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The MOST and Other Radio Telescopes*

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Abstract

The MOST performs rotational synthesis, in common with the Australia Telescope and other arrays overseas. However, the MOST's unique construction fits it into a complementary rather than a competitive niche, with its particular strength being rapid surveys of large areas of sky.

1. Introduction

The Molonglo Observatory Synthesis Telescope (MOST), located near Canberra, is operated by the Astrophysics Department of the University of Sydney. Fig. 1 shows a general view of the telescope. The MOST uses the well-known principle of earth-rotation aperture synthesis, but in a novel way, resulting in a unique instrument. Its properties are therefore rather different from those of synthesis arrays such as the Australia Telescope. Many of the differences are due to the MOST's construction as a conversion of the east–west arm of the former one-mile Molonglo Mills Cross, the most obvious being the continuous cylindrical paraboloid configuration instead of the more usual array of discrete parabolic dishes. Certain properties of the MOST, such as the large collecting area and distributed feed system, follow from this and others such as the use of real-time beam forming follow in turn. The net result is a synthesis telescope of good sensitivity, and with the ability to survey large and complex regions quickly, constructed at a fraction of the cost of building a new telescope from scratch.

2. Basic Properties of the MOST

The history of the 408 MHz Cross and its conversion to the MOST is given in the accompanying paper by Mills (1991, see p. 719). A simulation study, prior to the conversion to the MOST, was published by Mills *et al.* (1976). A general description of the MOST was given by Mills (1981) as the conversion was being completed, and an account of the beam forming process by Durdin *et al.* (1984). Mills (1985) gave further details and an account of some of the astronomical programs.

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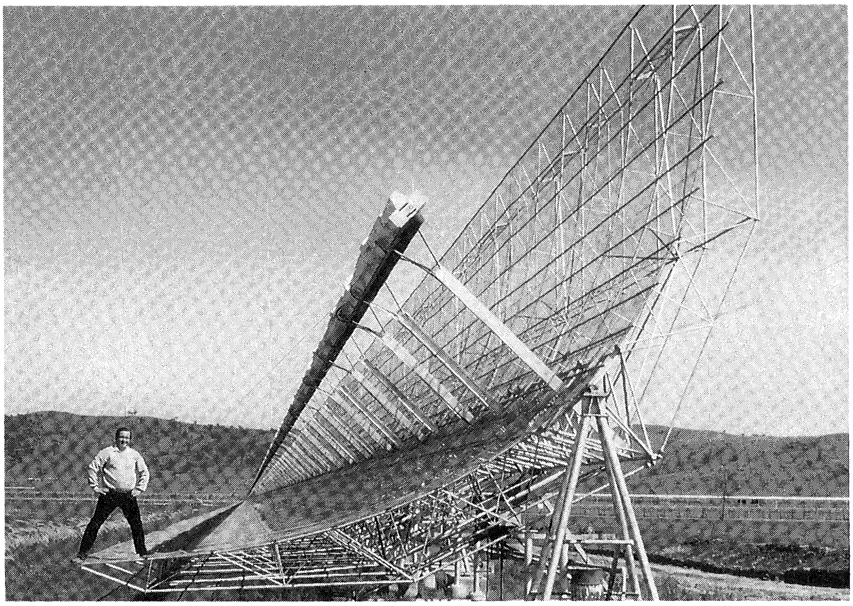

Fig. 1. A view of the MOST, looking west along the eastern arm. Astronomer Alan Vaughan shows the scale of the instrument.

