the MoM project (usually 'Pulsars' or 'MSSS')
-out template_output_file ==> Specify the name of the output XML template file (i.e. out.xml)

[[+multi]] ==> Turns on the multi-beam input specification; otherwise beam separator is ignored in input file.
[[-LST]] ==> This flags the input start time (command line or file) as LST, otherwise UT is assumed.
[[-stations stations_list]] ==> Comma separated list of stations (i.e. CS001,CS002,RS405)
[[-antenna HBA_or_LBA]] ==> The antenna name - HBA, HBAHigh, HBALow or LBA (default = HBA (BF); HBAHigh (IM))
[[-subsHBA subband_range]] ==> The BF HBA subband range (default = '200..443')
[[-subsHBAHigh subband_range]] ==> The IM HBAHigh subband range (default = '77..320')
[[-subsHBALow subband_range]] ==> The IM HBALow subband range (default = '54..297')
[[-subsLBA subband_range]] ==> The subband range (default = '154..397')
[[-chansubsHBA channels_per_subband_HBA]] ==> The channels per subband for HBA (default = 16 (BF), 64 (IM))
[[-chansubsLBA channels_per_subband_LBA]] ==> The channels per subband for LBA (default = 16 (BF), 64 (IM))
[[-integstepsHBA integration_steps_HBA]] ==> The BF integration steps for HBA (default = 16)
[[-integstepsLBA integration_steps_LBA]] ==> The BF integration steps for LBA (default = 16)
[[-integHBA integration_interval_HBA]] ==> The IM-obs integration interval for HBA (default = 2)
[[-integLBA integration_interval_LBA]] ==> The IM-obs integration interval for LBA (default = 3)
[[-gap duration]] ==> The time between ALL observations in minutes (default = 3)
[[-IS list_or_ALL]] ==> Turn OFF incoherentStokesData [set to ON by default]; 'ALL' or row-number-list '2,4,5'
    (rows start at #1); must use +CS|+FD|+BF switches when IS is turned off for all rows
[[-IM list_or_ALL]] ==> Turn on Imaging (correlatedData) with BF observations; 'ALL' or row-number-list '2,4,5'
    (rows start at #1)
[[-IS list_or_ALL]] ==> Turn on incoherentStokesData [Standard] with Imaging observations; 'ALL' or
    row-number-list '2,4,5' (rows start at #1)
[[-CS list_or_ALL]] ==> Turn on coherentStokesData with Imaging observations; 'ALL' or row-number-list '2,4,5'
    (rows start at #1)
[[-FD list_or_ALL]] ==> Turn on filteredData with Imaging observations; 'ALL' or row-number-list '2,4,5'
    (rows start at #1)
[[-BF list_or_ALL]] ==> Turn on beamformedData with Imaging observations; 'ALL' or row-number-list '2,4,5'
    (rows start at #1)
[[-modeHBA antenna_submode]] ==> The HBA antenna sub-mode (Zero, One (default), Dual, Joined)
```

```

[[-modeLBA antenna_submode]] ==> The LBA antenna sub-mode (Outer (default), Inner, Sparse Even, Sparse Odd, X, Y)
[[[-namecol]] ==> The first column in the input file contains an additional column which will be used as the Obs
Name in MoM

```

For help on Imaging input format and options, use '-help IM' switch
For help on BF (BF+IM) input format and options, use '-help BF' switch

A couple of typical runs of the script are as follows:

```

$ multi-templatesNbeams.sh -in 101030_3C273.txt -inswitch BF -intype source -project
'LEA006' -out temp.xml

```

```

$ multi-templatesNbeams.sh -in 101030_sun.txt -inswitch BF -intype position -project
'LEA012' -chansubshba 64 -out temp2.xml

```

Examples

The MoM XML generator shell script is run using several different input options. Listed first are the types of text file formats allowed as input, followed by an explanation of all the input argument options.

- 1. Input File (“in.txt”) options – single beam:** first set using source names with maximum number of items specified and another with only positions. The subsequent examples show how to use input files with fewer number of columns.

