Some Simple Mosaicing Calculations for the AT

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This memo does some simple calculations of three mosaicing schemes, to determine their applicability for the AT. Additionally it is of interest whether the schemes place constraints on the new ACCs.

The Schemes

Three different mosaicing schemes are considered, each of which would be described as a 'time sharing' approach to mosaicing. That is, each scheme changes its pointing centre typically several times per minute, though the pointing centres will be separated by of order 10 arcminutes. To get a good sampling, we assume that we sample at spacings separated by no more than half the primary beam FWHM. This moderately heavy sampling allows us not to need to rely significantly on data at or beyond the half power points.

The primary concern here is the relative efficiency of the schemes at scanning the region of interest, in terms of the area of sky covered in unit time, and the fraction of that time spent integrating. It is assumed that sensitivity is not an issue, and that short integration times are adequate to built up reasonable signal-to-noise ratios. Clearly this will often not be the case, and there must be some trade-off between the number of fields scanned and the noise level on individual fields.

The three schemes are:

- 'Conventional scan': This is the normal scanning approach, where the antenna pointing centre and the phase centre are moved to a new point in the sky, allowed to settle, and an integration taken. The pointing/phase centre changes every integration time. The pointing centres would be separated by half the primary beam FWHM.
- 'Fast scan': Here the antenna pointing centre is changed continuously, at nearly the fastest slew rate. The phase centre is either no changed at all, or changed only before each integration time. Scanning while you integrate means the effective primary beam shape will be the true primary beam smeared along the scanning path. The data reduction step would have to deal with this peculiar primary beam shape. One possible scan pattern would be a raster scan, with each raster representing an integration and phase centre change. This would produce several sausage shaped primary beams. Rasters would be spaced by half the primary beam FWHM. Another scan pattern is a spiral, where a primary beam close to a uniform disk may be achievable.

  This scheme is the most novel of the three schemes, and may place the hardest constraints on the antenna drives. The fast slew rate must be both accurately measurable and repeatable. As with all three schemes, the same scans (on the sky) should be used throughout the observation (to make data reduction manageable). As the source rotates relative to the antennas during the observation, the slew rate 'repeatability' requires the azimuth drive to 'repeat' what had been done, at a different time of the observation, by the elevation drive.
- 'Slow scan': Here the antenna pointing centre is again changed continuously, but at a slow slew rate. The slew rate and integration time would be chosen so that there was not appreciable smearing of the primary beam in one integration time. The data reduction step would not need to concern itself with the peculiar primary beam patterns.

Model Assumptions

The integration time is t_{int}, which is set at the shortest time the AT can manage, 5 sec. The primary beam FWHM is assumed to go as $\theta_{PB} = D/d\nu$, where d is the antenna diameter (22 m for the AT), and D is taken as 1100 arcmin GHz m. The time taken to slew a distance θ is assumed to be $S\theta + t_s$, where S is the slew rate, and t_s is the 'settling time'. The settling time accounts for the time needed to accelerate and decelerate to/from the full slew rate, and for any damping time needed.

For the 'conventional scan', one settling time is assumed to be required before each integration.

For the 'fast scan' scheme, we assume a spiral scan pattern, and that only one settling time is required before the start of a new scan. The actual number of settling times, and constraints placed on it by the integration time, will depend on the scanning pattern used. For example, with a raster scan, a settling time will probably be needed at the end of each raster, and a raster must represent one integration period.

For the 'slow scan' scheme, we assume no settling times are required, because the slew rate is relatively slow. We do assume, however, that only a fraction, ϵ, of the primary beam FWHM, is crossed in a given integration time. ϵ is thus the beam smearing tolerance of the slow scheme.

We are interested in the number of fields, etc, that can be measured in time T_t. We assume that T_t is the time taken for the longest baseline to traverse a uv cell (a uv cell is the resolution that we can measure in the uv plane, and is given by the size of the transform of the primary beam pattern). The traversing time is given by:

$$\frac{cT_{earth}}{2\pi D}\frac{d}{L}$$

where c is the speed of light, T_{earth} is the rotation period of the earth, and L is the longest spacing. This gives the traversing time as 47 seconds for the 6km array, and 95 seconds for the 3km array.