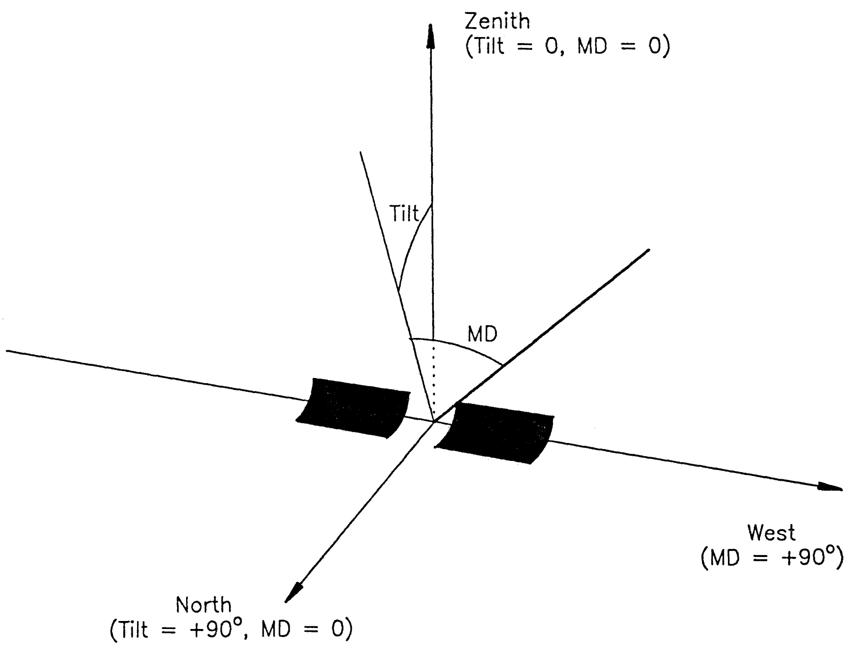

Fig. 2. The natural coordinate system for the MOST consists of tilt and meridian distance (MD). Beam steering in tilt is obtained by mechanically rotating the entire antenna structure about its long axis, while MD steering is obtained by changing the phase/delay gradient along the arms. The diagram indicates the coordinate axes as well as a line in the meridian plane at tilt +10° and a heavy line at the same tilt but with MD approximately +42°.

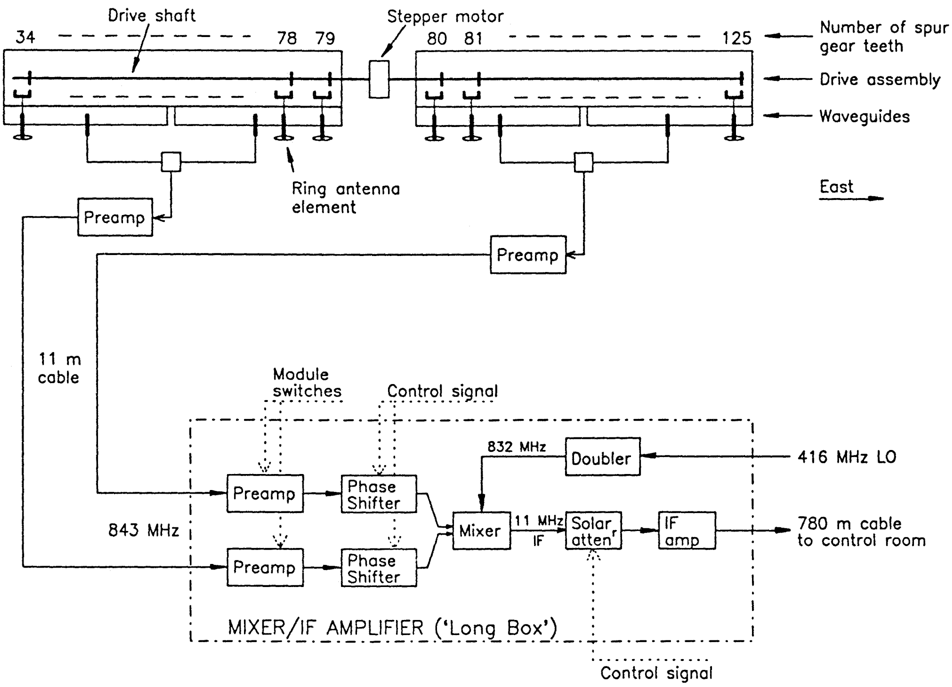

Fig. 3. Schematic (not to scale) of the structure and functions making up one bay of the MOST. The upper part of the diagram depicts the two adjacent modules (each containing two waveguides) that make up the bay. Only a few of the 44 ring antenna elements in each module can be shown. The lower part of the diagram shows the mixer/IF amplifier in block form. Each arm consists of 44 such bays. To allow for small differences in the performance of the two modules in each bay, there is also a phase adjustment in one input to the 'long box' and an amplitude balance control at the mixer (these components are not shown here). For test purposes, the 'module switch' facility allows the contribution from one of the two modules to be omitted, by cutting the DC power to the appropriate preamplifier.

It is not possible to present here a comprehensive account of the operating principles of the MOST. What follows will be restricted to fundamentals and aspects of the MOST's construction and operation that are relevant to comparisons with other synthesis instruments.

The MOST consists of two collinear cylindrical paraboloids of dimensions $778\ \mathrm{m} \times 11 \cdot 6\ \mathrm{m}$, separated by a gap of 15 m and aligned east–west. The total length of the instrument is 1571 m and the physical aperture is some $18050\ \mathrm{m}^2$. Its operating frequency is 843 MHz. A line feed system of 7744 resonant ring elements collects the signal and feeds 176 preamplifiers and 88 IF amplifiers. Each of the 88 IF signals is returned to the control room. Telescope functions are controlled and coordinated by a special purpose Telescope Control Computer, while an HP A700 computer is used for data acquisition and processing.

