ALMA Phasing Project H Maser Procedures

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Prepared by:	Organization Role	Date and Signature
G. Crew	MIT	
Approved by:	Organization Role	Date and Signature
Authorized by:	Organization Role	Date and Signature

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Chapter 1

Introduction

1.1 Purpose

The H Maser provided to ALMA by APP comes with extensive documentation, and is designed to run unattended. It is also under a support contract from T4Science (http://www.t4science.com). This document is intended to gather all maintenance or other procedures in one place for convenience.

1.2 Scope

This document is limited to certain essential procedures and assumes access to the underlying reference documents for full particulars.

1.3 Reference Documents

The following documents contain additional information, are referenced in this document, and should be consulted for further, more detailed information.

Table 1.1: *Reference Documents*

Reference	Document Title	Document ID
[RD1]	Installation_Operation_and_Maintenance_ User_manual_iMaser_T4S-MAN-0012_1_7emc-2.pdf	
[RD2]	T4S-MAN-0015v1.3_Network_Monit_User_Manuel_ a14_Option-RE-DIST.pdf	
[RD3]	T4S-PROC0011_IP_address_change_ IO_card_general.pdf	
[RD4]	APP Update to Corr/Control Design	ALMA-05.11.61.01-0001-A-DSN
[RD5]	Installation of interrack cables and switchover procedure, Hydrogen Maser Frequency Standard for the CLOA – ALMA Phasing Project	ALMA-05.11.21.02-0002-A-PRO

1.4 Acronyms

ALMA Atacama Large Millimeter/submillimeter Array

APP ALMA Phasing Project

MIT Massachusetts Institute of Technology

Chapter 2

Network Access

This section itemizes the various ways the Maser appears on the network.

2.1 Network Commanding

The H Maser currently deployed at the AOS at IP address `10.197.48.50`. If it needs to be re-deployed at a new address, follow [RD3] to change its internal configuration, and redeploy the `MASER` in the `TMCDB`.

2.2 Network Commanding

For monitor and control through the network interface, the Maser speaks UDP at port 14000. From linux machines it is convenient to use `netcat` [see the man page for `nc(1)`]; but there are also linux/mac applications that can equivalently be used to perform the task. The commands are documented in [RD2]. To verify connectivity, you can use the `GETID` command:

```
aos-gns > nc -u -p 14000 10.197.48.50 14000
GETID;
$GETID;Hard=T4S.711.oct12.b.37;Soft=T4S-SW-100-a-15;
```

Generally the commands are echoed "$CommandName" and the response to the command if the comand is understood and "!CommandName" if not: *e.g.*

```
html=1;
$html=1;
blahblah=43;
!blahblah=43;
```

2.3 Web Monitoring

The maser has an internal web server to provide its current housekeeping. This is available at `10.197.48.50:80` on the AOS network.

2.4 ALMA Monitoring

The Maser software Device ([RD4]) provides all of the above housekeeping at similar cadence to the normal monitoring system (as configured in `TMCDB`). It is supported in `R2014.2` (and may be backported to other releases). When it is in use, H Maser data is collected at http://monitordata.osf.alma.cl; *e.g.* the data from July 12, 2014 is to be found at http://monitordata.osf.alma.cl/index.php?dir=2014%2F07%2F2014-07-12%2FCONTROL_VLBI_Maser%2F.

