

# LWA Station-Level Observing Procedure and Associated Metadata

Ver. 4

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# 1 Introduction

This memo documents the procedure for using the initial operational capability (IOC) monitoring and control system (MCS) to conduct observations with LWA-1. This includes the procedure for designing observations, as well as the process for working with MCS to schedule and conduct the observation. This memo also serves to document the content and format of observation “metadata”; that is, data which is produced by MCS as part of the processes of scheduling and conducting the observation. Metadata is distinct from the primary instrument output, which is captured by MCS data recorders (MCS-DRs). The latter is documented in the ICDs of the DP and MCS-DR subsystems ([1] and [2], respectively).

## 2 Definitions

We begin with some definitions. For the purposes of this documentation, we shall refer to *projects*, which are said to consist of one or more *sessions*, which in turn are said to consist of one or more *observations*. Formal definitions of these terms follow:

- A **project** is a set of observations which collectively support a defined scientific objective. For LWA-1 post-IOC, a project will usually be an observing proposal which has been approved, possibly with changes or with additional information provided by the project office (PO).
- A **session** is a subset of *observations* (defined next) conducted within the scope of a *project* that is conducted using exactly one of the 5 principal DP outputs (that is, one of the 4 beam outputs or the TBW/TBN output) within a contiguous time duration, typically a few hours in length. Informally, a session might be described as an “observing run”.
- An **observation** is henceforth defined as the process of collecting a *contiguous* block of data from the session-specified DP output, during which the parameters defining the observation (as documented in this memo) do not change. From the perspective of an LWA-1 user, observations are “atomic” units for scheduling purposes.

An observation is said to be conducted in one of the following **observing modes**. These are:

- RA/DEC Tracking (TRK\_RADEC). This is a beam output mode in which the beam tracks a specified right ascension (RA) and declination (DEC).
- Solar Tracking (TRK\_SOL). This is a beam output mode in which the beam tracks the Sun.
- Jupiter Tracking (TRK\_JOV). This is a beam output mode in which the beam tracks Jupiter.
- Stepped Tracking (STEPPED). This is a beam output mode in which the beam is pointed to sequence of specified directions according to a predetermined schedule. The direction can be specified as either RA/DEC or AZ/EL. The beam is utterly fixed until the next scheduled repointing (so if RA/DEC is specified, the beam remains fixed at the corresponding AZ/EL until the next repointing). This mode can also be used to fix the beam for the entire duration of an observation (i.e., an observation consisting of just one “step”), to step *center frequency* as opposed to pointing, or to step in both center frequency and pointing in any combination.
- Transient Buffer – Wideband (TBW).
- Transient Buffer – Narrowband (TBN).
- Diagnostic Mode 1 (DIAG1). In this mode, all parameters of the observation are ignored (except, of course, for OBS\_MODE). MCS/Executive accepts the observation and will return metadata, but will not do any observing (so no data will be recorded) and will instead output metadata almost immediately. The primary use of this mode is to test that MCS/Executive is operational and communications between all three MCS components (Task Processor, Executive, and Scheduler) are operational.

For example: A *project* might consist of 10 *sessions*, with each session corresponding to a single contiguous 4-hour time allocation of one beam (both tunings) on each of 10 different days. Let’s say each session consists of observing 4 sources, and that the process for observing any given source is to point the beam at a strong calibrator while tuned to a given pair of frequencies (corresponding to the two tunings of the assigned DP beam output) for 10 minutes, and then to point the beam at the source for 50 minutes, and then to repeat the for a second different frequency pair. In this case, each session consists of 8 observations. All the observations are (probably) using the TRK\_RADEC mode, but 8 combinations of RA/DEC and frequency pair are required. To further illustrate, it should be noted that in this case it is given that only one DP beam output was allocated; if however *two* DP beam outputs were allocated, then the project could be completed in one-half the elapsed time, using 2 concurrent sessions of four observations each, per day; total 20 sessions.

See the appendices for other examples of *sessions* and *observations*.

### 3 Process

In this section we outline the process for defining, scheduling, and conducting observations, and the associated input and output metadata. Note that MCS schedules *sessions*, not specifically observations. However, individual observations can be scheduled as sessions having only one observation.

