Bima memo 60 - Aug 1997

DYNAMIC SCHEDULING: Implementation at Hat Creek

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ABSTRACT

We plan to use the atmospheric path RMS as a parameter for a dynamic scheduling program at Hat Creek. The RMS path can be measured by a satellite phase monitor or we can use a short observation of a quasar to measure the atmospheric phase RMS every few hours. A power law fit to the quasar observation is used to estimate the RMS path on the longest baseline. The scheduling program can be script driven, providing a convenient way to accommodate the specific observing environment at Hat Creek. We have extended the LST time format used in observing scripts at Hat Creek to allow dynamic scheduling over multiple days.

1. Introduction

The scheduling program, **tac**, sorts a prioritized list into an observing schedule. We plan to use a measurement of the atmospheric phase RMS as a parameter for the dynamic scheduling program at Hat Creek (BIMA memo 58). Satellite phase monitors provide a frequent measurement of atmospheric phase noise, independent of the array configuration and observing program. We propose to build a satellite phase monitor for use at Hat Creek. Until this is available, we can use a short observation of a quasar to measure the atmospheric phase RMS every few hours. The atmospheric phase RMS increases with baseline length, following a power law with index, $\beta/2$, between 0.3 at long baselines and 0.8 at short baselines, consistent with the Kolmogorov-Taylor theory. (e.g. Armstrong and Sramek, 1982; Wright, 1996). Recent improvements in the system noise at Hat Creek suggest that a 5 min observation of a strong quasar at 90 GHz (or 28 GHz) will provide a reliable estimate of the atmospheric phase RMS which can be used for dynamic scheduling. Note that a 5 min observation does not sample the full atmospheric turbulence spectrum, but is appropriate for interferometer observations where the calibration suppresses fluctuations on longer time scales. The scheduling program can be used on-line at the telescope, or off-line as a planning tool. This memo describes a specific implementation of the dynamic scheduling program at Hat Creek, the interface to the observers' scheduling environment, and the measurement of the RMS phase.

2. Observations

We used observations of 3C273 from 31mar96 at 86 GHz with 'good', winter seeing and from 10aug97 at 28 GHz with 'poor', summer seeing. Both datasets contained baselines from 10 to 100 m. We fitted linear, quadratic, and power law functions to the RMS phase. We tried fitting versus the projected baseline length, and versus the topographic baseline length. The choice of baseline variable depends on the atmospheric model. For a thin layer of turbulence, the paths to the antennas are separated by the topographic baseline length, but for a thick layer the separation is the projected baseline. The data are plotted in Figures 1 and 2 for both baseline variables. The increase in the atmospheric path RMS with baseline is quite clear. A power law gives a better fit to the data than a linear or quadratic function. The fits are tabulated in Table 1. The RMS path is fitted at a 100m baseline, which is usually sampled in all the Hat Creek array configurations, and is useful for comparison with satellite phase monitors in use on 100m baselines (OVRO, CSO-JCMT). Extrapolation outside the sampled baselines depends on the slope adopted. The smaller RMS fit using projected baselines suggests a turbulent layer thickness greater than the 100m baseline. The results are consistent with more extensive observations at Hat Creek and elsewhere (e.g. Armstrong and Sramek, 1982; Wright, 1996). We obtain a power law with index, $\beta/2$, around 0.7 for baselines up to 100m, consistent with three-dimensional Kolmogorov turbulence ($\beta/2 = 5/6$). On spatial scales larger than the thickness of the turbulent region, the turbulence is expected to become two-dimensional and the RMS path scales as $baseline^{1/3}$ (Tatarskii, 1961). Previous observations at Hat Creek showed a slow change in $\beta/2$ from 0.8 to 0.3 between 100 and 300m, with an elevation dependence, $sin(elevation)^{-0.7\pm0.2}$ (Wright, 1996). For 3-dimensional turbulence the rms phase should scale approximately as $sin(elevation)^{-0.5}$, for 2-dimensional turbulence, as $sin(elevation)^{-1}$. The elevation dependence cannot be fitted from a short observation, but enters when scaling the RMS to the zenith. We tabulated the RMS path for $sin(elevation)^{-0.5}$, and $sin(elevation)^{-1}$. The elevation dependence could be measured with a long quasar observation, or with multiple satellite monitors. If no measurement is made we should probably use $sin(elevation)^{-0.7}$, intermediate between 2D and 3D turbulence models.