(a) The Tilt Drive System

One of the coordinates for steering the telescope is obtained by mechanical rotation of the cylindrical paraboloids about their long axis (the so-called 'tilt'

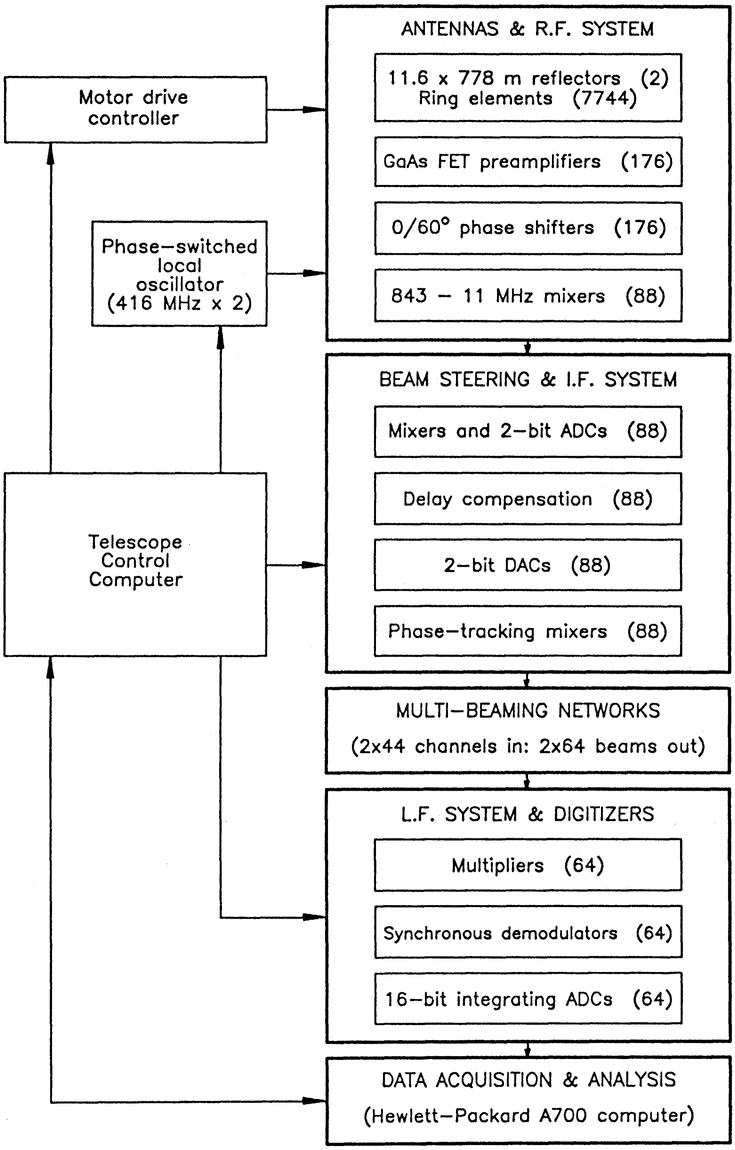

Fig. 4. Block diagram of the signal processing path of the MOST. Various practical elaborations such as the frequency and phase control system for the local oscillator, and the details of the dual-period phase switching are not shown.

direction, equal to declination when at the meridian plane—see Fig. 2). The motor, shaft and gearbox system for this motion is unchanged from the Cross (although now under computer control).

(b) The Meridian Distance Beam Steering System

The orthogonal coordinate, designated the 'meridian distance' (MD) direction, had no direct counterpart in the Cross since the latter was a meridian transit instrument. The beam steering system is complex because it involves a number of different sub-systems, but is worth outlining here because aspects of the telescope performance (such as the grating ring amplitude) depend on the details of operation.

Fig. 3 shows an outline of the components which make up one of the 88 'bays', each of 17·7 m length. The fundamental component is the circularly polarised resonant ring antenna element (Mills and Little 1972) which can be phased simply by mechanical rotation. A shaft driven by a stepper motor under computer control provides rotation for the 88 ring elements in each bay. A variable phase gradient can be set up across the bay because the number of teeth on the driving gears increments by one from one ring element to the next. The shaft is rotated at a rate which maintains the phase gradient appropriate for tracking the field centre.

The ring elements feed the RF signal into resonant waveguides, each 4·42 m long. In the present system signals from adjacent pairs of waveguides are added directly, forming a group of 44 elements in an 8·84 m 'module', and are then passed to a GaAs FET preamplifier. After an 11 m cable run to a mixer/IF amplifier unit ('long box') situated behind the mesh, the signals undergo further 843 MHz preamplification, then are passed through an 'anti-grating' phase shifter unit, before signals from the pair of modules in a bay are summed at the mixer. A switchable 23·9 dB attenuator for solar observations precedes the IF amplifier. The local oscillator is distributed by a trough line along the arms at 416 MHz, and doubled at the mixer/IF amplifier units, to produce the first IF of 11 MHz which is returned to the control room through equal length cables.