1. The PI creates a *session definition file*. A session definition file is a text file which defines the session and its constituent observations. The format of a session definition file is specified in Section 4.
2. An operator submits the session definition file to MCS using `tpss`, a program which runs on MCS/TaskProcessor. Using `tpss`:
  - (a) The session definition file is parsed and checked for errors, and any derived information is displayed to the operator for confirmation.
  - (b) Specific resources are assigned to the observation. For example, it is at this point that the operator might assign a particular DP output beam to the session. Concurrently, `tpss` is checking for resource conflicts (e.g., making sure the assigned beam is not already allocated at the requested time).
  - (c) The operator also ensures that a reasonable value is assigned to `SESSION_CRA` (see description below), and that this value is consistent with other concurrently-running sessions and the station-level CRA policy.
  - (d) The operator edits the session definition file “REMP0” fields (see Section 4) as appropriate. These are remarks pertaining to review and scheduling that the PO or operator wish to convey as metadata. `tpss` is run at least once so that these comments are included in the version of the session definition file that is submitted to MCS/Executive.
  - (e) `tpss` outputs the following files:
    - The session definition file, now modified as a result of Step 2d. In this version of the SDF, the value assigned to every keyword is explicitly indicated.<sup>1</sup> The name of this file has the format `_${PROJECT_ID}_${SESSION_ID}.txt`, where `_${PROJECT_ID}` and `_${SESSION_ID}` are the values associated with the parameters `PROJECT_ID` and `SESSION_ID` (defined in Section 4), respectively.
    - A *session specification file*. The name of this file has the format `_${PROJECT_ID}_${SESSION_ID}.ses`. This is a binary file that specifies parameters that apply session-wide. These parameters are defined in Section 5.
    - One *observation specification file* for each defined observation. The filenames have the format `_${PROJECT_ID}_${SESSION_ID}_${OBS_ID}.obs`, where `_${OBS_ID}` is the value associated with the parameter `OBS_ID`, defined in Section 4. These are binary files that completely specify the scheduled observation. The format of these files is given in Section 6. It is these files, plus the session specification file, that are the actual input to MCS/Executive for conducting observations.
3. The session runs, and the primary DP data output is captured by MCS-DR.
4. As each observation concludes, MCS makes a modified copy of the observation specification file with the filename `_${PROJECT_ID}_${SESSION_ID}_${OBS_ID}_${OBS_OUTCOME}.dat`, where `_${OBS_OUTCOME}` is the value associated with the parameter `OBS_OUTCOME`, defined in Section 7. `_${OBS_OUTCOME}` is an integer which indicates the outcome of the observation; such as whether the observation succeeded or failed. For parameters in the session definition file (and corresponding parameters in the input observation specification file) which are set to “MCS Decides”, the contents of this file reflect the actual values used.

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<sup>1</sup>Exception: Keywords for STEPPED mode observations are only written out if the observing mode is STEPPED, and `OBS_Beam.Delay[n] [p]` and `Beam.Gain[n] [p] [q] [r]` are written out only if `OBS_STP_B[n] = SPEC_DELAYS_GAINS` for a STEPPED mode observation.

5. As the conclusion of the session, MCS creates a gzipped tarball with filename having the format  $\${PROJECT\_ID}\_{\${SESSION\_ID}}.tgz$ . The tarball includes the following:
- The session definition (`.txt`) file, session specification (`.ses`) file, and observation specification (`.obs`) files from Step 2e.
  - The in-processing log (`.ipl`) file for the session. This is a human-readable text file that documents MCS/Executive’s interpretation of the (`.ses`) and (`.obs`) files and conversion into a session command script (see next item).
  - The session command script (`.cs`) file for the session. This is a binary file which contains the precise sequence of commands that MCS/Executive followed in executing the session.
  - A *session metadata file*, with filename having the format  $\${PROJECT\_ID}\_{\${SESSION\_ID}}\_metadata.txt$ . This is a human-readable text file reporting summary information about the session; in particular, information about the success or failure of each observation. The format of this file is given in Section 7.
  - If  $\${SESSION\_INC\_SMIB}= 1$ , the *station static MIB initialization file* is included. This file describes the “static” (unchanging) characteristics of the station, such as the array geometry, the installed components, and the connections between components. This is a binary file.
  - A directory named `dynamic`, which contains files describing time-varying information collected over the duration of the session. Files which may appear in this directory include:
    - `sdm.dat`, the station dynamic MIB file [3] at the time the session ended.
    - The various subsystem MIBs (named according to their identifying three-letter acronyms), depending on session definition file parameters having keywords beginning “`SESSION_MRP...`”. The root filenames of all files in this directory are suffixed with “`_MJD_MPM`” to indicate the modified julian date (MJD) and milliseconds past UTC midnight (MPM) at which they were recorded.
  - If  $\${SESSION\_LOG\_SCH}= 1$ , the MCS/Scheduler log file, `mselog.txt` is included; it is edited to cover the time period of the session.
  - If  $\${SESSION\_LOG\_EXE}= 1$ , the MCS/Executive log file, `meeelog.txt` is included; it is edited to cover the time period of the session.
  - Depending on the session definition file parameter `SESSION_INC_DES`, there may be a directory named `design` which contains various design data and possibly other information relevant to system calibration. See [3] for additional information.

The tarball described in item 5 above, plus the output observation definition files described in item 4 above, constitute the output metadata for the session.

## 4 Format of a Session Definition File

Session definition files are human-readable text files. See the example provided in Appendix A.

Session definition files consist of lines, with each line having the following structure:

- A keyword identifying a parameter
- At least one whitespace character
- Data intended to be assigned to the parameter
- Newline (line terminator)

A line may be up to 4096 characters long. Lines which are empty lines (i.e., containing only the newline character) are allowed, ignored, and encouraged as a way to improve the readability. The “data” field contains only alphanumeric characters (including space) plus standard punctuation and common symbols, but not special/invisible characters. Note that any whitespace between the end of the intended data and the newline is significant.

Generally, session definition files have three or more parts. The first part is a set of lines identifying the PI and project. The second part is a set of lines identifying the session, including parameters that apply session-wide. The third part is a set of lines identifying the first observation, including parameters that apply to that observation. Each additional observation is defined by repeating the third part with the desired modifications. Only parameters which are different from the previous observation need to be defined for subsequent observations.