3. Scheduling Program

The scheduling program, **tac** can be script driven. Using a script provides a convenient way of separating the generalities of the scheduling program from the specific implementation at Hat Creek (thanks to Jim Morgan, for this suggestion). We have written a **csh** master script to control dynamic scheduling at Hat Creek. The script first sets environment variables for observations at Hat Creek, and then loops through an observation of a strong quasar, the dynamic scheduler, and the scheduled project. The fitted atmospheric path RMS is written to a file, and used by the scheduling program to schedule the appropriate project. The scheduling interval, start and stop times for dynamic scheduling, and other parameters can be set by the current observer in charge of the array observations.

The file with the fitted atmospheric path RMS is kept as a record of the seeing, and can be used off-line in the dynamic scheduling program to re-play the schedule using different parameters, or to plan future schedules. It is convenient to save the atmospheric path RMS as files for each calendar year, with the data stored as **ascii** values for the year day and RMS path in millimeters. This format is independent of observing frequency, and allows the files to be easily edited, plotted, and used off-line for planning.

We tried running the script using the 1996 phase monitor data from OVRO with a 1 to 2 hour scheduling interval. Both intervals produced a sensible schedule with the highest priority projects being completed with contiguous blocks of time where the weather permitted. The atmospheric path RMS is checked at each scheduling interval. The current project is observed to completion if the weather does not change significantly. The current project is stopped if the weather is either not good enough for the current project, or has improved significantly so that a higher priority project can be scheduled. The scheduling program maintains a list of the current status of the observations for each project, the integration time and HA range acquired. This status can be written out as a record of the current status, and read in as a starting point for continuing observations, or predicting future schedules.

4. Interface to observers

The user prepares an observing script using the **project** commands to specify the observing frequency, correlator configurations and observations. The observing script may be stopped and re-started with dynamic scheduling, so extra attention must be given to observations which do, or do not, need to be repeated after a re-start. For example, when the same observe script is contiguously scheduled, then a quasar calibration need not be repeated. On the other hand, if an observing script is re-started after a break because of unsuitable weather, then some calibrations may need to be repeated. A parameter in the observing script, such as the maximum interval between calibrations, would be useful. The dynamic scheduling program keeps track of the weather and the LST range observed for each project, but the details of calibration observations needed after a re-start should be specified in the observing script. The scheduling program, **tac**, is only a time allocation program; it does not adjust the observations specified in the users' observing scripts. It remains the responsibility of the user to make best use of the time allocated.

At Hat Creek we use LST scheduling using an HHMM time format in the observing scripts. Some projects, such as planetary observations, need a specific UT range. Both the starting LST and UT are input to the scheduling program as real values to enable scheduling over multiple days. At Hat Creek, the tasks **utsymbol** and **lstsymbol** return the UT and LST in HHMM format for use in the observing scripts. To extend the schedule over multiple days we have provided a program **timecalc**, which facilitates time calculations within shell scripts and provides real value inputs to the scheduling program.

5. Conclusions

* A quasar observation gives a direct measurement of the RMS path over the baselines being used for the observations, but takes some observing time, and is not an *independent umpire*.

* A satellite phase monitor provides a continuous measurement of the RMS path on a fixed baseline, independent of the array observations, but requires an atmospheric model to scale the RMS path to the array baselines.

* Both quasar observation and satellite phase monitor require an atmospheric model to scale the RMS path to the elevation of the observations. If no measurement is made we should probably use $sin(elevation)^{-0.7}$, intermediate between 2D and 3D turbulence models.

* Files of the atmospheric path RMS are kept as a record of the seeing, and can be used off-line in the dynamic scheduling program to re-play the schedule using different parameters, or to plan future schedules.

* A master script provides a convenient way of separating the generalities of the scheduling program from the specific implementation at Hat Creek.

* The dynamic scheduling program keeps track of the weather and the LST range observed, but the details of calibrations needed should be specified in the observing script.

* The scheduling program, **tac**, is only a time allocation program; it does not adjust the observations specified in the users' observing scripts. It remains the responsibility of the user to make best use of the time allocated.