The overall signal processing path is illustrated in Fig. 4. In the control room the 44 'bay' IF signals from each arm undergo further frequency conversion and then are digitised and delayed in shift registers to provide coarse-step field centre tracking off the meridian plane. The signals are then reconstituted in analogue form, fine phase tracking for the desired field centre is applied, and the signals proceed to the real-time beam forming system: combining the 44 bays on each arm with appropriate phase shifts, 64 contiguous fan beams are formed from each arm. They are spaced at half beamwidth intervals, i.e. 22 arcsec at the meridian.

The beam spacing is halved to 11 arcsec by an interlacing process in which the beam set is moved backwards and forwards by half of one beam spacing at one or two second intervals. This results in 128 beams for later analysis. Despite the time-sharing of beams directed at any particular MD value, there is no loss of signal/noise because the sampling is at all times at the Nyquist limit. However, the process introduces extra 'sampling' noise which is filtered out before mapping; see Reynolds (1986) for further information. The beam-forming resistor matrix is similar in principle to that used for the multibeaming in declination of the north–south arm of the Cross (Large and Frater 1969). At this stage the beams represent the additive combination of all bays in one arm. The corresponding beams from the east and west arms are then multiplied together to form one of the MOST's 64 instantaneous interferometer fan beams. The synchronous demodulator units perform phase sensitive detection (with respect to the 400 Hz phase switching which is inserted via the local oscillator on one arm, to cancel out instrumental drifts).