The following is a list of defined parameters, in the order in which it is required that they appear in the session definition file. In each case, we give the identifying keyword, followed by information on valid values. We begin with parameters identifying the PI and project:

- **PI\_ID**: PI Identification. This is intended to enable concise, unambiguous identification of the PI. PI identification codes should be assigned and maintained by the Project Office. It is recommended that this be a sequentially-assigned integer.
- **PI\_NAME**: PI Name. This is redundant information given **PI\_ID**, but is included primarily for user convenience. The recommended format is *Last\_Name, First\_Name Middle.Initial(s)*.
- **PROJECT\_ID**: Project Identification. This is a string of no more than 8 characters. This is intended to enable concise, unambiguous identification of the project. Project identification codes should be assigned and maintained by the Project Office. Since this is used as part of the filename of some files, it strongly recommended that these be minimum length, free of whitespace, and constructed to be easy to sort; for example “E00037” where “E” identifies a class of projects and “00037” means the 37th project in this class.
- **PROJECT\_TITLE**: This is redundant information given **PROJECT\_ID**, but is included primarily for user convenience.
- **PROJECT\_REMPI**: Remarks from the PI on the project. This intended to be convey information that might not be present or obvious through other session definition file parameters.
- **PROJECT\_REMPO**: Remarks from the Project Office on the project. This intended to be convey information that might not be present or obvious through other session definition file parameters.

Next, keywords identifying the session:

- **SESSION\_ID**: Session Identification. This is intended to enable concise, unambiguous (in combination with **PROJECT\_ID**) identification of the session. Session identification codes are sequentially-assigned integers, beginning with 1.
- **SESSION\_TITLE**: This is redundant information given **SESSION\_ID**, but is included primarily for user convenience.
- **SESSION\_REMPI**: Remarks from the PI on the session. This intended to be convey information that might not be present or obvious through other session definition file parameters.
- **SESSION\_REMPO**: Remarks from the Project Office on the session. This intended to be convey information that might not be present or obvious through other session definition file parameters.

The following session parameters are optional. If not specified, MCS will attempt to assign reasonable values:

- **SESSION\_CRA**: (“Configuration Request Authority”) This is a integer between 0 and 65535 which indicates the priority of this session (with respect to other concurrent sessions) in determining authority to set FEE and ASP settings, which affect all concurrent sessions. “0” (the default if not specified) means no authority; the keywords **OBS\_FEE** and **OBS\_ASP\_\*** will simply be ignored. When multiple sessions are running concurrently on the station and at least one of them has **SESSION\_CRA** > 0, the session with the largest **SESSION\_CRA** sets FEE and ASP settings within the constraints of the station CRA policy set in the Station Static MIB Initialization File (SSMIF). In the event of a tie, MCS will proceed as if all concurrent sessions have **SESSION\_CRA**= 0.
- **SESSION\_DRX\_BEAM**: This is an integer 1-4 which can be used to request the corresponding DP beam output channel. The value “-1” = “MCS decides” (value used if not specified). This is not meaningful if **OBS\_MODE** = TBN or TBW, and is ignored for those observing modes.
- **SESSION\_MRP\_***sss*: This sets the recording period for the MIB associated with the level-1 subsystem *sss*, where *sss* is the usual three-letter acronym (e.g., “ASP”, “DP\_”, etc.). Integer minutes. For example: **SESSION\_MRP\_ASP** = 5 will cause MCS to archive (record) a copy of the ASP MIB every 5 minutes for the duration of the observation. The recorded MIB files are then available as metadata following the observation. “0” = “never record”, and “-1” = “MCS decides”. Note that the setting of this parameter does not imply anything about how often the MIB is *updated*; see “**SESSION\_MUP\_***sss*”. Typically, users will want **SESSION\_MRP\_***sss* ≥ **SESSION\_MUP\_***sss*. When invoked, the order of invocation of subsystems must be: ASP, DP\_, DR1, DR2, DR3, DR4, DR5, SHL, MCS.
- **SESSION\_MUP\_***sss*: This requests a minimum update period for the MIB associated with the level-1 subsystem *sss*, where *sss* is the usual three-letter acronym (e.g., “ASP”, “DP\_”, etc.). Integer minutes. For example: **SESSION\_MUP\_ASP** = 5 will request MCS to force a 100% update of the ASP MIB every 5 minutes for the duration of the observation. “0” = “request no updates (but don’t prevent them either)”, and “-1” = “MCS decides”. It should be noted that there is only one set of MIBs for the station, and that they are common to all sessions. Therefore, if MCS or some other concurrently-running session successfully requests a shorter update period, then this parameter will have no effect. When invoked, the order of invocation of subsystems must be: ASP, DP\_, DR1, DR2, DR3, DR4, DR5, SHL, MCS.
- **SESSION\_LOG\_SCH**: If this is “1”, the portion of the MCS/Scheduler log file (**mselog.txt**) corresponding to the time period of the session is saved as metadata. This is assumed if not specified; otherwise, use “0” = “don’t save”.
- **SESSION\_LOG\_EXE**: If this is “1”, the portion of the MCS/Executive log file (**meeleg.txt**) corresponding to the time period of the session is saved as metadata. This is assumed if not specified; otherwise, use “0” = “don’t save”.

- **SESSION\_INC\_SMIB**: If this is “1”, then the station static MIB is saved as metadata, as described in Section 3. “0” = “don’t save”, which is assumed if the parameter is not specified.
- **SESSION\_INC\_DES**: If this is “1”, then available and relevant design and calibration information is saved as metadata, as described in Section 3. “0” = “don’t save”, which is assumed if the parameter is not specified.