REFERENCES

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Table 1: RMS path [mm] and slope at 100m baseline

—	projected baseline				topological baseline			
Date frequency	RMS	$\beta/2$	elevation	RMS fit	RMS	$\beta/2$	elevation	RMS fit
31mar96 86 GHz	0.35	0.74	-0.5	0.07	0.25	0.75	-0.5	0.11
31mar96 86 GHz	0.19	0.74	-1	0.07	0.13	0.75	-1.	0.11
10aug97 28.5 GHz	0.87	0.69	-0.5	0.10	0.77	0.70	-0.5	0.12
10aug97 28.5 GHz	0.66	0.69	-1.	0.10	0.57	0.70	-1.	0.12

6. Figure captions

Figure 1. Atmospheric path RMS on 31mar96 measured at 86 GHz. The data are plotted versus the projected baseline length, and versus the topographic baseline length.

Figure 2. Atmospheric path RMS on 10aug97 measured at 28 GHz. The data are plotted versus the projected baseline length, and versus the topographic baseline length.

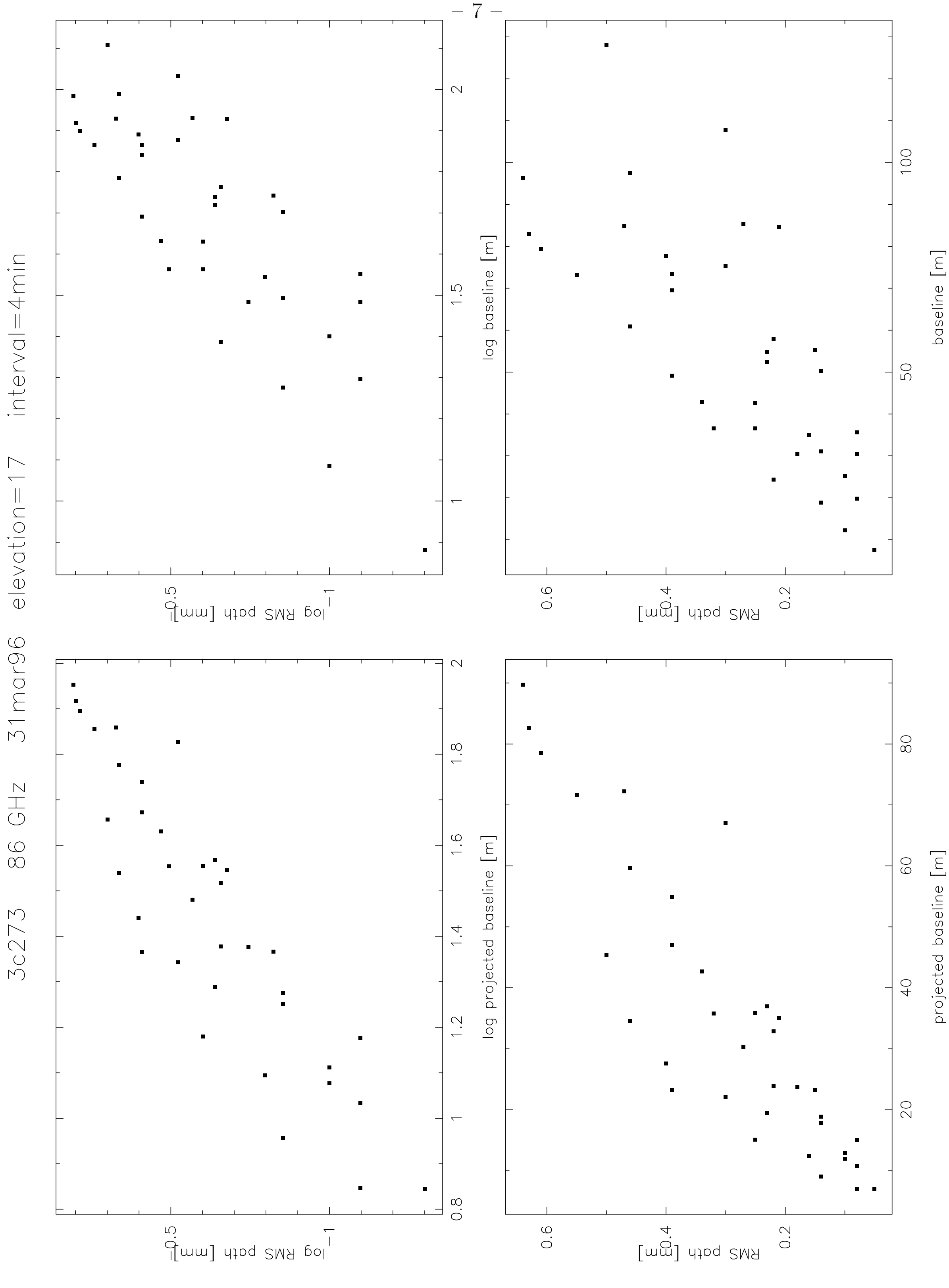

Fig. 1.— Atmospheric path RMS on 31mar96 measured at 86 GHz.

