# 2 Preparing for Observations

This chapter deals with how to prepare for observations on the compact array after having been granted observing time. The compact array online observing control program CAOBS requires a schedule file, and how to create this file is the main focus of this chapter.

In general, at least one member of the observing team should be present at Narrabri. Overseas observers, or others who find it difficult to travel to Narrabri may need to find a local collaborator. The ‘friend’ implied by the ‘Help required?’ question on the application form is usually at Epping and will assist in setting up the schedule file and in the initial analysis of the data.

Remote observing is available for experienced Compact Array observers. To apply to make an observation remotely, use the form at `http://www.narrabri.atnf.csiro.au/observing/remote_form.html` or email `rem_obs@atnf.csiro.au` at least **two weeks before the observations**, providing dates and times. Remote observers must have their own UNIX account at Epping and Narrabri. See `http://www.narrabri.atnf.csiro.au/observing/remote_conditions.html` for remote observing conditions and `http://www.narrabri.atnf.csiro.au/observing/rem_obs.html` for details on how to conduct observations remotely.

## 2.1 Scheduling Strategy

Obtaining high quality data depends on making a schedule that observes the program sources along with suitable calibrators frequently enough to satisfy the program’s science goals. This section will describe common goals, and provide some advice on how to best schedule such observations.

### 2.1.1 Snapshot Observations

If many sources need to be imaged in a single 12 hour observation, and complex structure is not expected in these sources, then observing in snapshot mode may be the best option. This mode is also known as making “cuts” across the source.

To make a snapshot schedule, determine how many cuts are necessary within in the time alotted for the experiment, as this constrains how long the schedule should run for. For example, if the experiment is given 12 hours of observing time, and each source needs four cuts, then the schedule must not run for more than 3 hours before repeating.

This repeat time must then be divided up between the sources in the schedule. Care must be taken though to ensure that weaker sources are given more integration time than stronger sources. Also, time must be reserved for calibrator observations and other overheads such as slewing and receiver translation.

### 2.1.2 Frequency Switching and Multi-frequency Synthesis

The CABB system allows two 2 GHz wide bands to be observed simultaneously, where the band centres are spaced up to 6 GHz apart (band-permitting). In and of itself this capability qualifies as multi-frequency synthesis. However, this capability does not cover the entire usable frequency range of the mm receivers, and so it may still be desirable to perform a frequency switching experiment.

Making a frequency switching schedule is as simple as duplicating scans and changing their frequencies to cover the desired range. Frequencies within any particular band can be changed every cycle if so desired, however there is an overhead of two cycles as the request for LO frequency changes propagates through the system. Changing bands often results in a turret rotation, and performing a turret rotation more often than every 15 minutes is not permitted. Note also that when changing to or from the 7mm receiver, the mm package must be translated, and this will take approximately 2 minutes.

As stated above, the centre frequencies of the two IFs may be placed up to 6 GHz apart. Doing so may have undesirable consequences however, as any band that is placed at the lower end of the 4-12 GHz CABB window will suffer from poor image rejection. By default, closely spaced IF pairs will be moved to the top of this CABB window, but if the two IFs are separated by $\sim$6 GHz, then the IF at the lower end may experience increased noise levels.

There are some further restrictions to the frequency pairs that can be observed simultaneously:

- A frequency using one receiver package cannot be observed simultaneously with a frequency using another receiver package. The receiver packages are: 16cm, 6/3cm, 15mm, 7mm, 3mm.
- A frequency that requires an LO configuration that produces an upper sideband (USB) IF cannot be observed simultaneously with a frequency that requires an LO configuration that produces a lower sideband (LSB) IF. This restriction is important in the 7mm and 3mm bands.

  At 7mm, the USB/LSB switch occurs at 40 GHz. Both centre frequencies must either be above 41 GHz or below 40 GHz in this band.

  At 3mm, the situation is rather more complicated:

  - If the highest central frequency is $> 100.6$ GHz and the lowest central frequency is $> 97.8$ GHz, then the band will be USB, and sensitivity will be optimised.
  - If the lowest central frequency is $< 97.8$ GHz and the highest central frequency is $> 100.6$ GHz, then the band will be LSB, but the LO will be driven past its rated limit, reducing the sensitivity.
  - If the lowest central frequency is $< 97.8$ GHz, and the highest central frequency is $< 100.6$ GHz, then the band will be LSB, and sensitivity will be optimised.
  - If the highest central frequency is $< 100.6$ GHz, and the lowest central frequency is $> 97.8$ GHz, then the band may either be LSB or USB, and will be automatically configured by CAOBS to optimise sideband rejection.

For more information, see:

- The *MIRIAD Users Guide*, particularly "Multi-frequency Synthesis Observing Strategies". This gives a very good description of frequency switching and the ramifications it has on the reduction of the data.
- *Multi-frequency Synthesis with the ATCA*, Sault, R.J. 1992, ATNF Technical Document Series, **39**, 3019
- *Multi-frequency Synthesis techniques in radio interferometry*, Sault, R.J. & Wieringa, M.H. 1994, *A&A Supp*, **108**, 585
- *Multi-frequency Synthesis*, Conway, J.E. & Sault, R.J. 1995, in *Workshops on Very Long Baseline Interferometry and the VLBA*, eds. J.A. Zensus, P.J. Diamond, P.J. Napier, ASP Conf. Series

### 2.1.3 Reference Pointing

Reference pointing should be used for observations where pointing accuracy is important, including for mm observations where the global pointing errors are a significant fraction of the primary beam size.

To schedule a reference pointing scan, choose a bright source within $20^\circ$ of the program source, and make a scan on that source with the settings `ScanType=Point` and `Pointing=Update`. This `Update` option uses the most recent solution, and has the advantage of giving corrections with respect to the previous solution, which can be used to estimate the real pointing accuracy when the same region of the sky is observed for a long period.

After doing a reference pointing scan, ensure that `Pointing` is set to `Offpnt` or `Offset` for all other scans on any calibrators and program sources. Using `Offpnt` will allow CAOBS to find the most appropriate recently-obtained pointing solution based on azimuth and elevation, whereas `Offset` will only ever invoke the latest pointing solution.

For reference, a pointing scan will take about 2-3 minutes to complete, regardless of what is given in the `ScanLength` field. Pointing solutions are only valid in a small area of sky surrounding the azimuth and elevation where the pointing was made, and a new pointing solution should be obtained roughly once every hour during observations.

### 2.1.4 Mosaicing

Mosaicing is normally used if the source or field to be imaged is large compared to the FWHM of the ATCA primary beam. Mosaicing mode can also be useful when a large number of nearby sources are to be observed, as observing overheads are reduced. Other applications include holography and source surveys using one dimensional cuts. In interferometry adjacent pointings are not independent and so we can get fundamentally better images by processing the different pointings together. Necessary information about the pointing grid pattern to use for proper Nyquist sampling and the time to be spent on each position to optimise tangential $uv$ coverage can be found in Chapter 21 of the Miriad Users Guide (`http://www.atnf.csiro.au/computing/software/miriad/userguide/userhtml.html`).