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iMaser59

14/08/2014 17:34:06 MONITORING RECORD ON 300 sec

U batt.A[V]	27.661	EB heater[V]	12.715	Pirani heat.[V]	12.115
I batt.A[A]	0.837	I heater[V]	6.66	Unused	0.054
U batt.B[V]	27.905	T heater[V]	8.247	U 405kHz[V]	11.803
I batt.B[A]	2.576	Boxes temp[°C]	46.777	U OCXO[V]	4.16
Set H[V]	5.38	I boxes[A]	0.585	+24 VDC[V]	24.9
Meas. H[V]	1.288	Amb.temp.[°c]	22.119	+15 VDC[V]	14.69
I pur.[A]	0.472	C field[V]	5.09	-15 VDC[V]	-15.665
I diss.[A]	0.481	U varactor[V]	5.588	+5 VDC[V]	5.16
H light[V]	2.897	U HT ext.[kV]	3.502	-5 VDC[V]	0
IT heater[V]	10.908	I HT ext[uA]	5.737	+8 VDC[V]	8.09
IB heater[V]	8.384	U HT int.[kV]	3.508	+18 VDC[V]	17.34
IS heater[V]	0.054	I HT int.[uA]	6.226	Unused	0.08
UTC heater[V]	14.18	H st.pres.[bar]	1.143	Lock	1
ES heater[V]	11.836	H st. heat[V]	14.874	DDS	1420405750.294469

Figure 2.1: *Sample Maser web page.*

The software device retrieves its data through the web interface and provides it to the monitoring system. You can also retrieve the same data via the `CCL` interface.

```
import CCL.Maser
maser = CCL.Maser.Maser()
maser.STATUS()
```

2.5   FTP Data

The maser provides an internal ftp site (`ftp://10.197.48.50`) which contains some configuration files and internally-collected monitor data. Normally the monitoring data captured as described in the preceeding section (2.4) is adequate, but in the event of some issue with the maser, T4Science will probably want to see this data for detailed analysis.

```
aos-gns > ftp 10.197.48.50
Connected to 10.197.48.50 (10.197.48.50).
220 Service ready for new user.
Name (10.197.48.50:gcrew): iMaser
331 User name okay, need password.
Password: #ndcu
230 User logged in, proceed.
Remote system type is Windows_CE.
ftp> dir
227 Entering Passive Mode (10,197,48,50,192,2).
125 Data connection already open; transfer starting.
01-06-14  16:34        <DIR>          Embedded_soft
01-06-14  16:34        <DIR>          Monitoring
```

The `Embedded_soft` directory contains command configuration files which may potentially be adjustable. Do not change any of them without knowing what you are doing as that may break the maser or the monitoring system.

```
ftp> cd Monitoring
250 Requested file action okay, completed.
ftp> dir
227 Entering Passive Mode (10,197,48,50,192,9).
125 Data connection already open; transfer starting.
...
# current files
08-14-14  17:24             761077 MonitInst.dat
08-14-14  17:24             714599 MonitMax.dat
08-14-14  17:24             715304 MonitMin.dat
...
# most recent archival files
08-05-14  04:51            2000081 MonitInst_05082014_04_51
08-05-14  04:51            1876731 MonitMax_05082014_04_51
08-05-14  04:51            1881079 MonitMin_05082014_04_51
```

The `mget` command is convenient for retrieving everything, which can then be tar'd and delivered to T4Science for their analysis. The Maser automatically reopens new files every 2 MB (or so). The current files have no time-tag in the name.

Chapter 3

Network Shutdown and Restart Procedures

This section covers issues related to power outages.

The Maser is on the AOS backup power supply system, so no action is required on short outages. Moreover, it has internal UPS batteries which are rated for 30 hours of operation. In the case of a prolonged outage, it can be placed in a *standby* power mode which draws less power. This allows the maser to return to service immediately after a prolonged outage (perhaps 2 days).

If the outage is longer that that, the Maser will shut down and will require a longer restart period. During this time the Rb Maser should be used for ALMA operations.

Sections 8 and 9 of [RD1] refer to buttons that existed textitbefore the network monitor and control upgrade was made. The functions of those buttons are now available only via the network as documented (poorly) in [RD2].

3.1 Remote Shutdown Procedure

Switch off the Dissociator, then switch off the Beam Stabilizer:

```
aos-gns > nc -v -u -C  10.197.48.50 14000
DISSSW=0;
BEAMSW=0;
```

See Section 2.2 for more detail on the network commanding.

Note that if the maser is remotely shutdown, it will need to be remotely restarted. (The remote commanding and physical switches must all be in a consistent state.)

