Technical Summary of the Mopra Radiotelescope

(Version: 27 October 2005)

1 General

Mopra is a 22-m single-dish radio telescope located at the edge of the Warrumbungle Mountains, near Coonabarabran, about 450 km north-west of Sydney. The telescope is located about 4 km from Siding Spring Mountain, the home of the Anglo-Australian Telescope and a number of other optical instruments. Mopra's latitude and longitude is -31:16:04,149:05:59, the elevation is 866 m, and telescope elevation limit is 12°. The telescope is mainly used for 3-mm spectroscopy and VLBI experiments (using an S2 data recorder plus a disk recording system). Although VLBI experiments are scheduled throughout the year, 3-mm spectroscopy is scheduled only for the period May-October (southern winter) when the atmosphere is best. Proposals for other times and observation types may be considered if they request a significant amount of time, and if a case is made for why Mopra is the observatory of choice.

During 2006, it is expected that the Mopra facility will be operated from a control desk at the ATNF Narrabri Observatory. Most observers would be expected to go to Narrabri to observe with Mopra. The proposing astronomers are responsible for running the observing process. The Narrabri Observatory provides accommodation facilities for visiting astronomers. More information on Mopra is available from:

`http://www.narrabri.atnf.csiro.au/mopra`

2 Remote Operation

In 2006 it is expected that Mopra observations will generally be performed remotely from Narrabri. A Mopra control desk and technical support will be available in Narrabri. Mopra remote operation depends on the successful completion of a broadband network upgrade. This is slated to be completed by early 2006.

3 Receivers

The telescope has receivers at wavelengths of 20, 13, 6 and 3 cm, 12 and 3 mm. The 12-mm system has good performance in the range 16 – 25 GHz. The 3-mm system can operate well in the range 77 – 116 GHz, but the antenna is less efficient at the highest frequencies. The receivers operate in a single-sideband mode.

Two orthogonal polarisation are measured simultaneously at all frequencies. The 3-mm and 12-mm systems are linearly polarised, whereas the other bands are circularly polarised.

Polarimetry with the AT Correlator is possible at all wavelength bands. Strong proposals to do polarimetry will be considered.

The 2006 observing season will be the first full season for the new MMIC receiver package at 3 and 12mm. This supersedes the 3-mm SIS system, and the narrowband 12-mm system that were formerly used. The MMIC receiver requires no mechanical tuning – effectively tuning is "automatic" and "instantaneous". Because of this, there is no need to sacrifice an observing channel to a band centred on SiO for pointing. When a pointing calibration is performed, the pointing schedules can immediately re-tune to SiO.

BAND	20cm	13cm	6cm	3cm	12mm	3.5mm	2.6mm
Frequency Range GHz	1.3-1.8	1.8-3.0	4.5-6.7	8.0-9.2	16.0-25.0	78-116	
FWHM	$33'$	$22'$	$10'$	$5'$	$2'$	$36 \pm 3''$	$33 \pm 2''$
System Temperature[a]	35 K	36 K	38 K	38 K	45 K	170 K	450 K
Sensitivity (Jy/K)	11	14	11	11	15	22	~30
Zenith opacity[b] τ	0	0	0	0	0.05	0.1	0.18
Line flux sensitivity[c] (10 mins, 10 km/s, 2 IFs)	51 mJy	51 mJy	30 mJy	22 mJy	24 mJy	70 mJy	238 mJy
Main Beam Efficiency	0.7	0.7	0.7	0.7	0.7	0.49	0.42
Line brightness sensitivity[c,d] (10 mins, 10 km/s, 2IFs)	6.6 mK	5.3 mK	3.9 mK	2.9 mK	2.3 mK	6.5 mK	18.9 mK

Table 1: Mopra system parameters

Notes
[a]Single-sideband noise temperatures (receiver+telescope+sky) with telescope near zenith under typical observing conditions (see note b).
[b] Typical opacity during normal winter observing conditions with no cloud cover.
[c]One frequency, dual polarisation. Includes the effect of zenith opacity. Backend efficiency assumed to by 100%. Actual efficiency depends on the number of bits used and the switching method used to remove the background noise power.
[d]The main beam efficiency is use in determining sensitivity. See reference 1 for more details.

Figure 1 shows the measured above-atmosphere values of $T_{\rm sys}$ across the 3-mm band. A sensitivity calculator for 3-mm wavelength Mopra observations is available at

`http://www.narrabri.atnf.csiro.au/mopra/sensitivity_mopra.html`

Calibration of all receivers is achieved by a switched noise-source injection technique. In addition the 3-mm receiver has a room-temperature paddle, that can be inserted into the optical path to allow an above-atmosphere $T_{\rm sys}$ to be deduced (i.e. the "chopper wheel" method). This takes approximately 27 seconds to perform and can be scheduled as part of the observing run.