For close-packed mosaicing (pointing centres every half-beamwidth), drive times are determined by the acceleration limit of $800^\circ/\mathrm{min}^2$. Half the drive time is spent accelerating and half decelerating. For drive times much further than $108'$ in azimuth or $27'$ in elevation, the drive times are dominated by the slew rate limits of $38^\circ$/min in elevation and $19^\circ$/min in azimuth. For example, a $16'$ drive for a 20cm mosaic will take, depending on the elevation and azimuth of the source, approximately 2.2 seconds. Data taken during the off-source period is blanked in the correlator using a predicted drive time. As drive times can be a significant overhead, care should be taken to not move the array more than necessary.

Mosaicing is less useful if frequency switching is desired, as no frequency changes can occur during the mosaic scan. Since slew times are often much greater than the time it takes for the correlator to switch frequencies, the overheads involved in repeating a mosaic scan for each separate frequency might quickly negate the normal benefits of mosaicing.

### 2.1.5 Observing Solar System Objects

Solar system objects differ from most astronomical sources in that the proper motions are large enough that the object position changes in the course of an observation. When observing such objects, the schedule file should be created in absolute time mode to ensure that CAOBS correctly tracks the object. CAOBS has the ability to phase track an object with a non-sidereal rate. Note, however, the pointing centre used during a scan does not track the source (the pointing centre used is the mid-position of the object during the scan). Thus the scans must be short enough that there is not significant motion of the source within the primary beam during a scan (the scheduler does not check this).

To schedule an observation of a major planetary object, simply put its name in the `Source` field of a scan. During the observations, CAOBS will interpret this name and calculate where the planet, Sun or Moon is and point the array towards it.

The scheduler will not however calculate where the planet will be during the scheduling process, which means that drive time calculations will not be valid unless the correct coordinates are input by the user. To get these coordinates, use the MIRIAD task `planets`.

For minor bodies, CAOBS cannot compute a position, so the correct position must be provided by the user. In absolute time mode, the scheduler treats source names beginning with the `@` symbol (eg. a source name of `@hbopp`) as pointing to an external ephemeris file (eg. a file `$ATCA_EPHEM:hbopp.eph`).

Ephemerides for minor solar system bodies can be computed before scheduling using JPL's Horizons on-line system, at `http://ssd.jpl.nasa.gov/?horizons`.

Only the telnet (terminal-based) access method is described here, but there is also a web-interface method available from the web page above that is self-explanatory.

Horizons asks the user a series of questions. To generate an ephemeris file for ATCA observations:

- telnet horizons.jpl.nasa.gov 6775
- First select an object by giving the source name (followed by a semi-colon for minor bodies) or by source number.
- In response to prompts, select `Ephemeris`, then `Observe`, then `Geo` to select geocentric RA/Dec ephemerides.

- Then give the start time of interest, in UTC, in the format suggested by the prompt. At the next prompt give the end time, and then the time increment; typically 1 hours is more than adequate, and the scheduler uses simple linear interpolation of the ephemeris values. The ephemeris supplied to the scheduler must start at least two time increments before the scheduled start time, and must extend beyond its end time.
- Accept `default output`, and at the `Select table quantities` prompt, enter `1,20` to get RA, Dec, distance and velocity of the object.
- Horizons will then display the ephemeris in the terminal. To get it to email the ephemeris, press `q` and the main menu will be displayed again. Then select `[M]ail` and enter the email address to send the ephemeris to.
- To log out of Horizons, press `Ctrl-D` (the terminal hangup signal).

The ephemeris file produced by Horizons needs to be massaged into the format that the scheduler requires. This is best achieved with the EPHFORMAT command available on XBONES.

- First, copy the ephemeris from the email sent by Horizons into a plain text file on XBONES
- Run the command EPHFORMAT with no arguments.
- At the first prompt, give the name of the text file with the Horizons ephemeris (including file extension). At the second prompt, give a short descriptive name for the output ephemeris file (excluding any file extension). EPHFORMAT will then write out the appropriate ephemeris file to `$ATCA_EPHEM:file.eph` where `file` is the name entered at the second prompt.

### 2.1.6 Spectral Considerations

When planning to observe a spectral line, there are further things to consider. One of the most important things to consider is where the line to be observed will fall within the bandpass, ie. which channel(s) it will appear in. There are several channels in CABB that are always flagged, and several more that are often contaminated with self-generated interference, and these should be avoided when observing spectral lines.

The CABB correlator always flags channels 513, 1025 and 1537 (multiples of 512 MHz). The central frequency specified in the schedule file will fall in the centre of channel 1025.

Self-generated interference will likely be present in channels 129, 157, 257, 641, 769, 1153, 1177, 1281, 1409, 1793 and 1921. All these channels can be easily flagged with the online correlator software and the interference does not leak into the adjacent channels.

## 2.2 Calibration Requirements

During a normal observation, many different calibration tasks need to be performed. This section describes all these different tasks, and how best to schedule them.

### 2.2.1 Flux Calibration

Flux calibration is required to translate the arbitrary gain scaling that is produced by an observation to an absolute flux scale. The most effective way of doing this is by observing a calibrator that has a known flux (on the absolute flux scale) and comparing it to the sources that you are observing that have unknown fluxes.

For the ATCA, there are currently only four flux calibrators, and of those only two are regularly used.

For frequencies between 1 GHz and 25 GHz, the preferred flux calibrator is PKS 1934-638. It has a known, stable flux, and conveniently has no linear or circular polarisation. The flux models for 1934-638 are described in the memos:

- **A Revised Flux Scale for the AT Compact Array** (*J Reynolds, 1994*, `http://www.atnf.csiro.au/observers/memos/d96783~1.pdf`)
- **ATCA Flux Density Scale at 12mm** (*B Sault, 2003*, `http://www.atnf.csiro.au/observers/memos/AT39.3_124.pdf`)

For frequencies higher than 25 GHz, the preferred flux calibrator is the planet Uranus. Its flux is known to vary with time, but it does so in a way that is understood and can be modelled. The planets Mars and Neptune can also be used, but Uranus is preferred because its angular size is smaller than Mars (making it easier to observe with typical Compact Array baselines), and it is brighter than Neptune (which would require a longer scan to provide the same signal-to-noise level).

To be as effective as possible, the flux calibrator should be observed when it is at the same elevation as the target source, and at as high an elevation as possible. Doing this means that any gain-elevation dependence is reduced, and the effect of airmass is also reduced. At low frequencies (below 7 GHz), these requirements are not as important as they are for higher frequencies, where the atmospheric effects become a large factor. Indeed, many (if not most) centimetre observers simply make a scan on 1934-638 at the beginning of their observations, and this is usually good enough to get a flux uncertainty of only 10%.

Because 1934-638 is a point source (at least at the resolution of the Compact Array), it can be observed the same way as any other calibrator. That is, a scan on 1934-638 should be included in the schedule, and should be preceded by a pointing scan when it is observed with the 15mm receiver.