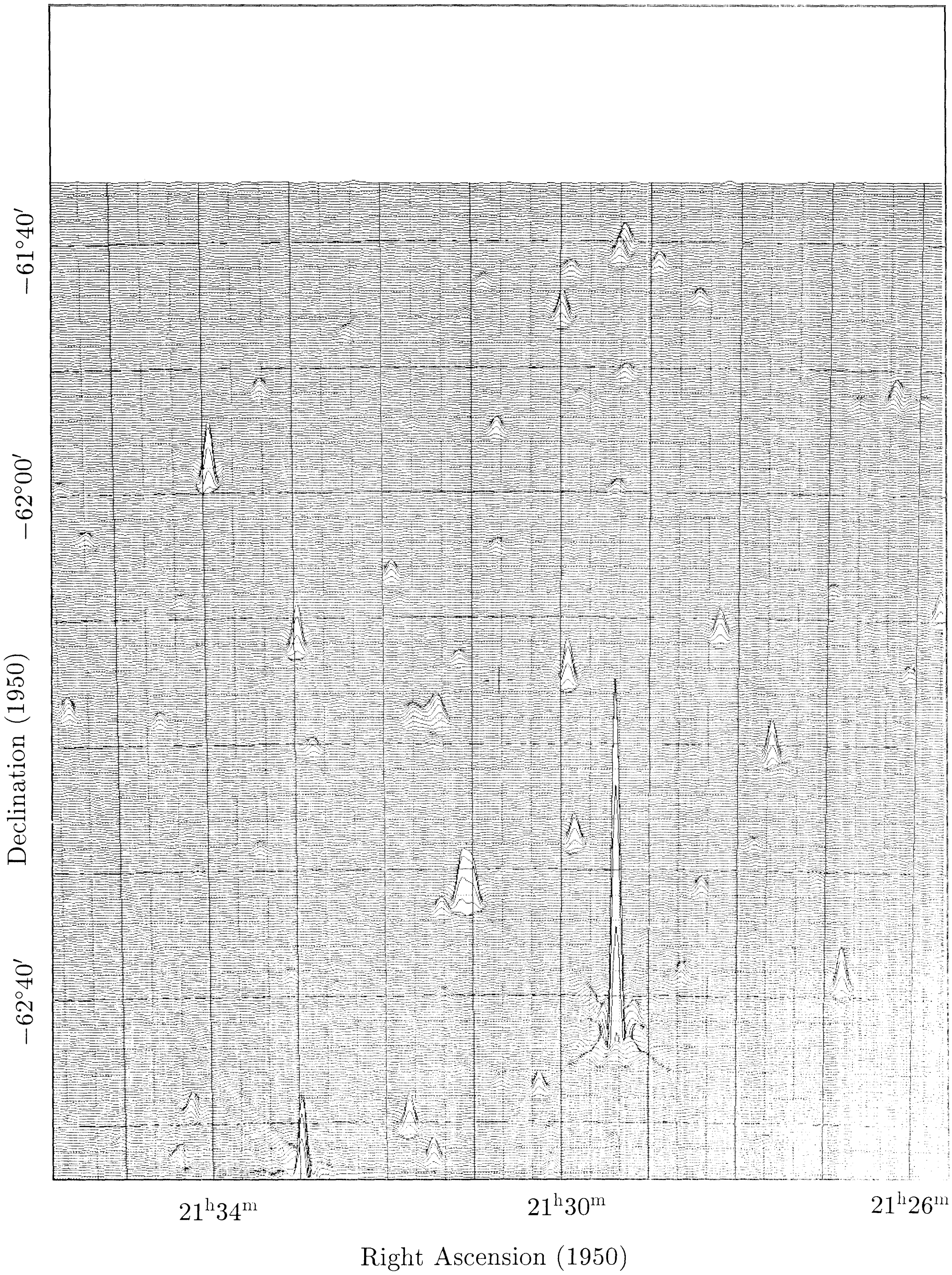

Fig. 5. Example of a 70′ map from the MOST. The field is centred on the cluster of galaxies Abell 3782. This is a ruled surface plot representation of the field, as available immediately at the end of the observation; no further processing has been carried out. The 'anti-grating phase shifters' were in operation for this observation, and as a result the image is usable to the edge of the map with minimal grating rings and little loss of sensitivity away from the field centre. The flux density of the strongest source is 810 mJy. The weakest sources that are obvious in this map have flux densities of 5 to 10 mJy.

(c) Synthesis Mapping at the MOST

The combination of tilt and meridian distance beam steering results in an 'alt–alt' system, which can follow a field for ±6 hours, without requiring excessive values of meridian distance, only if the field is south of declination $\sim -30°$. (A 12 hour observation is needed for complete synthesis with an east–west array, since it is the period over which the fan beams rotate on the sky to cover all position angles.) For fields near the $-30°$ limit the signal-to-noise ratio is considerably lower for the first and last hour or so due to the lower gain of the system produced by foreshortening at large meridian distance angles.

The fan beam responses are digitised and integrated in hardware for 2 seconds before being passed to the observatory's HP A700 computer where they are integrated into 24 second samples. The image ('map') of the field being observed is produced by a process known as 'fan-beam synthesis' or 'back-projection' rather than the usual Fourier Transform, because the data are presented in the form of instantaneous beam responses, not interferometer visibilities, and because a standard two-dimensional FFT is not applicable to data where the primary beam is non-circular and rotates on the sky during the observation. For a discussion of fan-beam synthesis, see Perley (1979) and Crawford (1984). For the MOST each beam response is added into a grid representing map pixels on the sky, along a line representing the particular fan beam (at the position angle depending on the hour angle of the sample). Weighting is applied to allow for the beam gains and the primary beam in the tilt direction. At the end of the synthesis, this method results in the completed map, and the 'raw' map can be plotted out within minutes. The beamshape is sufficiently good that for many purposes no further processing is required. The synthesised beam has a FWHM of $43'' \times 43''\operatorname{cosec}\delta$ (R.A.×Dec.).

The 64 beams (128 interlaced) span $23'$ (at the meridian) and result in a synthesis map covering $23' \times 23'\operatorname{cosec}\delta$ (R.A.×Dec.). To increase the area surveyed in one 12 hour period to $70' \times 70'\operatorname{cosec}\delta$, almost all observations make use of the multiplexing facility in which the beam set spends 1/3 of each 24 second sample directed towards the field centre and 1/3 at each of the two directions offset by 64 beam spacings in meridian distance. The thermal noise at any point in such a time shared $70'$ map is increased by $\sqrt{3}$ over that for a simple $23'$ map, but in fact most maps are limited partly by dynamic range effects as well as thermal noise, so the small loss in sensitivity is outweighed by the great gain in area surveyed, except for progams in which only a small area is of interest. Fig. 5 shows the raw image from a $70'$ field, as an example of what the MOST can produce in a single 12 hour observation.

(d) Grating Ring Suppression

Synthesis telescopes consisting of an east–west array of regularly spaced receiving elements produce images with the well-known artifact of elliptical grating rings surrounding each source. It is desirable for the grating ring radius to be as large as possible compared with the field of view, so that the rings do not occur within the mapped area at any significant amplitude.

Deconvolution methods such as CLEAN or Maximum Entropy can be used to remove residual rings, in regions of emission that are not too complex.

The multi-stage signal processing system for beam creation and steering in the meridian distance direction makes the MOST's grating response properties rather more complex than for an array such as the Australia Telescope. Each of the 7744 antenna elements is separated from its neighbours by $0\cdot54\,\lambda$ so it is possible to have a grating response at large meridian distance when the telescope is directed to extreme meridian distances (greater than $58\cdot4°$) on the other side of the meridian. In practice this response is only excited by the sun, and seldom occurs.

The more important grating rings occur in the synthesised maps at multiples of a separation (in right ascension) of $1\cdot15°$, and are due to the periodic structures at $17\cdot7$ m (bays) and $8\cdot84$ m (modules). The actual ring amplitude in the map depends on the distance from the field centre. For a beam directed at the field centre no such ring occurs (the amplitude is zero), because the phasing between antenna elements within a bay and the delays inserted between bays leave the $0\cdot54\,\lambda$ spacing between individual elements as the only departure from the ideal phase gradient. Away from the field centre, however, the grating responses rise because the differential phasing between elements within a bay remains at the value for the field centre, while the off-centre beams are formed by different gradients of phase/delay between bays along the arms. The result is a periodic phase error, increasing with distance from the field centre.

