32T Test Plan – Drift Scans and Diurnal Variation (2c)

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Documentation Number: 46-03001.01
Latest Revision Letter: Rev 02
Latest Revision Date: 6 January 2010

1 Introduction

Drift scans are simple and effective diagnostics of overall antenna and receiver performance (Rogers et al. 2004). In a drift scan, the auto-correlated power of an antenna-receiver path is measured as a function of frequency and then compared to a prediction based on the antenna primary beam pattern, receiver properties, and a model of the sky noise. As the sky drifts over the course of 24 hours, the power at each frequency, measured as a function of time, should yield a characteristic curve resulting from structure in the Galactic emission, with a dominate peak when the Galactic center is overhead and a secondary peak when the opposing Galactic plane transits.

A good fit between the measured power and predicted power for a drift scan provides confirmation that the antenna primary (phased array) beam is known reasonably well on large scales. It is important to note that uncertainty in our knowledge of the radio sky at the frequencies measured by the MWA adds an element of ambiguity to this analysis, although the magnitude of this uncertainty can be reasonably estimated. Assuming a known antenna pattern and adequate sky noise model, a drift scan will yield a fairly direct estimate of the effective receiver temperature (referenced at the input of the antenna and in sky noise units). With knowledge of the ambient temperature as a function of time, the temperature dependence of the LNA gain can also be fit or constrained from a drift scan. Finally, measuring a drift scan over a period significantly longer than 24 hours (e.g. for multiple days) helps to confirm that the system is stable and well behaved since there should be little variation in the power profile from day to day (except for small, predictable changes due to the difference between sidereal and solar time).

This Plan describes the use of drift scans to characterize the MWA 32T system and is responsive to requirement #2c and #2d contained in the memo "MWA 32-T Objectives and Quality Assurance Evaluation Criteria", dated 4 September 2009 (46-03001.99).

2 References

1. Haslam, C. G. T., et al. 1982, *A&AS*
2. Rogers, A. E. E., et al. 2004, Radio Science, 39, 2023

3. Rogers, A. E. E. & Bowman, J. D. 2008, AJ, 136, 641
4. de Oliveira-Costa, A., et al. 2008 (arXiv:0802.1525)

Related memos at:
http://mwa-lfd.haystack.mit.edu/twiki/bin/view/Main/MWAtechnicalMemoSeries:

1. MWA LNA Stability, Eric Kratzenberg
2. edges-memo #030: Test of MWA LNAs, Alan E. E. Rogers
3. edges-memo #031: Measurements of MWA antenna impedance, Alan E. E. Rogers
4. edges-memo #032: MWA active antenna noise simulation,s Alan E. E. Rogers
5. Lincoln Laboratory Anechoic Chamber Test Report, C. L. Williams, J. D. Bowman, J. N. Hewitt, R. Jackson, M. F. Morales, M. S. Matejek, A. E. E. Rogers, E. H. Morgan
6. Analysis of Drift Scans from 32T-X1 and Characterization of System Temperature, Judd D. Bowman
7. Analysis of Drift Scans from 32T-X2, Judd D. Bowman
8. Analysis of Drift Scans from 32T-X2.5 and Characterization of Revised Dipole Designs, Judd D. Bowman
9. NEC tests of perturbations to MWA tiles, Alan E.E. Rogers, C. Williams
10. Comparison of NEC2, NEC4 and WIPL, Alan E.E. Rogers, C. Williams

3 Measurement Description

Drift scan measurements require the use of antennas, beamformers, receivers, and data acquisition system. In order to isolate the antenna-receiver path, the measurements described in this plan to do not use the prototype hardware correlator, but instead employ direct data capture to disk for later processing into auto-correlated spectra or to the software correlator (cite/refer) to produce auto-correlated spectra recorded in real-time. The usual infrastructure requirements for operating the 32T system (e.g. air conditioning, power generation, on-site personnel, etc.) are applicable to these measurements.

3.1 Receiver sample mode

Data will be recorded in burst mode (what is the integration duration?) to cover the full observable band simultaneously with 1.28 MHz spectral resolution.

