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Stand Alone Operation of the AT Antennas

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INTRODUCTION

The Parkes 64 m and the new 22 m antenna at Siding Spring will be used as Long Baseline Array elements of the Australia Telescope. When these antennas are not being used as LBA elements they may be used as stand alone instruments for single dish radioastronomy. During Compact Array observations requiring a maximum baseline less than 3 km, the '6 km' antenna at Culgoora will be available. Of particular importance to the AT are provision of sensitive wide-field line spectra and short spacing information for Compact Array observations. In this note the role of the Parkes, Siding Spring and Culgoora antennas is reviewed, and the instrumental requirements for single dish operation are investigated.

LBA

The AT Long Baseline Array officially consists of the six 22 m Culgoora Compact Array antennas (either single or combined output), the 22 m Siding Spring antenna and the 64 m Parkes antenna. For some of the time one of the Deep Space Network telescopes at Tidbinbilla (the 64 m or one of the 34 m antennas) may be included. Since the LBA will be a tape-based system, the possibility exists of including other antennas in the array when available. Tape recorders for non-AT antennas are not included in the AT budget, however. (See LBA Working Group report of 20/9/84 for a list of Australian and New Zealand antennas.)

In the original radio linked LBA, simultaneous line and continuum signals were to be available on each of two IF outputs from the AT LBA antennas, and simultaneous line and continuum LBA processing was envisaged. How this will be accommodated in the tape based system has not yet been decided. The type of tape recorder system and its bandwidth has not yet been fixed. The minimum bandwidth specification for the radio linked system was 10 MHz per IF channel.

The Parkes telescope will be used with the LBA up to at least 23 GHz, and AT feeds and receivers will be provided. It is not yet known whether dual band feeds can be designed to work at prime focus, and receiver changes will be required to change frequency at least between L/S, C/X and K/Q bands. At 22 GHz only the inner 44 m of the Parkes 64 m dish is illuminated. The Siding Spring antenna is usable to 115 GHz, and operation of the LBA up to 115 GHz is envisaged for the Culgoora and Siding Spring antennas. It is intended that this antenna be equipped with the turret arrangement for remote switching among dual band feeds. Above 44 GHz, only the inner 11 m of the 22 m antennas are illuminated. The Tidbinbilla telescopes are good to 23 GHz. There is no provision for AT feeds and receivers for the Tidbinbilla antennas in the AT budget. These are the only radioastronomy antennas in Australia capable of operating at 23 GHz or higher, except for the Radiophysics 4 m dish in Epping. The 4 m is scheduled for retirement in 1986.

THE PARKES TELESCOPE

In order to provide short spacing (< 30 m) data for the AT Compact Array (CA), an antenna at least twice the diameter of an individual CA element is needed. Although other methods exist for obtaining short spacing data (cf. Image Formation from Coherence Functions in Astronomy, 1979, D. Reidel), the single dish mapping method is probably the simplest and most accurate. The technique uses a fully sampled single dish map over the area of sky covered by the primary beam of a compact array antenna. This map is then Fourier transformed into the uv plane and the desired spacings extracted. The Parkes telescope can provide short spacing data for the CA up to 23 GHz. At 44 GHz and higher, other methods will be needed.

Since short spacing data is required for each Stokes and frequency channel developed by the CA correlators, the task of providing it is simplified if the Parkes correlator output is identical to the CA output. The requirements on the Parkes telescope are therefore: (1) accurate mapping capability at all AT frequencies up to 23 GHz, and (2) correlator output identical to the CA. Another reason for insuring point (2) is the provision of sensitive wide-field spectra for line observers. One of the major difficulties in spectral line observations is the selection of channels for averaging and mapping. Without sensitive spectra representative of the full field of view, observers are often forced to map every line channel observed. Since the Parkes beam is smaller than the beam of the 22 m antennas, the average spectrum over the area mapped will be required.

In order to insure identical correlator capacity for Parkes and the CA, Parkes requires the same number of correlator modules as a single baseline of the CA. The Parkes correlator must work in autocorrelation mode, and be configurable to match the polarization and frequency channel combinations possible with the CA correlator. For the purposes of short spacing data, it is not essential that Parkes have the same simultaneous mapping capability as the CA. If, for example, only one frequency band at a time is available at Parkes, two separate observations will be required to provide short spacing data for dual band CA maps.