The $1\cdot15°$ rings were particularly strong in the outer parts of the time-shared 70′ maps; the time-sharing process is too rapid to allow driving the antenna elements (via their stepper motors) to point at the centre of the offset beam pattern postions. However, since the beginning of 1990, the amplitude of the $1\cdot15°$ ring in the outer parts of the 70′ maps has been reduced to a maximum of 12% of the former value (and considerably less over most of the field) by installation of the 'anti-grating phase shifters' (Amy and Large 1990, 1992; Large and Whiteoak, in preparation). When observing in one of the offset beam patterns, these remotely controlled varactor-loaded microstrip line units apply a 60° phase shift to one of the two module signals at each bay. This is the appropriate amount to correctly combine the two module signals at the centre beam *of the offset beam pattern.* The phase shifters must therefore change in synchronism with the multiplexing of the beam sets. The result is that grating rings are now minimal in amplitude even to the edge of the 70′ maps. This is a major improvement because in regions with many sources, such as the galactic plane and the Magellanic Clouds, the outer parts of 70′ maps made before 1990 were markedly affected by grating ring artifacts.

(e) Specifications of the MOST

The main specifications of the telescope are given in Table 1. The noise value given is larger than the thermal noise (which is $\sim 0\cdot2$ mJy for a 23′ image) because low level sidelobes from nearby strong sources are normally also important in setting the minimum reliable flux density (i.e. limiting the dynamic range). The precise effect varies from field to field depending on the sources present.

Table 1. Specifications of the MOST

Centre frequency	843 MHz
Bandwidth	3 MHz
Polarisation	Right Hand Circular (IEEE)
Declination range for full HA	$-30° > \delta > -90°$
Synthesised beam	$43'' \times 43''$cosecδ (R.A.xDec.)
Field size (unmultiplexed)	$23' \times 23'$cosecδ
Field size (multiplexed)	$70' \times 70'$cosecδ
Effective noise after 12 hour	$0 \cdot 5 \sim 1$ mJy/beam (1σ)
Surface brightness sensitivity	$0 \cdot 4 \sim 0 \cdot 9$ K (1σ)
Dynamic range (typical)	20 dB

(f) Additional Facilities

While 12 hour synthesis observations represent the chief observing mode of the MOST, there are a number of other facilities of importance:

- The method of 'cuts' involves taking short observations (say 4 or 6 minutes) of a field at each of about 6 to 10 well-spaced hour angles. Using this method about 10 fields can be observed in one night. For strong sources with relatively simple structures the results are quite satisfactory, although map sizes are presently limited to 23′. Additional information and examples are given by Hunstead (1991; present issue, p. 743). One problem is the additional wear imposed on the telescope by the greatly increased slewing activity.
- A procedure known as 'scan' is used to make single short observations of strong calibration sources. It extracts information about the amplitude, position offset and inter-arm phase error. About 4 to 6 such calibration scans are made before and after every 12 hour synthesis.
- A special mode is available to study the phase and amplitude of responses from each bay in turn, by observing a strong source and turning off all of one arm except the bay under test. Other special modes are used for tasks such as the calibration of beam gains.
- A transient event recorder (Amy *et al.* 1989) looks for impulsive events in whatever field the telescope is observing.
- A total-power mode is available for pulsar observations. This gains $\sqrt{2}$ in sensitivity over operation as a multiplying interferometer, while sacrificing stability which is not important for rapidly varying signals.
- The MOST is capable of participating in Mk II VLBI observations at 843 MHz. A successful run between Molonglo, Parkes and Hobart has already demonstrated the feasibility of such work, and further sessions are planned.

3. The MOST Compared with Other Telescopes

This section will attempt to place the MOST in perspective with other large radio telescopes, by comparing the major parameters which determine telescope performance. The discussion will concentrate on the Australia Telescope, because the AT is the new facility available to Australian astronomers, and is in the southern hemisphere. Being a new, high performance telescope, it also makes for a stringent comparison.

(a) The MOST and the Australia Telescope

The compact array of the AT (Norris 1988) consists of five antennas of diameter 22 m that are movable along a 3 km east–west track, or six antennas along a 6 km line (but the sixth antenna must remain near the far end of the east–west line). As an east–west array using earth rotation synthesis, it shares with the MOST the economy of maximum *uv* coverage for a minimum amount of telescope structure, but also the disadvantage of a synthesised beam having a declination width proportional to cosecδ, hence poor performance for fields near the celestial equator. For the AT this was a deliberate choice, given that the Very Large Array (VLA) in New Mexico is usable to about $\delta = -40°$, and that Australia could not afford an array with a similar number of antennas (27 for the VLA). For the MOST, the east–west array configuration arises from the layout of the former Cross, given the financial and practical impossibility of adding mechanical tilting to the old north–south arm.