Next, required keywords defining an observation:

- **OBS\_ID**: Observation Identification. This is intended to enable concise, unambiguous (in combination with **PROJECT\_ID** and **SESSION\_ID**) identification of the observation. Observation identification codes are sequentially-assigned integers, beginning with 1.
- **OBS\_TITLE**: This is redundant information given **OBS\_ID**, but is included primarily for user convenience. Optional.
- **OBS\_TARGET**: This is intended to provide a convenient, standard place to indicate the intended “target” of the observation. This might be a specific source (e.g., “Cas A”), or might be used to indicate that this is an “All-Sky” (TBW/TBN) observation. This field is provided for the convenience of the observer only, and no specific format is required. In particular, it should be noted that this field is NOT used in any way by MCS to determine observing mode or pointing direction. Optional.
- **OBS\_REMPI**: Remarks from the PI on the observation. This intended to be convey information that might not be present or obvious through other session definition file parameters. Optional.
- **OBS\_REMPO**: Remarks from the Project Office on the observation. This intended to be convey information that might not be present or obvious through other session definition file parameters. Optional.
- **OBS\_START\_MJD**: Modified julian day (MJD) on which the observation is to start. Coordinated Universal Time (UTC) is assumed.
- **OBS\_START\_MPM**: Time of day at which the observation is to start, written as integer milliseconds past UTC midnight (MPM). The range of values is 0 through 86399999; or, for days containing a leap second, 0 through 86400999.
- **OBS\_START**: Start time of the observation written in a format of the PI’s choice. This is redundant information given **OBS\_START\_MJD** and **OBS\_START\_MPM**, but is included for user convenience. The suggested format is “UTC yyyy mm dd hh:mm:ss.sss”. This parameter is not used by MCS.
- **OBS\_DUR**: The duration of the observation in integer milliseconds. This parameter is ignored if **OBS\_MODE** = **STEPPED** or **TBW** (for **TBW**, see instead **OBS\_TBW\_SAMPLES**).
- **OBS\_DUR+**: The duration of the observation written in a format of the PI’s choice. This is redundant information given **OBS\_DUR** (or **OBS\_TBW\_SAMPLES**) and is ignored by MCS, but is included for user convenience. The suggested format is “hh:mm:ss.sss”. Optional; this parameter is not used by MCS.
- **OBS\_MODE**: Observing mode, as explained in Section 2. Valid entries here are: **TRK\_RADEC**, **TRK\_SOL**, **TRK\_JOV**, **STEPPED**, **TBW**, **TBN**, and **DIAG1**.
- **OBS\_RA**: RA (decimal hours) for beam pointing, epoch J2000. Meaningful only if **OBS\_MODE** = **TRK\_RADEC**; otherwise this parameter is ignored.
- **OBS\_DEC**: DEC (decimal degrees) for beam pointing, epoch J2000. Meaningful only if **OBS\_MODE** = **TRK\_RADEC**; otherwise this parameter is ignored.



OBS_BW	OBS_MODE =	OBS_MODE =	OBS_MODE =
	TRK_RADEC, TRK_SOL, TRK_JOV, or STEPPED	TBN	TBW
1		0.250 MSPS	1.000 kSPS
2		0.500 MSPS	3.125 kSPS
3		1.000 MSPS	6.250 kSPS
4		2.000 MSPS	12.500 kSPS
5		4.900 MSPS	25.000 kSPS
6		9.800 MSPS	50.000 kSPS
7		19.600 MSPS	100.000 kSPS

Table 1: Relationship between the parameter `OBS_BW` and sample rate, adapted from information in the DP ICD [1]. Note that the DP ICD does not specify filter shapes; however bandwidth (e.g., 3 dB bandwidth) for modes other than TBW can be inferred to be slightly less than the indicated sample rate; for TBW it is determined by ARX configuration.

- `OBS_B`: Beam type. Meaningful only if `OBS_MODE = TRK_RADEC, TRK_SOL, or TRK_JOVE`; should not appear otherwise. Options are:
  - `SIMPLE`. Beamforming is by equalizing geometrical delays implied by the pointing direction and array geometry. MCS attempts to account for instrumental delays, gains, and phases through the system.
  - `MAX_SNR`. Delays are selected so as to maximize beam sensitivity. This is known to result in significant improvement in sensitivity over `SIMPLE` beamforming [4], but may have undesirable effects on main lobe shape or sidelobe characteristics.

If not specified, `OBS_B` will be set to `SIMPLE`.