```

1 #1) Example input file with maximum number of items specified:
2 # pulsar antenna channels/ integration start-time duration stations subbands
3 # subband steps minutes
4 B1133+16 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS004,CS005 200..220
5 B1133+16 LBA 64 4 2010-07-22T15:03:00 10 CS001,CS002,CS005,CS006,CS007 55..200
6 B1133+16 HBA 16 16 2010-07-22T15:15:30 10 CS001,CS002,CS003,CS004,CS005 200..220
7 B1133+16 LBA 16 16 2010-07-22T15:27:30 10 CS001,CS002,CS003,CS006,CS007 77..220
8 B1133+16 LBA 64 4 2010-07-22T15:39:00 10 CS001,CS002,CS003,CS004,CS006,CS007 44..189
9 #
10 #####
11 #
12 #2) Example input file with maximum number of items specified without subbands:
13 #
14 # pulsar antenna channels/ integration start-time duration stations
15 # subband steps minutes
16 #
17 B1133+16 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS004,CS005
18 B1133+16 LBA 64 4 2010-07-22T15:03:00 10 CS001,CS002,CS005,CS006,CS007
19 B1133+16 HBA 16 16 2010-07-22T15:15:30 10 CS001,CS002,CS003,CS004,CS005,CS006,CS007
20 B1133+16 LBA 16 16 2010-07-22T15:27:30 10 CS001,CS002,CS003,CS006,CS007
21 B1133+16 LBA 64 4 2010-07-22T15:39:00 10 CS001,CS002,CS003,CS004,CS006,CS007
22 #
23 #####
24 #
25 #3) Example of input file using ra dec positions:
26 #
27 # ra dec antenna start-time duration stations subbands
28 # minutes
29 #
30 13.98 +68.487 HBAHigh 2010-07-22T14:50:00 10 CS005,CS006,CS007 200..261

```

```

31 13.98 +68.487 LBA 2010-07-22T15:03:00 20 CS001,CS006,CS007 230..351
32 70.498 +1.728 HBALow 2010-07-22T15:15:30 10 CS001,CS002,CS003,CS004 230..351
33 217.17 -1.623 LBA 2010-07-22T15:39:00 120 CS001,CS002,CS003,CS004 200..447
34 217.17 -1.623 HBAHigh 2010-07-22T15:52:00 60 CS007 200..401
35 #
36 #####
37 #4) Example input file 4 column input
38 #
39 # pulsar antenna channels/ integration
40 # subband steps
41 #
42 B1133+16 HBA 16 16
43 B1133+16 LBA 64 4
44 B1133+16 LBA 64 16
45 B1508+55 HBA 16 64
46 #

```

2. **Input File (“in.txt”) options – multiple beam:** first set using source names with maximum number of items specified and another with only positions. The subsequent examples show how to use input files with less number of columns.

Multiple Beams are designated by the “;” separator on the same input line. Any of the above 6 input file column options can be used for multiple beam designation (see help file for full list of input file types). **You can mix** single and multiple beams within one input file.