3.2 Cadence

The spectrum will be sampled at a cadence of once every 15 minutes or faster. Because the MWA antenna tiles have unique beam patterns for each independent setting of the phased array delay lines, multiple pointings of the antennas will be sampled in a repetitive pattern, however the zenith pointing will be the primary focus of the measurements and the only pointing guaranteed of achieving the 15 minute cadence. [Can Chris provide the list of pointings and the specific cadence?]

3.3 Duration

The drift scan measurements will be conducted for a minimum of 72 consecutive hours (3 days) with a minimum of 4 antennas. Short gaps in the data may be present due to RFI excision or on-site activities such as refueling the generator.

3.4 Ambient Temperature

Ambient temperature measurements at one of the sampled antennas will be acquired during the 72 hour measurements using an external USB self-contained temperature data logger (either borrowed from Curtin/CSIRO, contact David Herne, or we can purchase our own at http://www.weathershop.com/USB1_temperature_logger.htm). The temperature logger will be placed in a small, thin-walled metal enclosure to prevent RFI contamination, and located next to an antenna for the duration of the drift scan measurements.

3.5 Analysis

The measurements will be analyzed using custom IDL and Matlab code. The antenna model will be generated from one of three methods:

1. Ideal dipole model, with ideal phased array combination
2. WIPL or NEC simulation of a single dipole, with ideal phased array combination
3. WIPL simulation of a full antenna tile

Method 1 is the default deliverable, but methods 2 and 3 will be pursued on a best effort basis.

The sky noise model will be derived from the Haslam et al. (1982) map extended to the appropriate frequencies using the spectral index of 2.52 found by Rogers & Bowman (2009). A second sky noise model based on Oliveira-Costa et al. (2008) will also be tested. Results from only one model will be delivered, however, with the model chosen based on the best match to the observations.

The drift scan measurements will be fit to a model of the following form (e.g. Rogers et al. 2004) to derive estimates of the effective receiver temperature:

$$P_v(t) = k_B \, v^{\frac{1}{2}} \, g_v^2 \left[T_{gal,v}(t) + s_v \, T_{sun,v}(t) + T_{rcv,v}\right]$$

where the frequency-dependent gain model can be expanded linearly to account for and/or constrain the temperature dependence of the gain according to:

$$g_v = g_{0,v} \, [1 + \delta(T_{amb})]$$

In this model, $T_{gal,v}(t)$ and $T_{sun,v}(t)$ are the results of convolving the primary antenna pattern with sky noise models for the Galaxy and the Sun, respectively. We are interested in solving for $g_{0,v}$, $T_{rcv,v}$, and $\delta(T_{amb})$, while treating s_v as a nuisance term to allow for uncertainty in the strength of the solar radiation.

4 Resources Required

4.1 Staffing

Operation during these tests, then, requires at least one person on site plus one remote test conductor. Analysis following the test will require two people for two weeks.

4.2 Hardware

To demonstrate the M&C capabilities we will not attempt to operate under all possible combinations of circumstance. The following are the minimum set of equipment required:

- 1 operational generator
- 1 operational air conditioner
- 4 fully operational tiles with beamformers (not DOC?, any other constraints for the tiles/beamformers?)
- 1 receiver connected to at least 4 tiles
- 1 data acquisition system
- 1 USB self-contained temperature data logger

4.3 Software

These measurements require the M&C scheduling system for 32T and the data capture software. The analysis requires custom IDL code that is partially implemented.

4.4 Execution Time and Constraints

No other users should plan on getting work done while this test is in process. It is estimated to take 72 hours to complete plus additional setup and shutdown time consistent with prior operations of the 32T system.

5 Success Criteria

Success is defined by the successful demonstration of characteristic sky noise structure in the measured drift scans, a reasonable estimate of the effective receiver noise temperature as a function of frequency, and consistent inter-day results.

Revision History

Rev Ltr	Date	Author	Description
01	2009-09-18	JDB	First copy received for filing
02	2009-12-30	RFG	Formatting