- `OBS_FREQ1`: Center frequency for the first DRX tuning, expressed as an integer “tuning word”. Also used to specify the TBN center frequency. The center frequency will be  $\text{OBS\_FREQ1} \times 196/2^{32}$  MHz. For example, `OBS_FREQ1 = 1073741824` corresponds to a center frequency of 49.000000 MHz. The valid range is 219130984 (10 MHz) through 1928352663 (88 MHz). This parameter is ignored if `OBS_MODE = STEPPED or TBW`.
- `OBS_FREQ1+`: Center frequency for the first DRX & TBN tunings, expressed in a format of the PI’s choice. This is redundant information given `OBS_FREQ1` and is ignored by MCS, but is included primarily for user convenience. The suggested format is “xx.xxxxxx MHz”. Optional.
- `OBS_FREQ2`: Center frequency for the first DRX tuning, expressed as an integer “tuning word”. See `OBS_FREQ1` for additional details.
- `OBS_FREQ2+`: Center frequency for the first DRX tuning, expressed in a format of the PI’s choice. See `OBS_FREQ1+` for additional details. Optional.
- `OBS_BW`: Bandwidth, expressed as an integer between 1 and 7. Refer to Table 1 for more information.
- `OBS_BW+`: Bandwidth, expressed in a format of the PI’s choice. This is redundant information given `OBS_BW` and is ignored by MCS, but is included primarily for user convenience.

Continuing with observation definition, the following keywords are meaningful only for `OBS_MODE = STEPPED`, and are ignored otherwise:

- `OBS_STP_N`: Number of steps, written as an integer.
- `OBS_STP_RADEC`: Coordinate system for the parameters `OBS_STP_C1` and `OBS_STP_C2`. “1” means RA/DEC, “0” means AZ/EL.

- `OBS_STP_C1[n]`: For beam pointing direction at step  $n$ , this is either RA or AZ depending on `OBS_STP_RADEC`. Decimal degrees.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_C2[n]`: For beam pointing direction at step  $n$ , this is either DEC or EL depending on `OBS_STP_RADEC`. Decimal hours or degrees.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_T[n]`: Start time for this step in integer milliseconds from `OBS_START_MPM`.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_FREQ1[n]`: Center frequency for the first DRX tuning during step  $n$ , expressed as an integer “tuning word”. The format is the same used for `OBS_FREQ1`.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_FREQ1+[n]`: Center frequency for the first DRX tuning during step  $n$ , expressed in a format of the PI’s choice. See `OBS_FREQ1+` for additional details.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_FREQ2[n]`: Center frequency for the second DRX tuning during step  $n$ , expressed as an integer “tuning word”. The format is the same used for `OBS_FREQ1`.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_FREQ2+[n]`: Center frequency for the second DRX tuning during step  $n$ , expressed in a format of the PI’s choice. See `OBS_FREQ1+` for additional details.  $1 \leq n \leq \text{OBS\_STP\_N}$ .
- `OBS_STP_B[n]`: Beam type.  $1 \leq n \leq \text{OBS\_STP\_N}$ . Options are:
  - `SIMPLE`. (See `OBS_STP_B` for additional details.)
  - `MAX_SNR`. (See `OBS_STP_B` for additional details.)
  - `SPEC_DELAYS_GAINS`. Beamforming is by applying user-specified delays and gains. The delays and gains are specified by the parameters `OBS_BEAM_DELAY [] []` and `OBS_BEAM_GAIN [] [] [] []`. MCS makes no attempt to account for instrumental delays and gains through system.
- `OBS_BEAM_DELAY[n] [p]`: Corresponds to `BEAM_DELAY[p]` in [1]; this is the value during step  $n$ . Meaningful only when `OBS_STP_B[n] = SPEC_DELAYS_GAINS`, and must be specified in this case; otherwise optional.  $1 \leq n \leq \text{OBS\_STP\_N}$ ,  $1 \leq p \leq 520$ . Keywords must appear in sequential order by  $p$ .
- `BEAM_GAIN[n] [p] [q] [r]`: Corresponds to `BEAM_GAIN[p] [q] [r]` in [1]; this is the value during step  $n$ . Meaningful only when `OBS_STP_B[n] = SPEC_DELAYS_GAINS`, and must be specified in this case; otherwise optional.  $1 \leq n \leq \text{OBS\_STP\_N}$ ,  $1 \leq p \leq 260$ ,  $1 \leq q, r \leq 2$ . Keywords must appear in sequential order by  $p$ , then  $q$ , then  $r$ .

The following observation parameters are optional, but allow additional control over the observation which may be useful in certain cases. If not specified, MCS will attempt to assign reasonable values.

- `OBS_FEE[n] [p]`: Controls power for the FEE on stand  $n$ , polarization  $p$ . “1” = “on”, “0” = “off”, “-1” = “MCS decides” (value used if not specified).  $1 \leq n \leq 260$  and  $p = 1$  or  $2$ .  $n$  can also be 0, which is interpreted as meaning that this setting should apply for *all*  $n$ . Must be listed in order of increasing  $n$ .
- `OBS_ASP_FLT[n]`: Selects the “filter setting” for the ARX corresponding to stand  $n$ . This corresponds to the ASP MIB parameter “FIL”. “0” = “split”, “1” = “full”, “2” = “reduced”, “3” = “off”, and “-1” = “MCS decides” (value used if not specified).  $1 \leq n \leq 260$ .  $n$  can also be 0, which is interpreted as meaning that this setting should apply for *all*  $n$ . Must be listed in order of increasing  $n$ .
- `OBS_ASP_AT1[n]`: Selects the first attenuator setting for the ARX corresponding to stand  $n$ . This corresponds to the ASP MIB parameter “AT1”. This is an integer value between 0 and 15, or “-1” = “MCS decides” (value used if not specified).  $1 \leq n \leq 260$ .  $n$  can also be 0, which is interpreted as meaning that this setting should apply for *all*  $n$ . Must be listed in order of increasing  $n$ .