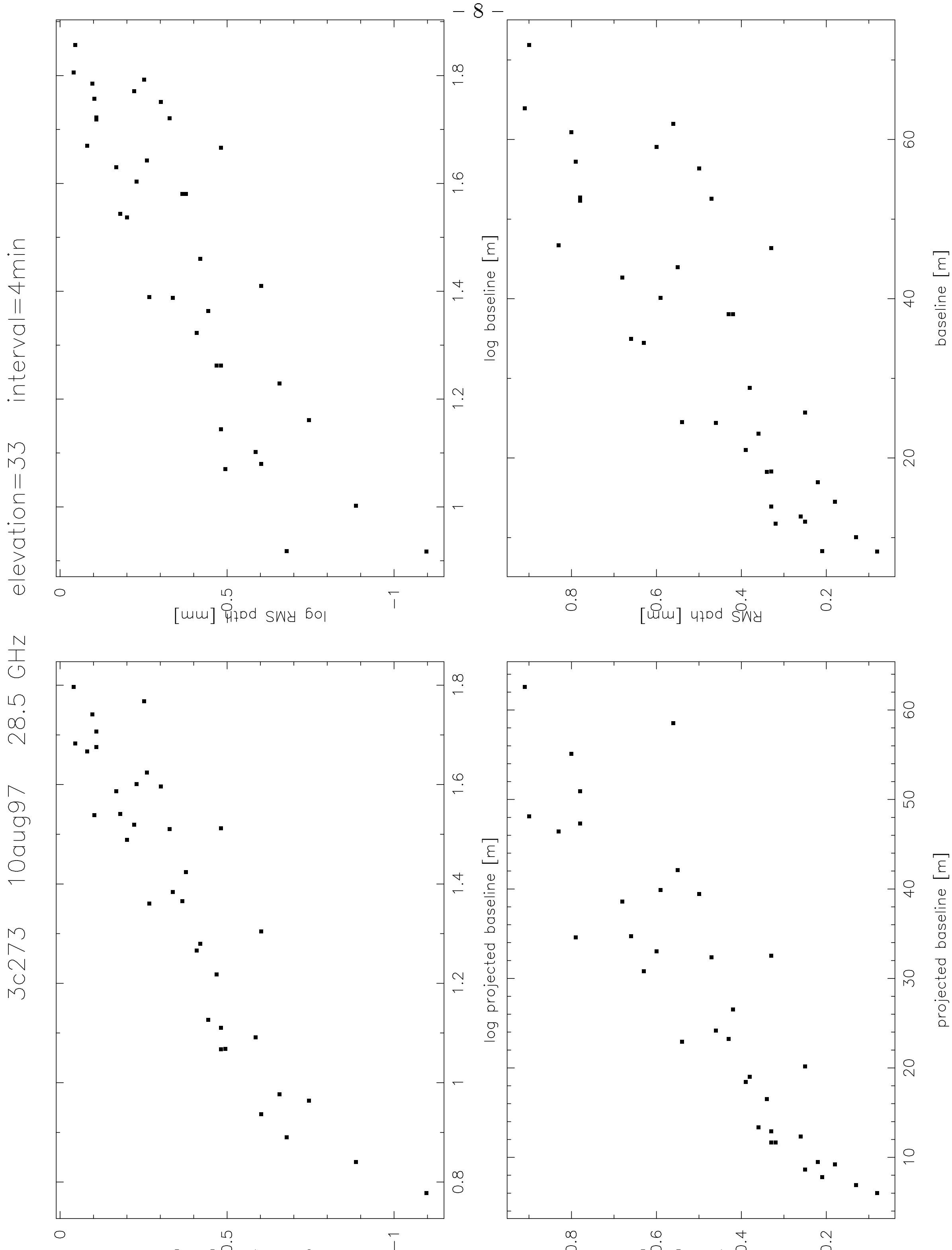

Fig. 2.— Atmospheric path RMS on 10aug97 measured at 28 GHz.