```

1 #
2 Multiple Beams are designated by the ";" separator on the same input line. Any of the
3 above 6 input file column options can be used for multiple beam designation. You can
4 mix single and multiple beams within one input file.
5
6 For multiple beams, the first beam gets the primary settings for the observation, either
7 using the columns in the input file or the command line arguments. The only items which
8 change for multiple beams are the Pulsar-Name and (optionally the subband-range). If
9 the subband range is not specified per beam, then the total subband range is divided by
10 the number of requested beams (remainder subbands are dropped).
11
12 1) Example input file with maximum number of items specified; lines 2 and 3 contain multiple beams:
13 Example Type I input file using source names:
14 # pulsar antenna chan_ integ start-time duration stations subbands ; pulsar subbands
15 # per_subs steps minutes beamN beamN
16 B1133+16 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS005 200..220
17 B1133+16 LBA 64 4 2010-07-22T15:03:00 10 CS001,CS002,CS006, 155..200 ; B1133+16 201..282
18 B1133+16 HBA 16 16 2010-07-22T15:15:30 10 CS002,CS003,CS005 200..220 ; B1133+16 201..251 ; B1919+
19
20 Example Type I input file using ra dec positions:
21 # ra dec antenna chan_ integ start-time duration stations subbands ra dec subbands
22 # per_subs steps minutes beamN beamN beamN
23 13.98 +68.487 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS004 200..220
24 13.98 +68.487 LBA 64 4 2010-07-22T15:03:00 10 CS001,CS002,CS005 155..200 ; 13.98 +68.487 201..282
25 13.98 +68.487 HBA 16 16 2010-07-22T15:15:30 10 CS001,CS002,CS003 200..220 ; 13.98 +68.487 201..251 ; 1
26
27 2) Example input file with maximum number of items specified w/o subbands; line 2 and 3 contain multiple beams:
28 Example Type II input file using source names:
29 # pulsar antenna chan integ start-time duration stations ; pulsar
30 # per_subs steps minutes BeamN
31 B1133+16 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS004,CS005
32 B1133+16 LBA 64 4 2010-07-22T15:03:00 10 CS001,CS002,CS005,CS006,CS007 ; B1133+25
33 B1133+16 HBA 16 16 2010-07-22T15:15:30 10 CS001,CS004,CS005,CS006,CS007 ; B1144+45 ; B1919+55
34
35 Example Type II input file using ra dec positions:
36 # ra dec antenna chan_per_subs integ_steps start-time duration stations
37 13.98 +68.487 HBA 16 16 2010-07-22T14:50:00 10 CS001,CS003,CS004,CS005

```

```

38         13.98 +68.487 LBA      64          4          2010-07-22T15:03:00 10 CS001,CS002,CS005,CS006,CS007
39         13.98 +68.487 HBA      16          16         2010-07-22T15:15:30 10 CS001,CS002,CS003,CS004,CS005,CS
40
41 3) Example input file 4 column input; lines 2 and 3 contain multiple beams:
42 Example Type III input file using source names:
43 # pulsar antenna chan_per_subs integ_steps ; BeamN-pulsar
44 B1133+16 HBA      16          16
45 B1133+16 LBA      64          4 ; B1133+25
46 B1133+16 LBA      64          16 ; B1144+45 ; B1919+55
47 B1508+55 HBA      16          64
48
49 Example Type III input file using ra dec positions:
50 # ra dec antenna chan_per_subs integ_steps ; BeamN-ra BeamN-dec
51 13.98 +68.487 HBA      16          16
52 13.98 +68.487 LBA      64          4 ; 13.98 +68.487
53 13.98 +68.487 HBA      16          16 ; 13.98 +68.487 ; 13.98 +68.487
54
55 4) Example input file 2 column input; lines 1 and 2 contain multiple beams:
56 Example Type IV input file using source names:
57 # pulsar antenna; BeamN-pulsar
58 B1133+16 HBA ; B1133+25
59 B1133+16 LBA ; B1144+45 ; B1919+55 ; B1755+19
60 B1133+16 LBA
61 B1508+55 HBA
62
63 Example Type IV input file using ra dec positions:
64 # ra dec antenna ; BeamN-ra BeamN-dec
65 13.98 +68.487 HBA ; 13.98 +68.487
66 13.98 +68.487 LBA ; 13.98 +68.487 ; 13.98 +68.487
67 13.98 +68.487 HBA
68
69 5) Example input file 1 column input; lines 1 and 4 contain multiple beams:
70 Example Type V input file using source names:
71 # pulsar ; BeamN-pulsar
72 B1133+16 ; B1144+45 ; B1919+55 ; B1755+19
73 B1133+16
74 B1133+16
75 B1508+55 ; B1144+45 ; B1755+19
76
77 Example Type V input file using ra dec positions:
78 # ra dec ; BeamN-ra BeamN-dec
79 13.98 +68.487 ; 13.98 +68.487
80 13.98 +68.487
81 14.68 +45.234
82 13.98 +68.487 ; 13.98 +68.487 ; 14.68 +45.234
83
84 6) Example input file has "NameColumn" and pulsar name (NOTE: the NameColumn must be 1st)!
85 "NameColumn" can be added to ANY of the above data tables, but it must always be the 1st column.
86 Example Type VI input file using source names and mutiple beams:
87 # namecol pulsar ; BeamN-pulsar
88 LOFAR_HBA00001 B1133+16 ; B1144+45 ; B1919+55 ; B1755+19
89 LOFAR_HBA00002 B1133+16
90 LOFAR_HBA00003 B1133+16
91 LOFAR_HBA00004 B1508+55 ; B1144+45 ; B1755+19
92
93 Example Type VI input file using ra dec positions:
94 # namecol ra dec ; BeamN-ra BeamN-dec
95 LOFAR_HBA00001 13.98 +68.487 ; B1144+45 ; B1919+55 ; B1755+19
96 LOFAR_HBA00002 13.98 +68.487
97 LOFAR_HBA00004 13.98 +68.487
98 LOFAR_HBA00005 55.76 +18.546 ; B1144+45 ; B1755+19
99

```

Examples of how to run the script:

Once an input file is specified, user can run the script like shown below:

```
1
2 $ multi-templatesNbeams.sh -in obs.txt -inswitch BF -intype source -project Pulsars -out output.xml
3
4 $ multi-templatesNbeams.sh -in obs.txt -inswitch BF -intype source -project Pulsars -out output.xml\
5     -subsLBA 10..45 +IM 6,7 +CS 6,7
6
7 $ multi-templatesNbeams.sh -in obs.txt -inswitch BF -intype source -project Pulsars -out output.xml\
8     -start 2010-07-22T14:00:00 -time 33 -stations CS001
9
10 $ multi-templatesNbeams.sh -in obs.txt -inswitch BF -intype source -project Pulsars -out output.xml\
11     -start 2010-07-22T14:00:00 -time 10 -stations CS001,CS002 -subsLBA 10..45 -IS 4,5 +CS 4,5
12
13 $ multi-templatesNbeams.sh -in obs.txt -inswitch BF -intype source -project Pulsars -out output.xml\
14     -start 2010-07-22T14:00:00 -time 30 -stations CS001 -gap 6 -subsHBA 200..245 +IM 2,4,6
15
16 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
17     -start 2010-07-22T14:00:00 -time 33 -stations CS001,CS002,CS003,CS004 +multi
18
19 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
20     -start 2010-07-22T14:50:00 -time 10 -stations CS001,CS002 -gap 6 +IM ALL +multi
21
22 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
23     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -subsLBA 10..45 +FD all
24
25 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
26     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -subsLBA 10..45 -subsHBA 200..401
27
28 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
29     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -project LEA032 +IM ALL
30
31 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
32     -start 2010-07-22T14:00:00 -time 33 -stations CS001,CS002,CS003,CS004
33
34 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
35     -start 2010-07-22T14:50:00 -time 10 -stations CS001,CS002 -gap 6 -project LEA032 +IM 1,2
36
37 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
38     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -antenna LBA -subsLBA 10..45
39
40 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
41     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -chansubsHBA 64 -integstepsHBA 4 +multi -namecol
42
43 $ multi-templatesNbeams.sh -in obs\_1col.txt -inswitch BF -intype source -project Pulsars -out output.xml\
44     -start 2010-07-22T09:40:00 -time 25 -stations CS001 -antenna LBA -chansubsLBA 64 -integstepsLBA 4
```