- **OBS\_ASP\_AT2**[ $n$ ]: Selects the second attenuator setting for the ARX corresponding to stand  $n$ . This corresponds to the ASP MIB parameter “AT2”. This is an integer value between 0 and 15, or “-1” = “MCS decides” (value used if not specified).  $1 \leq n \leq 260$ .  $n$  can also be 0, which is interpreted as meaning that this setting should apply for *all*  $n$ . Must be listed in order of increasing  $n$ .
- **OBS\_ASP\_ATS**[ $n$ ]: Selects the split attenuator setting for the ARX corresponding to stand  $n$ . This corresponds to the ASP MIB parameter “ATS”. This is an integer value between 0 and 15, or “-1” = “MCS decides” (value used if not specified).  $1 \leq n \leq 260$ .  $n$  can also be 0, which is interpreted as meaning that this setting should apply for *all*  $n$ . Must be listed in order of increasing  $n$ .
- **OBS\_TBW\_BITS**: Number of bits per TBW output sample. Valid values are 12 (value used if not specified) and 4. This is only meaningful for **OBS\_MODE** = TBW, and is ignored otherwise.
- **OBS\_TBW\_SAMPLES**: Number of samples to acquire in a TBW observation. The largest valid values are 12000000 for **OBS\_TBW\_BITS**= 12 and 36000000 for **OBS\_TBW\_BITS**= 4. If not specified, the largest valid values are used. This is only meaningful for **OBS\_MODE** = TBW, and is ignored otherwise.
- **OBS\_TBN\_GAIN**: This corresponds to the DP TBN command parameter “TBW\_GAIN”. This is an integer value between 0 and 15, or “-1” = “MCS decides” (value used if not specified).
- **OBS\_DRX\_GAIN**: This corresponds to the DP DRX command parameter “DRX\_GAIN”. This is an integer value between 0 and 15, or “-1” = “MCS decides” (value used if not specified).

## 5 Format of a Session Specification File

The session specification file is a packed binary file which indicates parameters used by MCS/Executive that apply session-wide. Note that if this is the post-observation file, any values indicating “MCS Decides” in the pre-observation file will be replaced with actual value used during the session (i.e., what MCS decided).

The format of the file is as shown below. The first column is a format specifier, which is decoded as shown below:

*sn*: character string, *n* bytes, right-padded with “\0” characters.

s1: signed integer, 1 byte, little-endian byte order.

s2: signed integer, 2 bytes, little-endian byte order.

u1: unsigned integer, 1 byte.

u2: unsigned integer, 2 bytes, little-endian byte order.

u4: unsigned integer, 4 bytes, little-endian byte order.

u8: unsigned integer, 8 bytes, little-endian byte order.

The second column indicates the parameter keyword. The third column defines any parameter values not previously defined, or provides additional comments as necessary.

u2	FORMAT_VERSION	Number identifying this version of the file format. (Same as version number of this document.)
s9	PROJECT_ID	
u4	SESSION_ID	
u2	SESSION_CRA	
s2	SESSION_DRX_BEAM	
u8	SESSION_START_MJD	This is the start MJD for the first observation of the session.
u8	SESSION_START_MPM	This is the start MPM for the first observation of the session.
u8	SESSION_DUR	Duration of the session, in milliseconds.
u4	SESSION_NOBS	Number of observations in the session.
s2	SESSION_MRP_ASP	
s2	SESSION_MRP_DP_	
s2	SESSION_MRP_DR1	
s2	SESSION_MRP_DR2	
s2	SESSION_MRP_DR3	
s2	SESSION_MRP_DR4	
s2	SESSION_MRP_DR5	
s2	SESSION_MRP_SHL	
s2	SESSION_MRP_MCS	
s2	SESSION_MUP_ASP	
s2	SESSION_MUP_DP_	
s2	SESSION_MUP_DR1	
s2	SESSION_MUP_DR2	
s2	SESSION_MUP_DR3	
s2	SESSION_MUP_DR4	
s2	SESSION_MUP_DR5	
s2	SESSION_MUP_SHL	
s2	SESSION_MUP_MCS	
s1	SESSION_LOG_SCH	
s1	SESSION_LOG_EXE	
s1	SESSION_INC_SMIB	
s1	SESSION_INC_DES	

## 6 Format of a Observation Specification File

The observation specification file is a packed binary file which completely describes an observation, save any session-wide parameters defined in the session specification file. Note that if this is the post-observation file, any values indicating “MCS Decides” in the pre-observation file will be replaced with the actual value used during the observation (i.e., what MCS decided). The same applies if for any other reason it is necessary to use settings different from those indicated in the input observation specification file.

The format of the file is as shown below. The first column is a format specifier, which is decoded as shown below:

- f4: floating point, 4 bytes, little-endian byte order.
- sn: character string,  $n$  bytes, right-padded with “\0” characters.
- i2: signed integer, 2 bytes, little-endian byte order.
- u2: unsigned integer, 2 bytes, little-endian byte order.
- u4: unsigned integer, 4 bytes, little-endian byte order.
- u8: unsigned integer, 8 bytes, little-endian byte order.