4 Pointing

The pointing model provides an accuracy of better than $9''$ rms. This can be significantly improved by periodic pointing measurements of a nearby SiO maser. An up to date list of the available pointing sources is present at the observatory.

5 Observing modes

The most popular observing modes for the telescope (excluding VLBI) are position switching and on-the-fly mapping. The choice is generally dictated by the sensitivity that must be achieved; raster mapping can cover large areas efficiently but with much poorer sensitivity. In both cases a backend dump time of 2 s is generally used to minimise overheads.

Position switching in practical terms can be carried out at intervals no shorter than 10 s due to the slew time of the antenna. This limits the usefulness of the telescope for radio-continuum observations and adds a slew overhead to other projects.

On-the-fly mode is available for spectral-line mapping of fields a few arc minutes in size, with on-site software available that allows efficient reduction of maps into FITS image cubes. A $5' \times 5'$ region can be

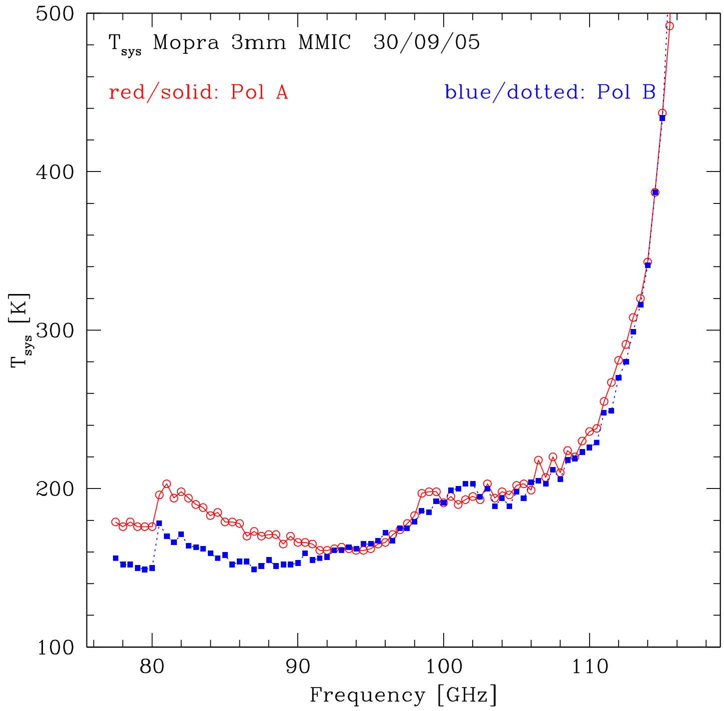

Figure 1: Above-atmosphere system temperature of the 3-mm system in "typical" observing conditions.

mapped with Nyquist beam sampling to an rms level of 0.3 K (uncorrected for main-beam efficiency) in about an hour, including overheads for OFF scans and temperature calibration.

Beam switching is not available. Frequency switched observation is possible and substantially more efficient than position switched observation, although it is less popular due to the skewed baselines being substantially more difficult to reduce.

6 Backends

Two back-ends will be available in 2006: the AT correlator and the 'Mopra Spectrometer' (MOPS). The backend chosen affects the exact frequency band available in the 3-mm band: for the AT correlator, the frequency range is 76.5–117.4 GHz, and for MOPS, the range is 79.8–116.9 GHz.

AT Correlator

The AT Correlator supports bandwidths of 256, 128, 64, 32, 8 and 4 MHz, with the varying maximum number of channels shown in the table below. The maximum bandwidth of 256 MHz restricts the usefulness of the system for extra-galactic millimetre spectroscopy. The correlator uses 1-bit samples for the 256 MHz bandwidths, and 2-bit for the smaller bandwidths. These give a "correlator efficiency" of 64% and 88% in the 256-MHz and narrower bandwidths respectively.

Table 2 gives the configurations into which the correlator can be set.

The spectral resolution is approximately 1.2 times the channel increment. Hanning smoothing will change this to about 2.0 times the channel increment.

The AT Correlator will probably be of most interest to observers wanting high spectral resolution of a limited number of lines.