Observing the planets is a little more complicated. Because they are not point sources on even the most compact of ATCA baselines, they cannot be used as a pointing reference. A nearby source must therefore be used to determine the pointing offsets before observing the planet. Also, because the planets will substantially fill the primary beam of the ATCA antenna, the apparent system temperature of the antenna will be increased while a planet is being observed. Because of this, if a paddle scan is made while observing a planet, the system temperature will not be correctly determined, and the flux scaling will be in error. When observing with the 3mm system therefore, the paddle scan should be made while observing the same nearby pointing reference calibrator.

To make a good observation of Uranus, follow the procedure:

- Determine a suitable nearby calibrator that can be used for pointing/paddle measurements. First, checking the ephemeris of Uranus with the PLANET task in Miriad. After the position of Uranus on the date of the observation has been determined, use the calibrator database (`http://www.narrabri.atnf.csiro.au/calibrators/`) or the "Search Cal" button in the Web Scheduler to find the closest suitable calibrator.
- If observing at 3mm, make a paddle measurement while tracking the calibrator.
- Determine the pointing offsets using the calibrator.
- Observe the calibrator for 2 minutes.
- Observe Uranus for a sufficient amount of time (10-15 minutes is usually more than enough).
- Observe the calibrator again for 2 minutes.

The procedure is similar for the other planets. Note that because the phases of the nearby calibrator are not used by the Miriad flux calibration task MFBOOT, it is not absolutely necessary to bracket the planet with a calibrator observation. It can however be useful to have that data to diagnose potential problems, should they arise.

### 2.2.2 Bandpass and Array Calibration

The ATCA receivers do not have perfectly flat responses to incoming radiation as the frequency changes. To determine how the the receiver responds as a function of frequency, it is necessary to make an observation of a bandpass calibrator.

A bandpass calibrator can be any source that has sufficient flux to enable the receiver response to be determined without thermal noise contributing significantly (ie. the observation must have a high signal-to-noise ratio). With CABB, this requirement is easily met by all but the weakest calibrators. It is useful however to choose a very bright source as the bandpass calibrator, because only a short integration on such a source is required to get a good bandpass calibration. Generally, one of the following sources is used for bandpass calibration, and which one is chosen is usually dependent on the LST at which the observation is made.

**Standard Bandpass Calibrators**

- 0420-014 ($\nu > 10$ GHz)
- 0537-441 ($\nu > 10$ GHz, **NOTE:** this source is not unresolved on long baselines!)
- 0823-500 ($\nu < 10$ GHz)
- 1253-055 ($\nu > 10$ GHz)
- 1921-293 ($\nu > 10$ GHz)
- 1934-638 ($\nu < 10$ GHz)
- 2223-052 ($\nu > 10$ GHz)

Because of their brightness, these calibrators are also useful for the initial setup of the array (determination of array delays and phases), and as such they are also often referred to as “setup calibrators”. It is recommended that one of these calibrators be used for this purpose.

As the receiver response does not change significantly as a function of time, it is usually sufficient to make an observation of a bandpass calibrator at the very start of the allocated time. Conveniently, if one of these bandpass calibrators is used as a setup calibrator, then the bandpass calibration observation can be made immediately following the completion of the setup without further slewing overhead. The amount of time spent integrating on the bandpass calibrator depends on its flux, but generally 5-10 minutes is sufficient at all frequencies. It is necessary to observe the bandpass calibrator with each frequency configuration that will be observed, as the bandpass solution will be frequency dependent. If the observations are at 3mm, a paddle measurement should be made immediately before the bandpass observation.

### 2.2.3 Gain and Pointing Calibration

As the antenna track the source around the sky, the conditions between the source and the antenna will vary, and as such, the gain of the system will change. These changes will be related to atmospheric conditions, gravitational deformation of the dish, ground spillover, etc.

To determine how the gain changes with time, it is convenient to observe a very simple source that is not expected to change over the period of the observation. More precisely, by observing a source that looks the same irrespective of time or $(u, v)$ coordinates, changes in gain can be determined directly. Therefore, gain calibrators should be unresolved, with a stable flux over the observation timescale.

The ATCA has a large list of gain calibrators, spread over the viewable sky. This list can be queried using the web interface at `http://www.narrabri.atnf.csiro.au/calibrators/`. This interface queries the database in one of three ways:

- **Cone search**: finds calibrators within a specified angular distance from a given sky position. Can optionally be restricted to sources brighter than a given flux in a specified wavelength band. The CABB Web Scheduler also has built in functionality to search for calibrators within twenty degrees of any source you have scheduled, which may be a more convenient way to find a calibrator for your project.
- **Name search**: finds a calibrator with a specified name. It is only necessary to provide an unambiguous name, which may not necessarily be the entire name, eg. there are three sources in the database which begin with “0537”: 0537-441, 0537-158 and 0537-286. To unambiguously specify one of these sources, at least the first six characters of the name must be specified.
- **Patch search**: finds all calibrators within a specified RA and Dec range. Can optionally be restricted to sources brighter than a given flux in a specified wavelength band.

Currently, two separate databases can be queried in the same way. The “Old” database consists of C007 monitoring observations of all the calibrators, primarily with the original ATCA correlator. This database does not always have the latest set of C007 observations, so is usually out of date. The “New” database is based on a pipeline reduction of all calibrator observations made with the CABB correlator, and on manual reduction of C007 observations as soon as possible after each run. Although this new database is still under development, most recent flux values can be considered as reliable.

The ideal gain calibrator would be very bright – to maximise the signal-to-noise ratio of the gain calibration – and very close to the target source. A gain calibrator that is too far away from the target source may not be sampling the same atmospheric conditions that exist between the source and the telescope, which might potentially lead to large phase errors in the gain solution, particularly in bad weather and at high frequencies. It is generally recommended that the gain calibrator be within 10 degrees of the target source.

Because of these restrictions, the gain calibrator also presents itself as the ideal candidate for pointing calibration. At high frequencies, where the primary beamsize is relatively small, it is very important to ensure that the telescope is pointing as accurately as possible. The ATCA has a facility to correct the pointing in a localised area of sky, by means of a pointing scan. This scan requires that it be executed on an unresolved, bright source – exactly the same criteria as for the gain calibrator. It is recommended that at frequencies above 10 GHz (or at all wavelength bands shorter than and including 15mm) periodic pointing scans should be made on the gain calibrator. Ideally, the time between pointing scans should be less than 1 hour.

### 2.2.4 Polarisation Calibration

The ATCA uses a dual linear orthogonal feed system to measure the incident radiation. Ideally, these two feeds would be completely independent of each other, but in reality this is not the case, and radiation that is measured by one feed can also mix into the other; this effect is called "leakage". Polarisation calibration is primarily concerned with measuring this leakage effect.