3.2 Remote Restart Procedure

Switch on the Beam Stabilizer:

```
aos-gns > nc -v -u -C  10.197.48.50 14000
BEAMSW=1;
```

and wait until the purifier current (IPur) and Hydrogen pressure (Meas.H) are stable and close to their previous values. This can take upwards of 15 minutes. Then turn on the Dissociator:

```
aos-gns > nc -v -u -C  10.197.48.50 14000
DISSSW=1;
```

See Section 2.2 for more detail on the network commanding.

3.3 Manual Shutdown Procedure

Full particulars are found in [RD1], Section 9:

1. Switch-off the RF oscillator/HF generator: "RF osc" switch.

2. Switch-off the Beam stabilizer: "Beam stab" switch.

3. Switch-off the HF receiver: "HF rcvr" switch.

Note that if the maser is manually shutdown, it will need to be manually restarted. (The remote commanding and physical switches must all be in a consistent state.)

3.4 Manual Restart Procedure

Full particulars are found in [RD1], Section 7:

1. Switch-on the HF receiver: "HF rcvr" switch.

2. Switch-on the Beam stabilizer: "Beam stab" switch.

3. Wait for "Ipur" and "Meas.H" to stabilize and be close to their previous operation conditions. (This usually takes about 15 min.)

4. Switch-on the RF oscillator/HF generator: "RF osc" switch.

3.5 Switch to Rb Maser

Full particulars may be found in [RD5], Section 9. Briefly:

- Disconnect the H Maser 10 MHz cable.

- Connect the CVRR1 internal cable to the splitter.

- Disconnect the H Maser 5 MHz cable.

- Connect the Rb Maser 5 MHz cable.

- Verify proper operation of the system

- Leave the H Maser on.

3.6 Switch to H Maser

Full particulars may be found in [RD5], Section 7. Briefly:

- Disconnect the Rb Maser 5 MHz cable.

- Connect the H Maser 5 MHz cable.

- Disconnect the CVRR1 internal cable from the splitter.

- Connect the H Maser 10 MHz cable.

- Verify proper operation of the system

- Leave the Rb Maser on.

Chapter 4

Monitoring Procedures

4.1 Routine Monitoring, Primary

The primary indicator of Maser health for ALMA is to review the maser counter datum (`MASER_VS_GPS_COUNTER` under the AOS `CONTROL_AOSTiming_CRD` on http://monitordata.osf.alma.cl). As with the Rb Maser, there is a counter that counts the number of 125 MHz cycles per GPS tick. The Rb Maser is conditioned by the GPS; so with the Rb standard the datum should increase by 125000000 each second.

The Maser is *NOT* conditioned by GPS, so it will in general increment by a similar number per second. What that number is, depends on how the Maser has been tuned. (Ideally, and to avoid confusion, it should be tuned so that the increment is exactly 125000000 per second.)

In any case, a systematic change of this expected behavior on any timescale is a problem.

4.2 Routine Monitoring, Secondary

The monitor data captured at http://monitordata.osf.alma.cl for the maser should be reviewed for variations. The CLOA room is temperature-controlled to within a few degrees, so the thermal sensors should not vary much; but the heater voltages will in general vary to thermally stabilize the maser against external temperature variations.

The alarm page [RD1], Section 12, identifies optimal values for all the parameters. Items that are in the Orange or Red ranges should be referred to T4Science/Haystack for consultation.