Correlator Configurations	Bits	Channels	Bandwidth (MHz)	Pols	Freqs	Bins
ac_128_256_2	2	256	128	2	1	1
ac_16_1024_2	2	1024	16	2	1	1
ac_256_256_2	1	256	256	2	1	1
ac_32_1024_2	2	1024	32	2	1	1
ac_4_8192_2	2	8192	4	2	1	1
ac_64_1024_2	2	1024	64	2	1	1
ac_8_4096_2	2	4096	8	2	1	1
bin16_ac_64_512_2	2	512	64	2	1	16

Table 2: AT Correlator configurations.

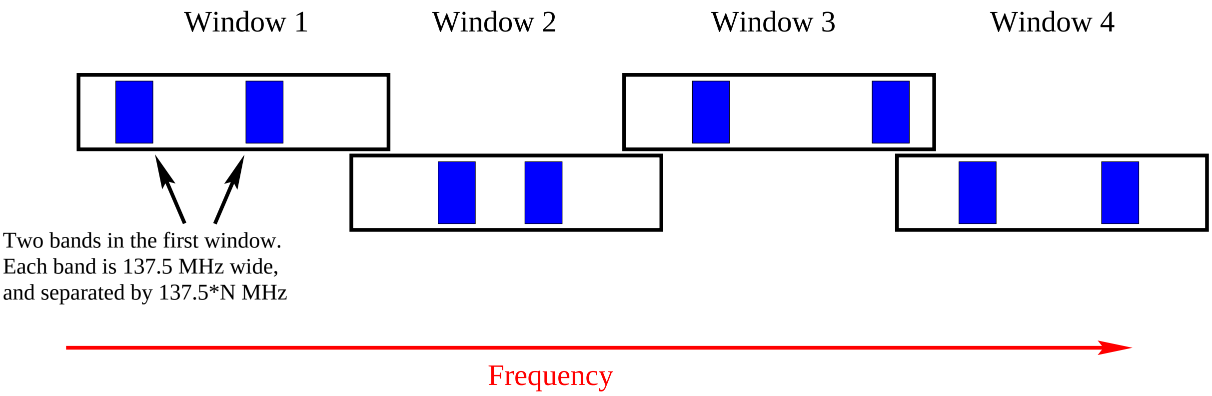

Figure 2: Representation of the MOPS configuration in narrowband mode. Four overlapping windows (each 2.2 GHz wide) are show. Each window has a pair of 137.5 MHz bands (shown in blue).

MOPS

The MOPS backend is a digital filterbank which can observe within an 8 GHz frequency range at any given time. This frequency range is broken into four overlapping 2.2 GHz windows whose centre frequencies are at fixed offsets from each other. The details of the capability of the MOPS filterbank backend have not yet be finalised. Observers will be updated with these details before the start of the winter. For large observing programs, it might be possible to tailor MOPS to meet specific observer requirements. Please contact Juergen Ott (`juergen.ott@csiro.au`) to discuss MOPS functionality. However a broadband and narrowband mode will be provided.

In broadband mode (eg suitable for extragalactic work) MOPS provides 4 overlapping windows. Each window is 2.2 GHz wide and has 2048 channels.

In narrowband mode (eg suitable for Galactic work) MOPS supports 8 bands being observed simultaneously. Each band will be 137.5 MHz wide and have 4096 channels, of which at least the central 75is usable. The 8 bands are configured as four pairs. Each pair must fall into one of the four 2.2 GHz windows. Apart from this, the frequency setting of each pair will be independent. The separation between the two bands of a pair must be $137.5 \times N$ MHz, where N can be chosen to be from 1 to 14. This means that the bands within a window cannot overlap.

The details of the overlap between windows have not yet been finalised. The possibility of also providing $137.5 \times (N + \frac{1}{2})$ MHz spacings between bands is being investigated. If successful, this would accommodate all spacings of spectral line pairs within a window. Until these details are available, observers may not be able to fully optimise proposed uses of MOPS. Proposers are asked to consider both possible MOPS flexibility and restrictions when making a request.

Figure 2 depicts a typical arrangement of bands within the 8 GHz frequency range. Each band could potentially be centred near a molecular transition.

7 Data reduction

The output of the system are spectra stored in RPFITS format. Reduction software for this data format exists on-site in the form of SPC, ASAP, Livedata and Gridzilla. Data can copied and taken away using personal laptops or using the local DVD writer and observatory supplied DVDs. An archive of recent data is retained at Narrabri.

References

1. Ladd, Purcell, Wong and Robertson (2004), "Beam size, shape efficiencies for the ATNF Mopra radio telescope at 86-115 GHz"
   `http://www.narrabri.atnf.csiro.au/mopra/mopra_beam.pdf`.