The second column indicates the parameter keyword. The third column defines any parameter values not previously defined, or provides additional comments as necessary.

u2	FORMAT_VERSION	Number identifying this version of the file format. (Same as version number of this document.)
s9	PROJECT_ID	
u4	SESSION_ID	
u4	OBS_ID	
u8	OBS_START_MJD	
u8	OBS_START_MPM	
u8	OBS_DUR	If OBS_MODE = 5 (TBW), this will be 0.
u2	OBS_MODE	1=TRK_RADEC, 2=TRK_SOL, 3=TRK_JOV, 4=STEPPED, 5=TBW, 6=TBN.
f4	OBS_RA	If OBS_MODE $\neq$ 1 (TRK_RADEC), this will be 0.
f4	OBS_DEC	If OBS_MODE $\neq$ 1 (TRK_RADEC), this will be 0.
u2	OBS_B	1=SIMPLE, 2=MAX_SNR; If OBS_MODE > 3, this will be 0.
u4	OBS_FREQ1	If OBS_MODE = 4 (STEPPED), this will be 0.
u4	OBS_FREQ2	If OBS_MODE = 4 (STEPPED), this will be 0.
u2	OBS_BW	If OBS_MODE = 5 (TBW), this will be 0.
u4	OBS_STP_N	If OBS_MODE $\neq$ 4 (STEPPED), this will be 0.
u2	OBS_STP_RADEC	If OBS_MODE $\neq$ 4 (STEPPED), this will be 0.
var	Step Def. Blocks	A total of OBS_STP_N step definition blocks (see below).
i2	OBS_FEE[ 1] [1]	See Note 1.
i2	OBS_FEE[ 1] [2]	
i2	OBS_FEE[ 2] [1]	
i2	OBS_FEE[ 2] [2]	
...		
i2	OBS_FEE[260] [1]	
i2	OBS_FEE[260] [2]	
i2	OBS_ASP_FLT[ 1]	
i2	OBS_ASP_FLT[ 2]	
...		
i2	OBS_ASP_FLT[260]	
i2	OBS_ASP_AT1[ 1]	

```

i2 OBS_ASP_AT1 [ 2]
...
i2 OBS_ASP_AT1 [260]
i2 OBS_ASP_AT2 [ 1]
i2 OBS_ASP_AT2 [ 2]
...
i2 OBS_ASP_AT2 [260]
i2 OBS_ASP_ATS [ 1]
i2 OBS_ASP_ATS [ 2]
...
i2 OBS_ASP_ATS [260]
u2 OBS_TBW_BITS      If OBS_MODE ≠ TBW, this will be 0.
u4 OBS_TBW_SAMPLES   If OBS_MODE ≠ TBW, this will be 0.
i2 OBS_TBN_GAIN      If OBS_MODE ≠ TBW, this will be 0. Also, see Note 1.
i2 OBS_DRX_GAIN      If OBS_MODE > 4 (STEPPED), this will be 0. Also, see Note 1.
u4 4294967295        = 232 - 1, used as a known value to confirm byte alignment when reading file.

```

The  $n^{\text{th}}$  *step definition block* is defined as follows ( $1 \leq n \leq \text{OBS\_STP\_N}$ ):

```

f4 OBS_STP_C1 [n]
f4 OBS_STP_C2 [n]
u4 OBS_STP_T [n]
u4 OBS_STP_FREQ1 [n]
u4 OBS_STP_FREQ2 [n]
u2 OBS_STP_B [n]      1=SIMPLE, 2=MAX_SNR, 3=SPEC_DELAYS_GAINS
var Beam Def. Block  Appears if OBS_STP_B [n] = 3 (SPEC_DELAYS_GAINS).
u4 4294967294        = 232 - 2, used as a known value to confirm byte alignment when reading file.

```

A *beam definition block* is defined as follows. See [1] for additional details.

```

u2 OBS_BEAM_DELAY [n] [ 1]  Corresponds to BEAM_DELAY [] in [1].
u2 OBS_BEAM_DELAY [n] [ 2]
...
u2 OBS_BEAM_DELAY [n] [520]
i2 BEAM_GAIN [n] [ 1] [1] [1] Corresponds to BEAM_GAIN [] [] [] in [1].
i2 BEAM_GAIN [n] [ 1] [1] [2]
i2 BEAM_GAIN [n] [ 1] [2] [1]
i2 BEAM_GAIN [n] [ 1] [2] [2]
i2 BEAM_GAIN [n] [ 2] [1] [1]
i2 BEAM_GAIN [n] [ 2] [1] [2]
i2 BEAM_GAIN [n] [ 2] [2] [1]
i2 BEAM_GAIN [n] [ 2] [2] [2]
...
i2 BEAM_GAIN [n] [260] [1] [1]
i2 BEAM_GAIN [n] [260] [1] [2]
i2 BEAM_GAIN [n] [260] [2] [1]
i2 BEAM_GAIN [n] [260] [2] [2]

```

## 7 Format of a Session Metadata File

The session metadata file is a human-readable text file intended to provide a summary of the session. In this file, each line corresponds to one observation. The format of an observation line is as follows:

```
OBS_ID (whitespace) OBS_OUTCOME (whitespace) MSG
```

OBS\_ID is as defined previously.

OBS\_OUTCOME is an integer code assigned by MCS to indicate the degree to which the observation was successful. OBS\_OUTCOME = 0 means that the observation executed with no noted problems sufficient to warrant concern. Otherwise OBS\_OUTCOME is the sum of the following codes:

0 (ME\_OC\_RCVD\_OK) indicates no reportable problems; session execution apparently went OK.