Accurate mapping capability up to 23 GHz basically requires a noise adding radiometer (NAR) and provision for beam switching. The NAR will continuously monitor and correct receiver gain variations, and is standard equipment on the AT receivers. Beam switching is required in order to cancel fluctuations in received power due to the atmosphere. Without beam switching it is usually impossible to obtain accurate continuum maps above a frequency of a few GHz. One of the primary advantages of interferometry is that receiver and atmospheric noise does not correlate, and the output depends only on fractional changes in the system temperature. For single dish work, a cloud looks just like a radio source unless a beam switched output is available. In the absence of a dual beam feed system, one is forced to do 'on-offs' by slewing the telescope on and off source. The degree to which this will work depends on the cycle time of the on-offs and the stability of the

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atmosphere. For line observations there is generally the alternative of frequency switching, but for continuum mapping there are no good alternatives to beam switching.

THE SIDING SPRING TELESCOPE

Unless the surface accuracy of the Siding Spring telescope is maintained at about 0.15 mm rms over the full 22 m diameter, it can not be effectively used to provide short spacing data for the CA at the higher frequencies. It can be used to provide zero spacing data, however, and also for general radioastronomy. Since it is likely to be free more frequently than the Culgoora antenna at the 6 km site, it may be the best choice among the 22 m dishes for stand alone operation. The Siding Spring dish has an advantage over the Culgoora antennas in its pointing, due to the wheel on track mount, and there has been mention of maintaining high surface accuracy beyond 11 m for this dish. More importantly, if differences in feed design are required for single dish work, it would be better to do it to the Siding Spring antenna rather than a CA antenna. A disadvantage is its location - about 100 km from Culgoora.

Zero spacing data is required for accurate CA mapping in order to avoid distortion caused by position dependent errors in the map zero level. This is particularly important for wide field mapping and extended sources. Missing zero spacing can also distort spectral line profiles derived from synthesis maps. Zero spacing data is simply the total flux density within the primary beam of the synthesis array in each Stokes and frequency channel observed. For the CA it is most accurately measured using one of the 22 m antennas. For this purpose accurate continuum measurements at all AT frequencies are required, so beam switching is also needed on the Siding Spring antenna. Since it is a single dish measurement, it requires an autocorrelating backend. If the Siding Spring antenna is to be used to provide zero spacing data for the CA, its basic requirements are the same as for the Parkes telescope; an autocorrelator to match a single baseline of the CA, and beam switching capability.

THE CULGOORA ANTENNA AT THE 6 KM SITE

Five of the six Culgoora antennas will be located on a continuous 3 km railtrack. The sixth antenna will be stuck on a short (200 m) section of track 3 km from the end of the continuous track. At present there is no plan to allow relocation of the '6 km' antenna onto the continuous section. For observations requiring maximum baselines of 3 km or less (probably the bulk of observations above 22 GHz) the 6 km antenna will be idle. When not being used for CA observations, it may be used for LBA observations. Another useful activity would be providing long integrations for wide field line spectra. This would require an autocorrelating backend, but not offset feeds.

Atmospheric variations are not as serious for line spectra as they are for continuum observations because the sky emission is subtracted in the baseline. There is also the expedient of frequency switching. For bandwidths above about 20 MHz the feed/subreflector ripple may become troublesome (ripple period is about 30 MHz), but frequency switching, position switching and baseline modeling should allow reasonable spectral measurements without beam switching.

AUTOCORRELATOR REQUIREMENTS

The basic requirement of the Parkes and Siding Spring autocorrelators is that they have the same flexibility and capacity as a single baseline of the CA line and continuum correlators. For the 6 km antenna, a capacity consistent with the CA line correlator is required. The specification given in the AT Correlator Workshop report (AT/10.4/003) is 8 modules (one block) for the line correlator, and 2 modules for the continuum. Future expansion to two blocks per baseline is expected for the CA line correlator. Since 5 blocks of the CA line correlator are unused when the 6 km antenna is idle, these can provide the hardware required for the Culgoora autocorrelator. For the Parkes and Siding Spring correlators, more XCELL chips should be ordered.