4.3 Optional Monitoring, Allan Variance

An Allan variance monitoring device is currently on site with a (good) reference crystal. It is deployed at IP address 10.197.48.197. There is a command to start the Allan variance monitoring, and another to stop it. You will need to restart it and return a few hours later.

```
aos-gns> nc -p 1299 10.197.48.197 1299
Welcome to the Symmetricom 5115A

=10.197.48.197 > show screens
# if you're curious

=10.197.48.197 > print spectplot
Printing to local file in ftp directory: /pub/printfiles.

=10.197.48.197 > print adevplot
Printing to local file in ftp directory: /pub/printfiles.

=10.197.48.197 > print freq
```

```
Printing to local file in ftp directory: /pub/printfiles.

=10.197.48.197 > show adev
# you'll see something like this:

TAUO: 1E0 (NEQ BW: 0.5 Hz)
   tau:          1  adev:       9.82e-14  err: +/-8.70e-16
   tau:          2  adev:       9.53e-14  err: +/-1.19e-15
   tau:          4  adev:       8.91e-14  err: +/-1.58e-15
   tau:         10  adev:       9.44e-14  err: +/-2.64e-15
   tau:         20  adev:      1.080e-13  err: +/-4.28e-15
   tau:         40  adev:       1.27e-13  err: +/-7.10e-15
   tau:        100  adev:       1.79e-13  err: +/-1.58e-14
   tau:        200  adev:       2.59e-13  err: +/-3.23e-14
   tau:        400  adev:        4.1e-13  err: +/-7.20e-14
   tau:       1000  adev:        7.6e-13  err: +/-2.08e-13
   tau:       2000  adev:       1.16e-12  err: +/-4.32e-13
   tau:       4000  adev:        2.2e-12  err: +/-1.09e-12

# and to start a new collection cycle:
=10.197.48.197 > control take
=10.197.48.197 > stop
=10.197.48.197 > start
=10.197.48.197 > control yield
```

If you "take" control, you should yield it as soon as possible. If your session times-out (for whatever reason) you can be locked out of the box until a power-cycle clears it.

To retrieve any files printed above, you use ftp to the device:

```
aos-gns> ftp 10.197.48.197
Connected to 10.197.48.197 (10.197.48.197).
220 ts FTP server (Version 6.00LS) ready.
Name (10.197.48.197:gcrew): ftp
331 Guest login ok, send your email address as password.
Password: #ftp
230 Guest login ok, access restrictions apply.
Remote system type is UNIX.
Using binary mode to transfer files.
ftp> cd printfiles
250 CWD command successful.
ftp> dir
...
ftp> mget *
...
```

Note that the directory only holds 15 files (0..14) and then they overwrite.

4.4   Optional Monitoring, Frequency Counter

An interval counter has been temporarily deployed to monitor the Maser tick relative to the GPS tick. This device was deployed at 10.197.60.66 and is accessible at port 5024.

The following script may be run to capture the offset between the Maser and the (instantaneous) GPS tick. Note that over the course of a day, the GPS tick will wander by some 30 ns due to diurnal ionospheric variations of total electon content.

```
import telnetlib,time
```

```
host='10.197.60.66'
port=5024
tn=telnetlib.Telnet(host,port)
tn.read_until("A>")
# set to start from known state
tn.write(b"*RST\n")
tn.read_until("A>")
# set a 5s measurement timeout
tn.write(b"SYST:TIM 5.0\n")
tn.read_until("A>")
# configure 2-ch measurement
tn.write(b"CONF:TINT (@1), (@2)\n")
tn.read_until("A>")

# set AC coupling for both channels
tn.write(b"INP1:COUP AC\n")
tn.read_until("A>")
tn.write(b"INP2:COUP AC\n")
tn.read_until("A>")

# set input impedance to 1 Mohm
tn.write(b"INP1:IMP 1.0E6\n")
tn.read_until("A>")
tn.write(b"INP2:IMP 1.0E6\n")
tn.read_until("A>")

# set start threshold to 1V
tn.write(b"INP1:LEV1 1.0\n")
tn.read_until("A>")

# set stop threshold to 1V
tn.write(b"INP2:LEV1 1.0\n")
tn.read_until("A>")

# set start slope to positive (rising), CH1
tn.write(b"INP1:SLOP POS\n")
tn.read_until("A>")

# set stop slope to positive (rising), CH2
tn.write(b"INP2:SLOP POS\n")
tn.read_until("A>")

# hold off gate close
tn.write(b"SENS:GATE:STOP:HOLD:SOUR TIME\n")
tn.read_until("A>")

# hold off for 200 ns
tn.write(b"SENS:GATE:STOP:HOLD:TIME 200E-9\n")
tn.read_until("A>")

# start meas when gate recd
tn.write(b"SENS:GATE:STAR:SOUR IMM\n")
tn.read_until("A>")

# stop meas when holdoff done
tn.write(b"SENS:GATE:STOP:SOUR IMM\n")
```

```
tn.read_until("A>")
# enable gate settings
tn.write(b"SENS:TINT:GATE:SOUR ADV\n")
for i in range(4320000):
    tn.write(b"READ?\n")
    tn.read_until("A>")
    s=tn.read_until("\r")
    print time.strftime('%Y-%m-%dT%H:%M:%S', time.gmtime()), time.time(), s
tn.close()
```