Beyond this similarity, the MOST and AT differ greatly. The AT operates at higher frequencies than the MOST, and has been designed to be frequency agile. The AT has spectral line and polarisation capabilities, the ability to use continuum bandwidths up to 128 MHz, and can be configured to a number of different maximum baselines, many of which give angular resolution substantially exceeding the MOST's. In point source sensitivity, the MOST is a large and sensitive telescope, with thermal noise of 0·2 mJy. However, very low noise front ends are a feasible proposition for the AT, because only a small number are required, and as a result the AT has excellent point source sensitivity of about 0·02 mJy (1σ at 1·4 GHz, 12 hour observation). As well as the lower system temperature (27 versus 110 K), the AT benefits from a wider bandwidth (128 versus 3 MHz). The figures are closer for the sensitivity to extended low-level structure: for the MOST thermal noise is $\sim 0{\cdot}1$ K, while typical 'rumble' is $\sim 0{\cdot}4$ K, compared with noise of $\sim 0{\cdot}35$ K for the AT at 1·4 GHz, 6 km array. However, the AT value corresponds to an angular resolution of $6''$ and could be substantially improved by observing with a shorter array. While the MOST's point source sensitivity is less than the AT's, it is nevertheless appropriate to the spatial resolution, in that the MOST is within a factor of a few of the confusion limit. (There are approximately 90 beam areas per source to a flux density limit of 2·5 mJy.)

The aspect in which the MOST excels is the rapid coverage of large areas of sky, including imaging of complex regions of emission. In one 12 hour observation the MOST observes 4900cosecδ square minutes of arc, compared with 950 for the AT (to half power of the primary beam) at 1·4 GHz in a 1×12 hour observation or 240 (equivalent, in each 12 hour period) for a 4×12 hour AT observation. In the one 12 hour period the MOST gathers data equivalent to complete *uv* coverage from 15 m to 1·6 km (with longer baselines effectively tapered down—see Durdin *et al.* 1984). Thus apart from the missing zero and short spacings, which cause the usual broad negative bowl around strong sources, the MOST fully samples the *uv* plane out to the maximum set by the telescope size in wavelengths. From this and its sensitivity, especially to extended emission, follows its ability to produce good images of very complex regions, used to advantage in projects such as the observation of the galactic plane, the Magellanic Clouds, and highly extended extragalactic sources. As a result of the well-sampled *uv* plane, the raw ('dirty') beam of the MOST has a remarkably good profile, and raw maps are sometimes all that is needed. It is common, however, to use CLEAN to eliminate the −8% first sidelobe of the beam.

Synthesis arrays using discrete antennas necessarily gather data from fewer simultaneous baselines than does the MOST. The AT (3 km array) observes 10 baselines at once, although the *uv* coverage can be extended by using bandwidth synthesis, and by subsequent observations with other antenna placements. The Westerbork Synthesis Radio Telescope (WSRT) observes 40 simultaneous baselines, and the VLA, with 27 antennas and all correlations performed, gets 351.

A number of differences between the MOST and other synthesis telescopes arise from the use of real-time beam forming at the MOST. The principal reason this is done is to avoid the need for a large correlator to handle all the interferometer pairs formed by the 44 bays on each arm, or alternatively to avoid a serious loss of sensitivity if only a fraction of the possible correlations were performed. Because the beams represent a one-dimensional Fourier transform of the instantaneous raw data, the use of fan-beam synthesis rather than two-dimensional Fourier mapping follows. The real-time beams preserve the full bandwidth of 3 MHz, and so are well suited to short time constant studies, such as the transient event recorder and pulsar observations. Another advantage of fan-beam synthesis as opposed to a two-dimensional FFT is that the aliasing of features outside the mapped area back into the map is avoided.

(b) Particular Strengths of the MOST

The ability of the MOST to survey large areas in a relatively short time depends on its large primary beam. The primary beam width in tilt is approximately 2·3°, but with some dependence on the meridian distance (Reynolds 1986). In the MD direction the concept of primary beam should be replaced by the total span in MD of the beams that are formed (allowing for multiplexing as described above) as well as a value for the relative gain of the extreme beams compared with that at the field centre. Since the signal is gathered by a line feed, the amount by which the gain drops at the edge beams of the field depends on the length of the smallest unit of the arm for which independent phase/delays are used in forming each beam. This is presently equal to 8·84 m (one module) and results in a gain which falls to 0·75 of its peak value at the extreme beams of a 70′ field. Before the installation of the anti-grating phase shifters the smallest unit for beam forming was the bay (17·7 m) and the edge beam relative gain was 0·39. Maintenance of a good beam gain goes hand-in-hand with suppression of grating rings, since both depend on minimising departures from the ideal phase gradient along the arm for the particular beam. The present system does not exhaust the possibilities for widening the field of view of the MOST—some plans for future enlargement are discussed below.