To accurately determine the leakage parameters (see the technical memo "AT Polarisation Calibration": `http://www.atnf.csiro.au/observers/memos/d97b7f~1.pdf`), it is necessary to sample a weakly polarised, unresolved calibrator at a large range of parallactic angles. Fortunately, observations of a gain calibrator will generally meet this requirement. Along with the determination of the relative leakage terms, it will also be possible to determine the gain calibrator's relative Stokes Q and U quantities, and its polarisation position angle.

Dave Rayner's "Circular Polarization User's Guide" is a useful guide on how to accurately measure circular polarisation with the ATCA (`http://www.atnf.csiro.au/observers/memos/circpolguide.pdf`).

### 2.2.5 Calibration Time Guidelines

Many decisions need to be made when scheduling an observation. These decisions relate to how long observing procedures require, and how often they should be performed. This section will give a summary of these time considerations, in a "frequently-asked-questions" format.

**How long will it take to set up the initial calibration?**

Barring hard-to-solve problems occuring, an experienced observer should allow up to 20 minutes of initial calibration time per frequency combination. A less experienced observer may require longer if things do not go exactly to plan.

**How frequently should the gain calibrator be observed?**

This depends on the conditions under which the observations are performed, such as atmospheric seeing, the array size and the central observing frequency. The ATCA provides a calculator at `http://www.narrabri.atnf.csiro.au/calibrators/calcycle.html` to advise observers on how often to visit their phase calibrator.

For this calculator, input the central observing frequency and the maximum baseline of interest (ie. don't include the 6km antenna if its data will be discarded). For the seeing monitor RMS phase, give a nominal value of 300 microns if the observations will be performed in winter, and 700 microns if they will be in daytime during summer; for other times, choose a value between those two extremes. For the phase screen speed, choose 5 m/s. For the Kolmogorov exponent, leave the default 0.83 unless the 6km antenna will be required, in which case enter 0.33 instead.

For example, for an observation at 19 GHz, with a seeing RMS of 300 microns, in a 750m array, the calculator determines that if the gain calibrator was visited every 2 minutes, the observations would have an RMS phase of 15°, be decorrelated by 3%, and have a maximum dynamic range of just 282. However it also determines that this is as bad as it gets, so that a 10 minute visit interval would give the same results. Since 2 minutes is a very frequent visit schedule, it would seem that self-calibration would be preferable for high dynamic range observations.

Dropping the seeing RMS to 100 microns (which would be a good winter day) improves matters significantly, allowing a dynamic range of 874 with no decorrelation and a 5° RMS phase for any visit interval greater than 2 minutes.

It is important however not to extend the interval too far, as then the atmosphere being sampled by the gain calibrator will be different to that the source has sampled during that time. For cm observations, one might need only visit the gain calibrator once or twice per hour in good conditions, while for mm observations, it is unwise to visit the calibrator less frequently than once every 15 minutes.

It is therefore advisable that while making a schedule, input conservative estimates into this calculator to determine the phase calibrator interval. However, if high dynamic range images are required, the schedule should be flexible enough that the interval could be shortened in case the conditions degrade during the observations.

**How much time is required per gain calibrator observation?**

The primary aim of a gain calibrator observation is to measure the atmospheric phase, so any gain calibrator observation must have a sufficient signal-to-noise ratio for this to be determined. For example, for an observation at 19 GHz, a signal-to-noise ratio of 50 is required to reach a seeing RMS of 300 microns. For that same observation with CABB, the continuum RMS would be 0.24 mJy/beam in one minute. Thus any gain calibrator with a flux greater than 12 mJy would suffice if it were observed for one minute.

The general guideline here is that one should observe the brightest possible nearby gain calibrator for 1-2 minutes per visit to get a good measure of phase.

**How much integration time is required on the primary flux calibrator?**

This consideration is largely governed by the flux accuracy required for the observations to be successful, and the strength of the primary flux calibrator at the observing frequency. If a flux accuracy of 1% is required, then the aim should be to make an observation with a signal-to-noise ratio of 100. For a observation with 2 GHz bandwidth, this is relatively easy, as even a 5 minute observation of 1934-638 at 50 GHz gives a signal-to-noise ratio in excess of 1000.

The sensitivity calculator should be used to estimate the observing time required to achieve the desired flux accuracy. However, it is never a bad idea to pad the required time out a little to ensure that enough good data will remain after flagging.

**How often should the bandpass calibrator be observed, and how much integration time is required?**

For continuum observations, it is not normally necessary to observe the bandpass calibrator for more than 5-10 minutes, and only one observation is required.

It has been observed that the CABB bandpass is not perfectly stable over the course of a normal 12 hour observation, and for this reason it is advisable to observe a bandpass calibrator more than once per observation, if bandpass accuracy is very important (eg. for spectral line studies). Visiting it three times (once at the start, once at the end, and once sometime near the middle) during a 12 hour observation should be sufficient to obtain a reliable bandpass solution. Alternatively, provided the gain calibrator is reasonably bright, the periodic visits to it may provide the information to accurately determine how the bandpass solution changes over time.

The integration time spent on the bandpass calibrator will have an effect on the accuracy of the flux that is measured after reduction. It is necessary to obtain each correlator channel's flux to the same accuracy as required for the flux calibrator, ie. obtain a signal-to-noise ratio of 100 *per channel* if the required flux accuracy is 1%. Since any source can be a bandpass calibrator, the sensitivity calculator should be used to find out the RMS noise per channel for your observations, and then a calibrator found from the calibrator database that provides enough flux to meet the signal-to-noise ratio requirements. For example, a typical CABB observation has 2048 channels, and at 50 GHz, the RMS noise per channel is about 35 mJy for a 5 minute observation. For a signal-to-noise ratio of 100, a calibrator with flux greater than 3.5 Jy is required, and a search through the calibrator database identifies 18 such sources. Of course, if a primary flux calibrator is strong enough to be a bandpass calibrator as well, then observing time can be conserved by not having a separate bandpass calibrator.

**If observing with more than one receiver, how long does it take to change receivers, and is there a limit to how often receivers can be changed?**

When changing to or from any receiver except 7mm, expect a 20 second overhead while the turret rotates. To go to or from the 7mm receiver requires a movement of the millimetre package translator, which will take approximately 2 minutes, and if the turret needs to rotate, it will do so only after the translation is complete, thus adding another 20 seconds to this. Hardware limits will prevent turret rotations occurring more frequently than once every 15 minutes.

**If observing at more than one frequency using the same receiver, how long does it take to change frequencies?**

Allow for an overhead of 20 seconds while switching frequencies that use the same receiver.

**At millimetre wavelengths, how often is a pointing scan required, and how long does one take?**

To maintain pointing accuracy, a pointing scan should be scheduled at least once per hour. A pointing scan will only improve accuracy for sources within 20 degrees of where the scan was made, so if the sources being observed cover a wider area than this, multiple pointing scans will need to be made to maintain pointing accuracy for all sources.

**At 3mm, how often is a paddle scan required, and how long does one take?**

To get accurate fluxes, it is a very good idea to perform a paddle scan at least once every 10-20 minutes, and more often if the weather is bad, or volatile. A paddle scan will take approximately 90 seconds.

