32T Test Plan – Measure polarization of a known source (7)

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Introduction

The MWA plans to make wide field of view images with complete polarization information. The ability to detect and characterize polarization of a signal from the sky is essential to meet the MWA science goals. This plan responds to Ref #7 contained in the memo "MWA 32-T Objectives and Quality Assurance Evaluation Criteria", dated 04 September 2009 (46-03001.99).

Due to 1) the intrinsically low polarized flux of astronomical sources at low radio frequencies, 2) the limited sensitivity and the consequent limited ability to calibrate the 32T array, and 3) the complications arising out of time variable and direction dependent ionospheric Faraday rotation effects, it is not feasible to use a polarized astronomical source to investigate the ability of the 32T hardware to measure polarized signal. We suggest using a linearly polarized satellite beacon signal to investigate this.

The only linearly polarized satellite beacon of which we are aware is the Defense Meteorological Satellite Program (DMSP) F15 satellite. It transmits linearly polarized tone at 150.012 MHz. The satellite has a 1 watt transmitter and the bandwidth of the tone is < 1kHz. The monopole antenna is pointed in the ram direction of the satellite. More detailed information about the transmitter beam is not available. The DMSP satellites are highly stabilized platforms and are all in 101 minute, sun-synchronous, near polar orbits at an altitude of 830 km. The satellite orbit typically allows observation of one high elevation pass a day every few weeks.

References

N/A – to the best of my knowledge

Measurement Description

We will observe multiple passes of the DMSP F15 satellite at high elevations with multiple tiles. The data will be processed in the usual interferometric manner. The spectral channel width will be chosen to be wide enough to accommodate the doppler shift of the beacon signal but not much wider and time resolution of ~1 s will be used. Being narrow-band in nature, these observations can adequately be done with the 1.28 MHz bandwidth offered by the software correlator.

We will use both auto and cross correlations to compute the Stokes parameters for the incident radiation. We will estimate the expected ionospheric Faraday rotation using the International Geomagnetic Reference Field model (IGRF) to describe the Earth's magnetic field over Boolardy, and the International Reference Ionosphere (IRI) to model the ionospheric electron density profile, scaled to local GPS zenith TEC observations. The time variation of the ionospheric Faraday rotation will be estimated by computing the Faraday rotation along the ray paths through the ionosphere to the satellite as it moves across the sky and will be compared with the observations.

The existing useful DMSP observations come from X8 and the data quality still remains to be verified. We currently have data for 2 passes on 2 receivers (Rx 1 and 2), 3 passes on Rx4 and 4 passes on Rx3. This data can be only for inter receiver interferometry, though this will make the data analysis more tedious, it should not impose any significant limitation for our current purposes.

Some uncertainties will be associated with these measurements. These will include:

1. We have no definite information about the antenna beam and intrinsic polarization properties of the beacon radiation. In absence of more specific information, we will have little choice but to using an analytic model for a monopole radiation, without any assurance of how good an assumption that might be. This should however not affect any relative or differential measurements like comparisons of different tiles or baselines.
2. We intend to use the International Geomagnetic Reference Field model (IGRF) to describe the Earth's magnetic field over Boolardy and the International Reference Ionosphere to model the ionospheric electron density profile, scaled to local GPS zenith TEC observations, to estimate the ionospheric Faraday rotation of the beacon signal. Based on earlier studies, we expect the ionosphere below to the 850 km DMSP orbit to contribute about 85% of the total ionospheric RM. While this estimate should be representative of the ionospheric RM suffered by the signal, one can reasonably expect the models based on long term averages to depart from actual measurements.

Resources Required

Staffing

1. The following will contribute to the bulk of the analysis – Oberoi, Matthews, Benkevitch, all at Haystack. We expect to seek help from Erickson and Coster, both also at Haystack, with specific tasks. Help sought from others across the project as appropriate.
2. If it is determined that more data is required, the crew on-site for the next expedition will need to arrange to make these observations.
3. I believe the GPS TEC data for X8 has not yet been retrieved from the field. We either need to retrieve that data or choose to work with TEC measured by the nearest GPS location available on the web, which might be a reasonable option. Anthea is our local expert on this and can help in identifying an appropriate source of TEC information.
4. *We need someone to define what should be 'reasonable' polarization performance for MWA tiles and how much tile to tile variation should be expect based on manufacturing tolerances.*

Hardware

The intent is to obtain data from as large a fraction of the array as possible. Ideally one would have all 32 tiles, though a statistically large sample of tiles is all that is needed to convincingly show that the system can measure polarization of incident radiation.

Software

1. For interferometry style analysis, the software to generate the visibilities exists and has been tested and debugged.
2. Existing radio imaging packages like AIPS will provide the platform for analysis of the data.

3. The software for computing the TEC from the GPS observations is available from Anthea and we will need her help in computing the TEC values.
4. The models like IGRF and IRI are public domain but they will need to installed and integrated with the rest of the software.
5. The software needed for comparing the observations with expectations is yet to be designed or developed. The software for computing the expected FR as a function of direction for a given pass of the DMSP F15 will be a part of this, there might be other pieces as well.

Execution Time and Constraints

A few ~20-30 min slots of observing time. Though the observing time requirements are quite limited, the observing slots are fixed and sparse. High elevation passes occur for a few consecutive days every few weeks. So if more data is needed, one will need to plan well ahead in advance and ensure that we have the system setup to make the observations when the satellite passes by.

Success Criteria

Determining that the measured visibilities are consistent with

1. the ionospheric Faraday rotation signature expected due to changes in the ray path through the ionosphere as the satellite traverses its track
2. the expectations for cross-polar leakage as a function of az,el
3. hardware manufacturing tolerance

would constitute success. These measurements should be done with a statistically significant sample of the available tiles.

If we go by this success criterion, I need the following information

1. *Are there any known constraint on polarization performance of the hardware from any of the science objectives?*
2. *What are our expectations for cross-polar leakage?*
3. *What are our expectations for variation in polarization performance between tiles based on hardware manufacturing tolerances?*
4. *Do we have any EM simulations on polarization performance of our tiles?*

Revision History

Rev Ltr	Date	Author	Description
01	2009-09-12	DO	Test plan for measuring polarization of a known source
02	2010-01-04	RFG	Fromatting