Choosing the total scan time as the traversing time is somewhat arbitrary. Though longer time intervals would lead to the uv tracks being undersampled in the tangential direction, this would probably not degrade image quality substantially.

Results and Conclusions

Tables 1 and 2 give, for the 6 km array, the area of sky and the number of fields (that is the area of sky divided by $\frac{1}{4}\theta_{PB}^2$) observed in a traversing time (T_t = 47 sec), as well as the percentage of time spent integrating. These are given for the three scan schemes, and at several frequencies. Table 1 uses the optimistic or typical values of $S = 20$ arcmin/sec, $t_s = 0.5$ sec, $t_{int} = 5$ sec, and $\epsilon = 0.05$ (the beam smearing tolerance of the slow scheme). Table 2 uses the more pessimistic values of $t_s = 2$ sec and $S = 10$ arcmin/sec. Table 3 gives the equations used.

These results make clear that the 'slow' scheme is very 'slow', and not competitive. The 'fast' scheme appears overwhelming superior (basically because it is scanning while the conventional scheme is sitting still integrating). The area scanned by the fast scheme depends virtually on the slew rate alone – settling time makes only a small contribution. It must be recognised, however, that the fast scheme is quite speculative. It is not clear if the on-line system or the antenna drives are capable of implementing such a scheme. The effects of errors in the scanning process, and the poorly known nature of the beam must also be investigated in the mapping step.

If the conventional scheme were used, the time expended on a series of scans consists of three parts – slewing, settling and integrating. At 1 GHz, the slew time can be an appreciable component (about 20 – 25% in Tables 1 and 2). However the slew time falls off inversely with frequency, and so it contribution is fairly negligible at higher frequencies. For $t_s = 0.5$ sec, settling time accounts for about 10% of the total time, whereas for $t_s = 2$ sec, it accounts for about 30% of the total time. Clearly it is desirable to keep t_s small compared to t_{int}. Although we have assumed that t_s is independent of frequency, this is probably not the case. It is likely that a longer settling time will be required at higher frequencies, to correct the small residual pointing errors, that could have been tolerated at lower frequencies.

Frequency GHz	Conventional Area arcmin^2	Conventional Fields	Conventional % Time	Fast Area arcmin^2	Fast Fields	Fast % Time	Slow Area arcmin^2	Slow Fields	Slow % Time
1	4352	7.0	74	23250	37.2	99	587	0.95	100
3	552	7.9	85	7750	111.6	99	65	0.95	100
10	52	8.4	89	2325	372.0	99	6	0.95	100
30	5.9	8.5	90	775	1116	99	0.7	0.95	100

Table 1: Parameters for $t_s = 0.5$ sec, $S = 20$ arcmin/sec

Frequency GHz	Conventional Area arcmin^2	Conventional Fields	Conventional % Time	Fast Area arcmin^2	Fast Fields	Fast % Time	Slow Area arcmin^2	Slow Fields	Slow % Time
1	3092	4.9	53	11250	18.0	96	587	0.95	100
3	417	6.0	64	3750	54.0	96	65	0.95	100
10	41	6.5	69	1125	180.0	96	6	0.95	100
30	4.6	6.6	71	375	540.0	96	0.7	0.95	100

Table 2: Parameters for $t_s = 2$ sec, $S = 10$ arcmin/sec

	Area Scanned	Integration Time
Conventional scan	$\frac{1}{4}(\frac{D}{d\nu})^2\frac{T_t}{t_s + t_{int} + D/(2d\nu S)}$	$\frac{T_t}{t_s + t_{int} + D/(2d\nu S)}t_{int}$
Fast scan	$\frac{1}{2}(\frac{D}{d\nu})S(T_t - t_s)$	$T_t - t_s$
Slow scan	$\frac{1}{2}(\frac{D}{d\nu})^2(\frac{\epsilon T_t}{t_{int}})$	T_t

Table 3: Equations Used in the Calculations