## 2.3 How to Prepare a Schedule File

### 2.3.1 Introduction

Observations on the compact array normally consist of a sequence of scans: a scan is a short period of observing where a single source is observed. A complete observation is made up of a number of scans. Observations typically alternate between program source scans and calibrator scans. Details of scans are kept in a *schedule file*.

The main observing task, CAOBS, reads the schedule file in order to determine what sources are to be observed, for how long, and in what order. The schedule file also defines the frequencies, integration averaging unit and correlator setup to use.

The ATCA web scheduler (`http://www.narrabri.atnf.csiro.au/observing/sched/cabb/`), is the tool to use to create ATCA schedule files in the CABB era. Schedules made with the old SCHED program are no longer understood by the CABB version of CAOBS and thus cannot be used. However, it is possible for the web scheduler to read in old schedules and save them for use with the new system. Please also note that an active ATNF username and password is required to gain access to the web scheduler page.

You should prepare **at least** two schedule files:

- A schedule file for setting up and primary flux calibration. It should include 1934-638 and, if 1934-638 will not be up when the observations start, another setup calibrator. If the observations are at mm wavelengths, the primary flux calibrator may be a planet, which is unsuitable for array setup. It is also advisable to observe a bandpass calibrator at the start of observing.

- A schedule file containing the program source(s) and phase calibrator(s), and perhaps contingency schedule files in case the preferred frequency is seriously affected by interference, or the selected calibrator proves to be resolved.

For observations of many sources, use the ATMOS program in MIRIAD to solve the "travelling salesman" problem and optimise the order in which the sources are observed.

With synthesis instruments, it is possible for system errors to lead to artefacts at the centre of the field. For experiments that are intolerant to such artefacts (such as detection experiments), displace the source position a few synthesised beamwidths from the field centre. Note that ATCA software never checks to see how close the telescope is pointing to the sun!

### 2.3.1.1 Source Rising and Setting Times

COORD is a useful program that calculates the altitude, azimuth, and rising and setting times of sources. Currently, this is most easily accessed via the Parkes website, `http://www.parkes.atnf.csiro.au/cgi-bin/utilities/coord.cgi` (though be sure to change from the default values when using the ATCA, i.e., change the site to Australia Telescope Compact Array, and change the elevation limit to 12 degrees for cm observing).

A quick estimate of how long a particular source will be observable for on the ATCA can be made with the table below. It shows, for a source at a particular declination, the LST range before/past zenith it is above 20° elevation. For example, for a source with coordinates RA=08:25:26.869, Dec=-50:10:38.4 (the coordinates for 0823-500), its rise time will be 02:03 LST (take 06:22 from 08:25), and its set time will be 14:47 LST (add 06:22 to 08:25).

| **Declination** | **LST range** |
|---:|---:|
| -80 | always above horizon |
| -70 | 07:54 |
| -60 | 06:56 |
| -50 | 06:22 |
| -40 | 05:57 |
| -30 | 05:35 |
| -20 | 05:14 |
| -10 | 04:53 |
| +0 | 04:29 |
| +10 | 04:01 |
| +20 | 03:26 |
| +30 | 02:34 |
| +40 | 00:24 |

Table 2.1: For sources at particular declinations, this table displays the amount of time the source would take to get from rise to transit, or from transit to set at the ATCA. For these numbers, a source is considered set if it is below 20° elevation.

### 2.3.1.2 Antenna Wrap Limits

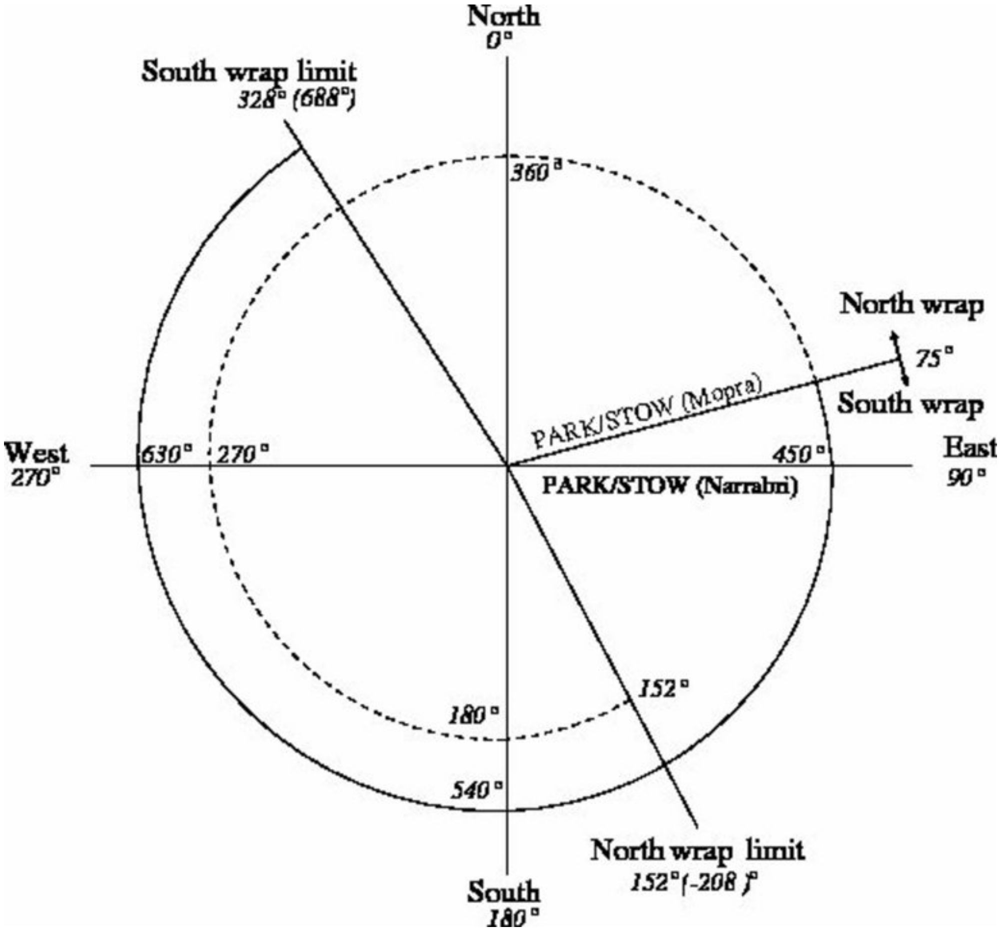

Figure 2.1: Wrap limits for the Compact Array and Mopra antenna.

The wrap limits for any antenna in the ATCA are CCW=$152.5°$ and CW=$327.5°$ as shown in Figure 2.1.

## 2.3.2 How to Use the Web Scheduler

The CABB web scheduler, located at `http://www.narrabri.atnf.csiro.au/observing/sched/cabb/` is used to prepare schedule files. The web scheduler checks the schedule for completeness and, where possible, checks choices such as observing frequency for hardware compatibility. Drive times, and source azimuths and elevations are computed automatically.