Variations on this script are possible. The output of the current script looks like:

```
...
2014-07-31T12:10:52 1406808653.0  +4.33144699058050E-007
2014-07-31T12:10:53 1406808654.0  +4.33169113120550E-007
2014-07-31T12:10:54 1406808655.0  +4.33090988120550E-007
2014-07-31T12:10:55 1406808656.0  +4.33188644370550E-007
2014-07-31T12:10:56 1406808657.0  +4.33169113120550E-007
...
```

showing a 433 ns separation between the two ticks. Note that the maser tick is not used for anything, so the important point here is that the output be slowly varying.

The GPS PPS tick and can be adjusted using the remote monitor and command interface as described in [RD2]. That same interface can also be used to adjust the maser frequency. Generally speaking, there should be no need to do either. For example:

```
aos-gns > nc -u -p 14000 10.197.48.50 14000
# adjust the PPS (nanoseconds)
RDREG=ADJ1PPS;
$RDREG=ADJ1PPS;=337498120;
ADJ1PPS=337497800;
RDREG=ADJ1PPS;
$RDREG=ADJ1PPS;=337497800;
# adjust the relative frequency synthesizer rate
RDFS;
$RDFS;=1420405750.294396;
SETFSREL=+5.0e-14;
$SETFSREL=+5.0e-14;
RDFS;
$RDFS;=1420405750.294469;
```

You should, however consult [RD2] for full details.

Chapter 5

Safety Procedures

Safety protocols associated with the APP Maser operation and maintenance are described in the following sections.

5.1 Shipping

If for any reason the maser should need to be removed from the ALMA LO system for shipment, the hydrogen source may fall under special compliance for import and export protocols. These are subject to change, so the operations and maintenance staff should be keep current with changes in these protocols and prepared to meet current regulations.

5.2 Installation and Handling

If for any reason the maser should need to be removed from the ALMA LO system for service or shipment, only personnel that have been previously trained in ALMA safety procedures and have experience with material handling shall be directly involved. Personnel directly involved shall at a minimum employ PPE which includes eye protection, gloves, safety shoes, and material handling equipment. If the maser rack should be unfastened from the seismic support structure, retain all mounting hardware required to re-install the rack to preserve seismic compliance. Some of the hardware subjected to high torque during installation may need to be replaced for reinstallation in order to comply with the seismic installation requirements. Reinstallation shall only be executed by personnel acquainted with current seismic compliance requirements.

5.3 Batteries and UPS

The UPS batteries are of type Sonnenschein dryfit A500 (A512/55A), sealed lead acid, maintenance free units, with a gelatinous electrolyte and shall not be opened for any reason. The electrolyte is corrosive and can cause skin burns, therefore no attempts shall be made to replenish the electrolyte because the units cannot be resealed once opened. The manufacturer provided MSDS shall be included in the site MSDS binder in closest proximity to the maser installation.

Even in a partially discharged state, the batteries are a high current, low voltage energy source. They have no "off" switch and can produce burns to personnel if terminals are accidentally shorted. Use of electrically insulated tools is recommended and only persons trained in UPS maintenance and handling of heavy batteries shall service the UPS.