It may be possible to reduce the module count by a factor of two for autocorrelation, but this needs to be looked into. For the two parallel hand polarization products (XX and YY) no phase information is required. For the cross polarization (XY) channel, both in-phase and quadrature-phase terms must be measured in order to derive all four Stokes parameters.

For Parkes and Siding Spring, the input IF switching and the various observing modes for autocorrelation are the same as for the LBA correlator, since they depend only on the available IF signals. For CA observations which use more than two IF's, two autocorrelation observations will be required. In these cases only half the autocorrelator will be used in each observation. It should be noted that restriction to two IF's is not necessary if the autocorrelator is located at the telescope. If four IF's were available on the Parkes and Siding Spring receivers a single autocorrelation observation would suffice for any CA observing mode (assuming identical dual band capability). Additional IF outputs could also be useful in accommodating simultaneous line and continuum autocorrelations without multiplexing onto a single IF output.

For the 6 km antenna, all configurations appropriate to the CA should be made available for autocorrelation. One could consider cascading a few blocks together for the 6 km autocorrelator in order to increase its range, since 5 blocks are available. Alternatively, one could use the blocks as autocorrelators for the 5 active antennas. A difficulty with this proposal is providing the appropriate bandpass calibration for autocorrelation during a synthesis observation. In some cases, however, the normal synthesis calibration will be sufficient. This is extremely attractive because it provides the sensitivity and wide field of view required to make an appropriate channel selection for CA line mapping.

For the Siding Spring autocorrelator, bandwidths greater than 160 MHz would be useful for galactic centre and extragalactic line observations at 115 GHz. For a 320 MHz bandwidth, the velocity coverage at the 115 GHz CO line is 830 km/s. This would be adequate coverage for most galaxies and for the galactic centre. There are methods for obtaining 320 MHz spectra from a 160 MHz correlator (NFRA ITR 148 'Proposal for Extending the Bandwidth of the 256 Channel Correlator at Dwingeloo' by J.L. Casse and J.D. O'Sullivan). Alternatively, the maximum bandwidth of the Siding Spring correlator could be increased by additional parallel processing.

BEAM SWITCHING

Providing offset feeds on the Siding Spring telescope may be difficult because of space limitations on the turret. Fortunately, beam switching is not necessary at L/S band. The problem is less severe for the Parkes telescope since separate receiver packages are planned for each frequency pair. For Siding Spring, it may be possible to position offset feeds at the higher frequencies (C/X, K/Q and W/F), but not in a way which will allow them to come on axis. In addition to the offset feeds, two wideband RF switches will be required for each feed; one for each polarization. Since these are lossy and must be in front of the LNA, they should be cooled. For the higher frequencies, switching rates on the order of 100 Hz may be desirable.

SUMMARY AND RECOMMENDATIONS

In order to provide zero spacing and short spacing data for AT Compact Array observations, the Parkes and Siding Spring telescopes require separate AT autocorrelators. Each autocorrelator requires 10 modules, for a total of 20 modules, or 320 XCELLS. For future expansion, another 16 modules are required, bringing the total to 36 modules or 576 XCELLS.

For accurate continuum mapping and flux measurements above 2 GHz, offset feeds are required for beam switching at Parkes and Siding Spring. Wideband RF switches will also be needed. These should be located inside the dewar.

Sensitive line spectra over a wide field of view may be provided by the Parkes and Siding Spring antennas, and also the 6 km Culgoora antenna when it is not being used with the CA. In some cases, the five telescopes on the 3 km track may be used simultaneously. This requires reconfiguration of five CA line correlator blocks (normally assigned to baselines which include the 6 km telescope) to handle autocorrelation. Apart from reconfiguration switching, no extra hardware is required for the Culgoora autocorrelator.

In order to enhance the performance of the Siding Spring antenna as a millimetre wave telescope, ways of increasing the bandwidth of its autocorrelator to at least 320 MHz should be investigated.