1 (ME\_OC\_RCVD\_ESF) indicates a failure in inprocessing the session. The cause might be determined from the `.ip1` (inprocessing log) file. A problem with inprocessing any one observation might cause all observations to be rejected.

*Additional codes to be described in future versions of this document.*

MSG is free-form text that provides additional remarks; for example, elaboration if OBS\_OUTCOME > 0.

## A Session Definition File Example

Below is shown the contents of an sample session definition file. If this file were the output of `tpss`, it would be given the name `TPSS0001_0001.txt`.

```
PI_ID          1
PI_NAME        Ellingson, Steven
PROJECT_ID     TPSS0001
PROJECT_TITLE  Project Title
PROJECT_REMPI  Project REMPI
PROJECT_REMPO  Project REMPO

SESSION_ID     1
SESSION_TITLE  tp_session_sch SDF test #1
SESSION_REMPI  Test SDF consisting of 2 short TRK_RADEC observations
SESSION_REMPO  Session REMPO

OBS_ID        1
OBS_TITLE     Observation 1 Title
OBS_TARGET    Observation 1 Target
OBS_REMPI     Observation 1 REMPI
OBS_REMPO     Observation 1 REMPO
OBS_START_MJD 55616
OBS_START_MPM 0
OBS_START     UTC 2011 Feb 24 00:00:00.000
OBS_DUR       10000
OBS_DUR+      00:00:10.000
OBS_MODE      TRK_RADEC
OBS_RA        5.6
OBS_DEC       +22.0
OBS_B         SIMPLE
OBS_FREQ1     438261968
OBS_FREQ1+    19.999999955 MHz
OBS_FREQ2     1928352663
OBS_FREQ2+    87.999999977 MHz
OBS_BW        7
OBS_BW+       19.6 MSPS (but not exactly sure what bandwidth this will be)

OBS_ID        2
OBS_TITLE     Observation 2 Title
OBS_START_MJD 55616
OBS_START_MPM 10000
OBS_START     UTC 2011 Feb 24 00:00:10.000
OBS_DUR       10000
OBS_DUR+      00:00:10.000
OBS_MODE      TRK_RADEC
OBS_RA        5.6
OBS_DEC       +22.0
OBS_B         SIMPLE
OBS_FREQ1     832697741
OBS_FREQ1+    37.999999997 MHz
OBS_FREQ2     1621569285
OBS_FREQ2+    73.999999990 MHz
OBS_BW        7
OBS_BW+       19.6 MSPS (but not exactly sure what bandwidth this will be)
```



## B Document History

- Version 4 (March 29, 2011):
  - Added DIAG1 observing mode.
  - For OBS\_STP\_T[n], deleted statement “Valid values are between 0 and OBS\_DUR–5.”
  - Deleted OBS\_COMMENT codes; now these lines are just text.
  - SESSION\_DRX\_BEAM is now specified to be a two-byte *signed* integer, and keywords beginning SESSION\_LOG\_ and SESSION\_INC\_ are now specified to be one-byte *signed* integers.
  - In the observation specification file, OBS\_START\_MJD, OBS\_START\_MPM, and OBS\_DUR are now specified to be *8-byte* unsigned integers.
  - Changed (simplified) the session metadata file.
  - Additional files are added to the end-of-session tarball.
  - Clarified details on contents of the `dynamic` subdirectory.
  - Fixed minor typos.
- Version 3 (March 1, 2011):
  - Replaced SDF example in Appendix 1.
- Version 2 (Feb 27, 2011):
  - Renamed “`tp_session_sch`” to “`tpss`”.
  - Replaced references to “UT” with “UTC”.
  - Replaced reference to “mean julian date” with “modified julian date”.
  - Explicitly indicated valid range of OBS\_START\_MPM.
  - Indicated that OBS\_RA and OBS\_DEC are decimal hours and degrees, respectively, epoch J2000.
  - Session definition file lines are now *required* to be in the indicated order.
  - OBS\_BW=5 now means 4.9 MSPS for DRX-formatted output, per change in DP ICD.
  - Length of PROJECT\_ID specified to be 8 characters.
  - Moved the list of session-specific optional parameters into the proper order.
  - Added parameter SESSION\_CRA.
  - Clarified that the TBN frequency is set by OBS\_FREQ1.
  - Format of Session Specification File significantly different.
- Version 1 (June 16, 2010): First version.

## References

- [1] M. Soriano, “Interface Control Document for Digital Signal Processing Subsystem (DP),” Ver. K, Long Wavelength Array Internal Report, Jan 28, 2011.
- [2] C. Wolfe, S. Ellingson, & C. Patterson, “Interface Control Document for Monitor and Control System Data Recorder (MCS-DR),” Ver. 1.0, Long Wavelength Array Engineering Memo MCS0025, Mar 22, 2010.
- [3] S. Ellingson, “LWA Station-Level Metadata,” Ver. 4, Long Wavelength Array Engineering Memo MCS0031, March 29, 2011.
- [4] S. Ellingson, “Sensitivity of Antenna Arrays for Long-Wavelength Radio Astronomy”, *IEEE Trans. Ant. & Prop.*, *in press*. Also available as Long Wavelength Array Memo 166, Dec 30, 2009, at <http://www.phys.unm.edu/~lwa/memos>.