Three steps are involved in using the web scheduler:

- A new scan is added to the schedule.
- The details of the scan are changed as desired.
- When all the scans have been defined, the entire schedule is written to file

When constructing a schedule, consider:

- Is the sequence of sources sensible, and how much time is expended on the drive times?
- Does the schedule contain all the sources, and at the appropriate frequencies and bandwidths?

The web scheduler can produce a list to help answer these questions. It is a good idea to study these listings very carefully before observing commences. The scheduler considers drive times: all coordinate entries are automatically followed by a calculation of the azimuth and elevation of the source, as well as the drive time from the previous source, using the entered value for LST. When entering a schedule file, the integration times are specified for each source (and calibrator source). Note that, except in the case of mosaic schedules and `DWELL` scantypes, these integration times include drive times, so the specified time must be somewhat longer than the amount of integration on source required. This is particularly important for secondary calibrators, when the drive time (up to a minute or so) may be comparable to the integration time (about two to three minutes). Alternatively, the `sctype` field can be set to `DWELL` to ensure a source or calibrator is tracked for the specified scan duration.

The schedule file submitted to CAOBS (the online Compact Array control task) need have no specific start time. Rather, the schedule file asks CAOBS to start the first scan as soon as possible. The sequence of scans will be exactly as specified in the schedule file. However, when using the web scheduler, the calculation of azimuths, elevations and drive times is possible only if the starting sidereal time is known (at least approximately). The sidereal time for the first scan in the schedule can be set in the web scheduler by giving the time in the `Time` field, and setting `TimeCode` to `LST`. Alternatively, the starting UT may be specified by setting `TimeCode` to `UT`, and by setting the `Date` to the appropriate start date by clicking on it and using the calendar that appears. Note that when viewing any scan other than the first in the schedule, the fields `Time`, `TimeCode` and `Date` all become read-only.

The environment flag can be used to instruct the online software to remember certain settings, such as attenuators, and to recall them whenever a scan with the same environment flag is encountered. However, this is generally not required, as the online software will remember user settings, and recall them when the same conditions are encountered again. There are at least 128 slots for user settings, so for a normal schedule, the environment flag will probably not need to be used.

### 2.3.3 Web Scheduler Examples

The following sections will describe how to make schedules, by illustrating a number of examples. A complete technical guide to the operation of the CABB web scheduler can be found in Appendix Web Scheduler (page 93).

#### 2.3.3.1 Continuum Schedule Example

In this section a simple continuum schedule file is constructed. It will contain three sources: a program source and two calibration sources. The following observing sequence will be specified:

- setup calibrator (0537-441, a catalogued source) for 5 minutes,
- program source (R.A. 05:21:35.5, Dec. -21:24:27.1 (J2000)) for 30 mins,
- a phase calibrator for 5 minutes.

These sources will be observed at the standard C/X band frequencies of 5500/9000 MHz. To create this schedule file, perform the following steps:

**Navigate to `http://www.narrabri.atnf.csiro.au/observing/sched/cabb/` in a web browser**

The first screen is displayed.

**Change the `Source` field to `test`**
**Change the `RA` field to `05:21:35.5` and the `Dec` field to `-21:24:27.1`**

The delimiter for coordinates must be a colon, and the default `Epoch` of `J2000` should only be changed if necessary.

**Change `ScanLength` to 00:30:00**
**Change `ScanType` to `Dwell`**

This ensures that 30 minutes are spent on source, regardless of slewing times.

**Ensure `Pointing` is set to `Global`**

Offset pointing is usually not required for low-frequency observations.

**Change the `Observer` field to `Jansky`, the `Project` code to `C123`**

These fields should be set in the first source - they will propagate to the other sources as they are added

**Change the `Time` field to `02:00:00`, and the `TimeCode` field to `LST`**
This indicates that the schedule will be started at an LST of 2h

**Click the `Freq1 Setup` bar**
This brings up the frequency selection fields

**Enter `5500` in the `Continuum` frequency box, and keep the `Chn. BW` selection box to `1` MHz.**
The velocity resolution should be calculated to be 54 km/s, and the velocity range will be 111631 km/s

**Click the `Freq2 Setup` bar**
This brings up the frequency selection fields

**Enter `9000` in the `Continuum` frequency box, and keep the `Chn. BW` selection box to `1` MHz.**
The velocity resolution should be calculated to be 33 km/s, and the velocity range will be 68219 km/s.

**Click the `Scan Parameters` bar**
This brings up the scan details

**Click the `Search Cal` button**
This presents a list of nearby calibrators to the right of the scan details, sorted by distance to the source. The closest strong (> 1 Jy) source to the program source is shown to be 0511-220.

**Click on the `0511-220` button**
The details for this source are displayed from the calibrator database below the source list. This source is a suitable phase calibrator as it is strong and has only a small defect.

**Click on the `0511-220` button**
Clicking on the button twice (without clicking another source button between clicks) inserts this source into the schedule above the currently selected source.

**Select source 1, and change the `ScanLength` field to 00:05:00**
**To copy this source to the end of the schedule, click on the `Edit` menu and select `Copy`, then select the `test` source, click on `Edit` and select `Paste`.**
The schedule should now have three sources (in order): 0511-220, test, 0511-220. The first source needs to be changed to 0537-441.

**Select source 1**
**Change the `Source` field to 0537-441 and press `TAB`**
The scheduler will automatically put the source coordinates for this known calibrator in the `RA` and `Dec` fields

**Click on the `File` menu and select `Save As`**
The `Schedule file selector` window will appear

**The schedule will be called c123_test.sch, so enter this into the `Filter` box to ensure that there is not already a schedule with this name**
If there is another schedule with the desired name, consider changing it

**Enter `c123_test.sch` into the `Schedule` box and press the `Save` button**
The file selection window will disappear, and the name of the schedule should now appear at the top of the window.

To produce a listing of the schedule, in order to check that the schedule proceeds as expected, click on the `Listing` tab.

#### 2.3.3.2 Zoom Mode Schedule Example

This example adds to the example from the previous section; ensure that the schedule created in the previous section is in the scheduler before continuing.

Now the aim is to observe 1 zoom band in each IF, each covering at least 70 km/s. The galaxy "test" is actually at a barycentric recessional velocity of 25000 km/s, and these observations will look for $CH_3OH$ methanol and $HC_3N$ cyanoacetylene lines.

To create a schedule that can perform suitable observations for this situation, follow the steps:

**Select the first scan in the schedule**

This should be 0537-441.

**Select the `Global change` menu item from the `Tools` menu**

**Change the `Date` of this scan to 30/11/2010**

The date that the observation will be performed is required to ensure that the observatory velocity is computed correctly.

**Hit the `Global Apply` button.**

The date will now change for all the sources in the schedule.

**Select the "`test`" source in the schedule**

**Click the `Freq1 5500MHz` bar**

This brings up the IF1 frequency selection fields.

