32T Test Plan – ORBCOMM Beam Maps (1)

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1 Introduction

Knowledge of MWA tile beams is necessary for the 32T array for use in the calibration of synthesis images and system temperature measurements. It is hoped that ORBCOMM beacons at 137 MHz can be used to measure the beams at this frequency to improve and validate current knowledge. This plan is responsive to requirement #1 contained in the memo "MWA 32-T Objectives and Quality Assurance Evaluation Criteria", dated 4 September 2009 (46-03001.99).

One of the complications described below, the amplitude-dependent quantization ripple in the measured beam patterns, has the potential to significantly complicate any analysis. The tasks outlined in this document were envisaged as straightforward beam measurements, and procedures to mitigate the ripple are beyond the scope of the exercise. Thus the tasks should only be pursed as far as warranted by the quality of the data. The first task should be an assessment of the ripple to decide which measurements are worthwhile.

ORBCOMM beacons are also expected to be useful for investigations of various primary beam parameterization schemes. These will not be a part of the 32T RTS and will not be considered part of this test plan.

2 References

1. http://mwa-lfd.haystack.mit.edu/twiki/bin/view/Main/X8OrbcommBeamMeasurements
2. [mwa-32t] X8 satellite beacon observations, Randall Wayth, *Fri Jul 24 09:34:35 EDT 2009* http://mwa-lfd.haystack.mit.edu/pipermail/32t/2009q3/001269.html
3. http://mwa-lfd.haystack.mit.edu/twiki/bin/view/Main/ReferenceDipole
4. http://mwa-lfd.haystack.mit.edu/twiki/pub/Main/32TileSystem/OrbcommSaturation.pdf
5. [mwa-32t] X8 observing plan - taking stock, Roger Cappallo, *Wed Jul 22 15:57:55 EDT 2009* http://mwa-lfd.haystack.mit.edu/pipermail/32t/2009q3/001254.html

3 Measurement Description

ORBCOMM satellites transmit between 137 MHz and 138 MHz, all visible satellites having a ~10 kHz beacon at a unique frequency. By slightly changing the SCTN frequency we can align coarse PFB channel 107 with the 1 MHz ORBCOMM band and collect data from all visible satellites. In a 24 hour period there are typically about 4 windows with durations of 2 – 4 hours in which many satellites are visible. With each satellite taking a little over 10 minutes to travel from horizon to horizon, we can hold the beamformer settings constant so that each window offers an excellent sampling of the beams, albeit over a small frequency range.

There are some difficulties associated with these observations:

- We have limited information about the transmitter beam shape, which needs to be removed from the measurements. To deal with this a simple dipole and receiver system was constructed at Curtin University [2 & 3] and has been used along side 32T while ORBCOMM data was collected during X8. For an overview of these data see [1].
- Dynamic range issues. Setting the attenuation too low results in saturation of the PFB channel precision [4], however quantization effects become important when the attenuation is high, and cause an amplitude-dependent ripple in the measured beam patterns [5]. This has the potential to significantly complicate any analysis. To get around this issue we may need to dynamically change the attenuator settings. This is possible but beyond the scope of these investigations. For now we will attempt to minimize and quantify the level of the quantization effects, while attempting to avoid saturation during the high elevation transits.
- Different satellites transmit at different power levels, which makes combining passes from multiple satellites into a single beam map more complicated. Some orbits flow against the grain of the majority, however, and can be used to calibrate transmitter gains. Simulated models will also be used.

A given satellite does not always have the same frequency, so associating a given spectral feature with a given satellite will be complicated to automate. At the moment each of the main passes is inspected by hand (~5 minutes per pass).

3.1 Ripple Assessment

The beam pattern quantization ripple will limit the accuracy and relevance of the following measurements, and the first task must be to investigate the size and prevalence of the ripple, and decide which measurements are worthwhile. For example, if the ripple amplitude is similar in size to beam deviations between tiles, then we cannot reasonably make conclusions and recommendations based on those data.

3.2 Beam smoothness and repeatability

At the end of the day having beams that vary slowly with time and angle, and which are similar from tile to tile, is the desired result. Even without removing the transmitter beams we can quantify these parameters. This can be done with data that has been collected (described in [1]).

3.3 Expected beams

Using the USRP reference dipole [2,3] we will attempt to remove the effect of the transmitter beams. This will enable comparisons with model tile and dipole beams. These could be simple analytic descriptions, or more rigorous models generated using E/M simulation packages. The latter will require assistance from one of the E/M simulation package users (Randall Wayth or Chris Williams or ???), and as such is subject to their availability.

3.4 Beam maps

If we can calibrate the transmitter gain of each satellite we can use multiple transits to constrain primary beam maps. The closer the measured power of individual transits is to the expected level, the better these maps will be.

4 Resources Required

4.1 Staffing

With the exception of the E/M simulations that may be required, the tasks above can be achieved by D. Mitchell to the levels described in section 5. Consultation with Randall Wayth and Chris Williams is required for the simulations. New data should not be required for these tests.

4.2 Hardware

If more data are required it may be advantageous to setup the reference dipole.

4.3 Software

D. Mitchell has a series of python scripts that can extract spectral features from a sequence of auto-correlation spectra and compare each time series with a model. These scripts are not user friendly and need some more work to better separate the spectral features.

4.4 Execution Time and Constraints

The analyses will take approximately one week of Mitchell's time. The available time is limited by RTS responsibilities.

5 Success Criteria

5.1 Ripple Assessment

Success in this task is defined as measuring the impact of the ripple and determining which of the following tasks are worthwhile.

Overall success is defined as accomplishing any worthwhile tasks for three different tile pointing: (azimuth, elevation) = $(0^{o},90^{o})$, $(45^{o},60^{o})$ and $(90^{o},60^{o})$.

5.2 Beam smoothness and repeatability

- Tile-tile comparisons of main-lobe and side-lobe measurements.
- Comparisons of main-lobe and side-lobe measurements for a single tile during multiple, similar satellite transits.
- Inspection of the data for angular discontinuities.

5.3 Expected beams

An estimate of deviations from the model beams in the main-lobe and large side-lobes.

5.4 Beam maps

Successfully generating high quality beam maps is not a requirement for 32T, but information gathered in the process that improves our beam models will be worked into the RTS.

Revision History

Rev Ltr	Date	Author	Description
02	2009-09-18	DM	First copy received for filing
03	2009-12-30	RFG	Formatting