Because the MOST obtains data at all interferometer baselines from 15 m to 1·6 km simultaneously, it produces an acceptable instantaneous response, namely a fan beam with low sidelobes after the first −48% lobe. (The negative lobe is a consequence of the missing zero spacing, ensuring that, in common with all multiplying interferometers, the signal integrated over all sky is zero.) Combined with the real-time beam forming and high time resolution, the consequent ability to form instantaneous strip scans makes the MOST probably the next most powerful instrument after the VLA for studying rapidly varying emission from complex regions. (A full 12 hour synthesis is not applicable where sources within the field vary within this period.) Since the installation of special switchable attenuators in February 1988, this capability of the telescope has been exploited by its use for a program of solar observations. One-dimensional strip scans have been formed with time resolution down to 1 second.

(c) Problems of the MOST

In recent years aperture synthesis images of extraordinarily high dynamic range have been produced using telescopes such as the VLA and the WSRT. The breakthrough in raising the dynamic range was the introduction of self-calibration, in which gain and phase errors of the individual antennas are corrected using the signal of the observed field itself. Although the MOST's dynamic range (typically 100 : 1 or better) is quite respectable compared with other telescopes, the unique construction of the MOST means that special methods of self-calibration are required for it. These are not yet in regular use. The immediate problem is that whereas a telescope such as the AT has only a small number of unknown instrumental gain and phase errors to be determined and corrected (one complex gain per antenna), the MOST has a multi-component distributed receiving system, and hence a low signal-to-noise ratio 'per unknown'. However, this signal/noise can be greatly improved if gain and phase errors vary sufficiently slowly either in space along each arm, or in time at one place, or both. An additional complication is that due to the redundancy of measured baselines, it is not possible to Fourier transform the multi-beam data to identify gain and phase errors of individual parts of the telescope. (However, the redundancy is helpful in producing tolerance to failures of isolated bays or modules.) Self-calibration has been developed and successfully applied to simulated observations and real data, using the parametrisation of telescope errors into gain, inter-arm phase and position offset, all as a function of time (Gray 1991). Investigations of methods of self-calibration are continuing.

Another aspect in which the MOST is unique is the variation of the system gain as a function of beam swing away from the meridian. Secondary scattering of radiation from the feed line enclosure results in multiple beam interference, producing a pronounced modulation of the gain as a function of meridian distance. The gain curve is quite stable and is allowed for on a routine basis in making maps.

4. Conclusions

It should be clear from the above that the MOST is very much a complementary instrument to the AT. The MOST is able to observe large and complex fields to a low flux density limit in just a single 12 hour period, but at a fixed frequency and with modest angular resolution. Such observations provide the surveys which can form the basis of later more specialised observations with the AT, or can replace AT observations for very extended sources which are not efficiently observed there. The MOST also provides flux densities at a lower frequency than currently available at the AT, and has proven a very valuable instrument for the regular monitoring of evolving sources such as Supernova 1987A and Nova Muscae 1991.

While the MOST is presently able to survey large areas quickly, it is not possible to make a survey of the entire southern sky in a reasonable time using the 70′ maps. Future plans for the MOST include making such a survey, by either or both of two methods. The first uses a drift scan 'sweep' mode in which data equivalent to 'cuts' observations could be obtained rapidly (but to a higher flux density limit than for normal 12 hour synthesis images). The second method would increase the field size for full synthesis to around 115′ by extending the principle of the anti-grating phase shifter to the 4·4 m waveguides which are paired to make up each module (and introducing 352 new preamplifiers).

A further instrumental enhancement now under development is a method of detecting sources that vary during a 12 hour observation, and that will be much more sensitive than the transient event recorder. The proposal is to make a map of the *variance* of emission at each point in the field, sensitive to variations on time scales of about 1 to 500 ms. It is not necessary for such sources to be periodic for them to be detected.

Acknowledgments

It is appropriate to acknowledge the vital roles of Bernard Mills and Alec Little in the success of the MOST. The telescope is scheduled to observe nearly every night of the year; the fact that it produces successful observations on 90 to 95% of those nights is due in large part to the diligence of the Observatory staff in maintaining the equipment. Operation and development of the MOST is supported by the Australian Research Council, the University of Sydney Research Grants Committee, and the Science Foundation for Physics within the University of Sydney. I thank all members of the staff of the Astrophysics Department for helpful comments. Fig. 4 is based on an earlier diagram by John Durdin.

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