**Click the topmost `Velo` button**

This brings up the velocity calculator.

**Select the `CH3OH` line from the `Spectral Line` dropdown box.**

The rest frequency of this line (6668.518) appears in the `Rest Frequency` box below.

**Enter `25000` in the `Source Velocity` field, and select `Bary` for the velocity frame, and `Radio` for the velocity convention.**

The `Sky Frequency` will be updated to 6112.490 MHz, and the zoom band frequency will be calculated as the nearest half-MHz, in this case as `6112.5`.

**Select the `Fix` checkbox**

This signifies that this galaxy is at 25000 km/s. Other lines in other zoom bands will now automatically be shifted by the same velocity.

**Click the `Apply` button in the velocity calculator.**

The velocity calculator will disappear and information will be inserted into the first zoom band. In this case, the `6112.5` MHz frequency translates into the channel 3274. The velocity resolution is given as 0.024 km/s, and the velocity range is listed as 49 km/s.

**Select the zoom band width to be `2` from the width drop box.**

The velocity range now increases to 73.6 km/s.

**Click the `Freq2 9000MHz` bar**

This brings up the IF2 frequency selection fields.

**Click the topmost `Velo` button**

This brings up the velocity calculator. Note that the velocity field has already been filled out and cannot be altered.

**Select the `HC3N` line from the `Spectral Line` dropdown box.**

The rest frequency of this line (9009.833) appears in the `Rest Frequency` box below, and the `Sky Frequency` will be updated to 8258.584 MHz. The zoom band frequency will be calculated to be `8258.5`.

**Click the `Apply` button in the velocity calculator.**

The velocity calculator will disappear and information will be inserted into the first zoom band. In this case, the `8258.5` MHz frequency translates into the channel 566. The velocity resolution is given as 0.018 km/s, and the velocity range is listed as 36.3 km/s.

**Select the zoom band width to be** `3` **from the width drop box.**
The velocity range now increases to 72.6 km/s, comparable to the width provided for the IF1 zoom band.

**Click the** `Scan Parameters` **bar**
This brings up the scan details.

**Select the** `Advanced view` **menu item from the** `Tools` **menu.**
This displays the advanced settings for this scan.

**Select the** `Master1` **option from the** `FreqConfig` **dropdown box.**
This signifies that the frequency configuration, including the zoom modes, from this scan, should be defined as the master configuration.

**Select the** `0537-441` **source from the schedule.**
**Select the** `Slave-1` **option from the** `FreqConfig` **dropdown box.**
Now this scan will exactly mirror the frequency and zoom mode configuration from the `test` scan, even if the configuration of the `test` scan is changed. When a scan is set as a slave scan, the `Freq` panels will display a message describing which frequency and scan it is slaved to.

**Select the** `0511-220` **source from the schedule.**
**Select the** `Slave-1` **option from the** `FreqConfig` **dropdown box.**
Now this scan will exactly mirror the frequency and zoom mode configuration from the `test` scan.

At this point, the schedule would correctly describe a zoom mode observation.

## 2.4 How to Prepare a Mosaic File

### 2.4.1 General Mosaic Strategy

Mosaic observations use a standard schedule file and an additional file, called the *mosaic file*, which lists the positions of the mosaic field centres. Up to 2048 fields can be specified in a single file. This mosaic file must consist of one line per pointing centre in the mosaic pattern. Lines beginning with the # character are ignored and can be used for comments.

The general mosaic file format is:

```
# Comments .... ignored by the software
#
d(RA)              d(DEC)          INT             $FIELD_1
d(RA)              d(DEC)          INT             $FIELD_2
d(RA)              d(DEC)          INT             $FIELD_3
d(RA)              d(DEC)          INT             $FIELD_4
```

The items in each line are: `d(RA)` is the offset Right Ascension of the pointing centre in "degrees of polar rotation" from the reference position. For example, `d(RA)~=~+15.00` will move +1 hr in RA at all declinations. `d(DEC)` is the offset declination of the pointing centre in degrees from the reference position. eg `d(DEC)~=~+1.000` will move the pointing centre one degree north. `INT` is the integral number of integration cycles to spend on each pointing centre. The '$\$$' is a prefix to the field name, and indicates that scans will follow in the order as they are listed in the mosaic file. The name of the field, `$FIELD_n`, must be different for each pointing centre and should be $\leq 9$ characters (naturally, $\$$ can not be used as a first character of the field name). **Note:** The `UVSPLIT` task in MIRIAD needs the field names to be different by '`_n`', where `n` is an integer. This file should be named `mosnam.mos`, where `mosnam` should be a short name that describes the mosaic.

To include a mosaic in a schedule file, insert a scan and set:

- `Source` to the name of the mosaic file, excluding the `.mos` extension, ie. `mosnam`

- `ScanType` to `Mosaic`
- the `RA` and `Dec` to the reference position for the mosaic, ie. the position that all the mosaic field centres are offset from
- `ScanLength` to the minimum time to be spent doing the mosaic, and must be greater than three integration cycles

All other scan settings have their usual effect, including the `Pointing` mode, and the observing frequencies. The mosaic file must be saved in the `/atca/mosaic` directory on XBONES so that CAOBS can locate it during the observations. The mosaic file name should be completely in lowercase letters, even if the corresponding source name in the schedule has uppercase letters, as CAOBS will report that the mosaic file could not be found unless it has an all-lowercase file name.

The mosaic scan will be observed repeatedly until the time specified by `ScanLength` has elapsed, after which the mosaic scan will continue until the last specified field centre is next observed. In this way, the mosaic sequence will always be executed an integral number of times, regardless of `ScanLength`.

The following example shows a mosaic file specifying a four pointing centre pattern on a $0.25°$ grid. Note that the RA offsets are coordinate increments not sky distances.

Mosaic file: mymap.mos

```
# mymap.mos by P. Smith
# A four pointing centre mosaic
# Ref. Position = 05:21:33, -65:56:41
0.0000      0.000      2      $mymap_1
0.6133      0.000      2      $mymap_2
0.6133      -0.250     2      $mymap_3
0.0000      -0.250     2      $mymap_4
```

The scan in the corresponding schedule file might have the parameters:

| | | | | | | |
|---|---|---|---|---|---|---|
| **Scheduler fields:** | `Source:` | `mymap` | `Observer:` | Smith | `Project:` | C555 |
| | `RA:` | 05:21:33 | | | | |
| | `Dec:` | -65:56:41 | | | | |
| | `Epoch:` | J2000 | | | | |
| | `ScanLength:` | 00:30:00 | | | | |
| | `ScanType:` | Mosaic | | | | |
| | `Pointing:` | Global | | | | |

With these settings, and with the default integration time of 10 seconds, the four pointing centres will be observed every 80 seconds, and the pattern will be repeated 23 times during the scan.

### 2.4.2 On-the-fly Mosaicing Strategy

On-the-fly (OTF) mosaicing has a couple of important differences to general mosaicing, which will be described here. Most importantly, although the mosaic pattern should be broadly the same – the hexagonal pattern is still the optimal sampling – the order of observation should be such that the telescope scans in a straight line for as long a distance as possible.