The batteries weigh 19 kg. each and this mass is concentrated in a small volume. Therefore battery handling carries a risk of injury from dropping and current ALMA safety practices shall be observed with a minimum recommended PPE to include safety shoes, eye protection, gloves and material handling equipment; especially if multiple units need to be handled simultaneously.

In normal operation, the sealed units do not vent hydrogen gas. In the case of a malfunction in the charging system, hydrogen outgassing could occur. APP recommends that ALMA operations

include periodic inspections of the charging system and assure the local ventilation is adequate for safe, continued UPS operation.

Exhausted batteries shall not be disposed of by placing in dumpsters or other common trash receptacles, but shall be handled under current environmental protocols for proper disposal. Disposal protocols are subject to change, but may potentially include a return for credit, in order to reclaim reusable materials.

5.4   Electronics Package

The maser employs ESD sensitive electronic modules, so appropriate precaution shall be taken if working with the cabinet door open. The electronics package also supplies a high voltage source to the Physics Package, which is adequately isolated from normal access to the cabinet, as long as none of the internal wiring or components is disturbed.

5.5   Physics Package and Hydrogen Source

The Physics Package is a self-contained subsystem within the maser which operates from a high voltage supply and employs internally a high vacuum pump and a hydrogen source (addressed below). This subsystem and the connections from the Electronics Package shall only be serviced by the manufacturer or their designated maintenance contractor.

The hydrogen source poses no threats to the user as long as it remains sealed in the physics package. The solid compound from which the molecular hydrogen is liberated ($LaNi5H)x$, only produces hydrogen in very small amounts as needed to maintain storage bulb pressure while the physics package is operating. The MSDS for this material states that risk due to fire and explosion from this material is extremely weak. Handling the source in raw or bulk form however, poses a health risk. Therefore no attempt should ever be made to access or service the material directly.

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Chapter 6

Maser Software Device

6.1   Routine monitoring

There is a software device for the maser which is used by the monitoring system to propagate housekeeping to the monitoring site (http://monitordata.osf.alma.cl under `CONTROL_VLBI_Maser` whenever software release 2014.2 or later is run. All the monitor points from the embedded Maser HTTP server are present with similar names.

6.2   Maser CCL Commands

Under release 2014.2 or later, a set of CCL commands may be used to access the maser housekeeping. There is a top-level status command:

```
aos-gns > ipython
import CCL.Maser
maser = CCL.Maser.Maser()
maser.STATUS()
```

which prints the data in the canonical `STATUS` way. In addition, there is a pair of command to capture the data in the same format T4Science uses in the internal data monitoring:

```
maser.getOneLineHeader()
maser.getOneLineOfData()
```

Additionally, a short report is also available (this command exists to support a GUI panel that has yet to be created):

```
(story,isHealthy,isLocked) = maser.getMaserStatus()
```

6.3   Maser CCL Monitor Points

And finally all the monitor points are explicitly available:

```
GET_MaserTime()
GET_UBattA()
GET_IBattA()
GET_UBattB()
GET_IBattB()
GET_SetH()
GET_MeasH()
GET_IPur()
GET_IDiss()
```

```
GET_HLight()
GET_ITHeater()
GET_IBHeater()
GET_ISHeater()
GET_UTCHeater()
GET_ESHeater()
GET_EBHeater()
GET_IHeater()
GET_THeater()
GET_BoxesTemp()
GET_IBoxes()
GET_AmbTemp()
GET_CField()
GET_UVaractor()
GET_UHTExt()
GET_IHTExt()
GET_UHTInt()
GET_IHTInt()
GET_HStPres()
GET_HStHeat()
GET_PiraniHeat()
GET_U405kHz()
GET_UOCXO()
GET_P24VDC()
GET_P15VDC()
GET_M15VDC()
GET_P5VDC()
GET_M5VDC()
GET_P8VDC()
GET_P18VDC()
GET_Lock()
GET_DDS()
```

Note that the housekeeping is only updated to this interface every few minutes, so reads at a higher data rate will not return higher sampling.