During an OTF mosaic, the phase center follows the mosaic points as specified, and the pointing center moves continuously across the pointings. In effect the primary beam of the antennas becomes elongated (to 1.5 beams) in the scanning direction.

To satisfy proper sampling of the sky, the antennas should not move by more than half a beam per integration cycle, so the spacing of pointings in the mosaic file should be the same as before. The way this is implemented in CAOBS assumes you are scanning in rows or columns, the direction of scanning is inferred from the next point. At the last point of a row or column the previous direction is maintained to complete the scan. One extra point, marked with the name TURN, needs to be specified at the start of the next row/column, to allow for the antennas to change direction and scan at the correct speed again. As an example, here is a 3x3 grid around 1934-638:

```
 0.0000   0.00   2  $@1934-on C
-0.1812  -0.16   1  $TURN-10
-0.1812  -0.08   1  $1934-11
-0.1812   0.00   1  $1934-12
-0.1812   0.08   1  $1934-13
 0.0000   0.16   1  $TURN-24
 0.0000   0.08   1  $1934-23
 0.0000   0.00   1  $1934-22
 0.0000  -0.08   1  $1934-21
 0.1812  -0.16   1  $TURN-30
 0.1812  -0.08   1  $1934-31
 0.1812   0.00   1  $1934-32
 0.1812   0.08   1  $1934-33
```

Note that you can specify a non-scanning position in an OTFMOS file by starting the field name with a `"@"`, like the 2 cycle calibration on 1934-on above. Also note the fields marked with TURN - these are the extra points required at the start of each row/column to give the antennas time to get to the correct position and scanning speed. They should be discarded when processing the data. To use the OTF mosaic mode, specify a scantype of `OTFMos` in the web scheduler and put a mosaic file like the one above in `/atca/mosaic/` on XBONES.

The primary advantage of OTF mosaicing over regular mosaicing is its speed in covering a large area of sky, making it possible to get good $uv$ coverage of a large field in a single observing run. It will not usually provide any better sensitivity than a carefully crafted regular mosaic.

Although OTF mosaicing is most useful at low frequencies where the slew time between mosaicing points are a more significant fraction of the total integration time, this mode could also be used for mm observations by using bin mode and moving the antennas by e.g., 16 beams in a single integration with 32 time bins. The MIRIAD program ATLOD will need some work to properly record the phase center and pointing center in this case.

## 2.5 Observation Requirements

This section describes what will be required for the observations to be successful. All observers should read this section!

### 2.5.1 Coming to the Observatory

For observers unfamiliar with the ATCA, it is recommended that they arrive so that they have at least one full weekday available before their observations, in order for them to become familiar with how to use the array and who to talk to if things go wrong.

### 2.5.2 Remote Observing

To be sure of a successful remote observing session, all observers are required to test their remote observing setup at least a week before their observations.

At a minimum, a remote observer requires:

- A computer capable of running a VNC viewer, on a high bandwidth connection.
- A telephone near to the computer, that can accept calls from the observatory.
- Recent experience with Compact Array observing (ie. within the last 12 months and with the CABB system).

Remote observations will be easier if a remote observer also has:

- Two or more monitors attached to their computer.
- A computer with SSH and X-Windows software.
- A handsfree speakerphone.

To test their setup, observers should contact the Duty Astronomer and ask to be allowed to login and perform the test. If the test will not disturb current observations, the remote observer should follow the instructions on remote observing found in Chapter 3 to ensure that they can monitor and control all the required VNC sessions. If problems are encountered here, they should contact the observatory staff with a description of the problems and ask for advice.

### 2.5.3 Data Consumption

It is recommended that all observers bring their own magnetic disks to the observatory in order to take data back with them. To calculate roughly how much data an observation will generate, use the following formula.

The number of bytes per cycle is:

$$b_{cycle} = N_{channels} \times N_{IFs} \times N_{products} \times b_{corr} \times N_{Stokes},$$

where $N_{channels}$ is the number of channels per IF, $N_{IFs}$ is the number of IFs, $N_{products}$ is the number of correlation products, $b_{corr}$ is the number of bytes per correlation product, and $N_{Stokes}$ is the number of Stokes quantities.

For a typical continuum observation, $N_{channels} = 2049$, $N_{IFs} = 2$, $N_{products} = 21$ (15 cross-correlations + 6 auto-correlations), $N_{Stokes} = 4$ and $b_{corr} = 12$ (4 bytes each for real, imaginary and weight components). With these numbers, a typical continuum observation produces $b_{cycle} = 4,130,784$ bytes per cycle.

The data-rate per hour therefore is:

$$b_{hour} = 3600/t_{cycle} \times b_{cycle},$$

where $t_{cycle}$ is the correlator cycle time in seconds. For a typical correlator cycle time of $t_{cycle} = 10$, a typical continuum observation produces $b_{hour} = 1,487,082,240$ bytes (1.385 GiB) per hour.

For each zoom band that is recorded, more space is required. The data-rate per hour is calculated as before. For typical zoom bands, $N_{channels} = 2049$, $N_{IFs} = 1$, and all other values are the same as for a typical continuum observation. Therefore each zoom band will generate an additional 709.1 MiB per hour. Eventually, with a possible 16 zoom bands per continuum IF, CABB will produce up to 23.544 GiB per hour (565 GiB per day!), or even more if the cycle time were to be decreased.

Storing that much data on DVD media would require 142 discs per day, while such a data volume can easily be stored on an inexpensive external hard drive, with the added benefits that data storage and retrieval would be far quicker and more convenient.

## 2.6 Pre-observation Checklist

Ready to observe? Check that all the following tasks have been done:

- Determined sources to use for:
  - setup calibrator
  - primary flux calibrator
  - bandpass calibrator
  - phase calibrator(s)
  - pointing calibrator(s) (only if doing reference pointing)
  - polarisation calibrator(s) (only if doing polarisation studies)
- Checked that all sources are visible during observing time.
- Prepared a schedule file using the CABB web scheduler for:
  - array setup

  - calibration
  - program observations
- Used the sensitivity calculator to make sure that integration time on calibrators is sufficient.
- Ensured that turret movements are limited to once every 15 minutes or longer.
- Generated a mosaic pointing file (only if doing mosaic observations), and copied it to the appropriate place on XBONES.
- Generated an ephemeris for the solar system object (only if doing solar system observations), and copied it to the appropriate place on XBONES.
- Calculated how much data the observations will generate, and obtained enough disk space to accommodate this.
- Checked for possible problems, and made contingency plans for:
  - Antenna shadowing
  - Wrong time range for flux calibrator observations
  - Bad weather forecast during observations
- Checked current issues page for issues that may cause problems with the observations. `http://www.narrabri.atnf.csiro.au/observing/CurrentIssues.html`
- Checked that remote observations are possible (only if remotely observing).
- Contacted observatory staff and duty astronomer if assistance will be required during observations.