Australian Government
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Space Surveillance with Passive Radar and the Murchison Widefield Array

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MWA MURCHISON WIDEFIELD ARRAY

Introduction

Passive Radar exploits readily-available, non-cooperative sources of radio frequency energy as illuminators of opportunity to measure reflections from the environment and objects of interest.

We have applied passive radar processing techniques to data from the Murchison Widefield Array to demonstrate the potential for passive radar for the surveillance of space.

The Murchison Widefield Array

The Murchison Widefield Array (MWA) is a precursor telescope for the Square-Kilometre Array project.

Figure 1 – Some receiver tiles near the centre of the array.

Key parameters of the MWA system include:

- 128 'tiles' with two polarisations (EW, NS)
- 16 elements per tile in a 4x4 configuration with analogue beamforming.
- Collection area of approx. 2,000 square metres
- Max baseline ~3 km: resolution of ~2 arcmin
- Frequency range of 80 - 300 MHz
- Instantaneous bandwidth of 30.72 MHz
- Located in the (radio-quiet) Murchison Radio-astronomy Observatory in Western Australia
- See http://www.mwatelescope.org, kaplan@uwm.edu

The MWA has previously been used in demonstrating detections of the International Space Station (Tingay et al. 2013, *Astronomical* Journal, 146, 103) and the moon (McKinley et al. 2013, *Astronomical Journal*, 145, 23) using reflected FM radio transmissions using imaging techniques (angle-only) that did not determine range or velocity. **In this work, we build upon these demonstrations to estimate all six dimensions of the state vector and to predict an object's orbit.**

Experiment

An MWA observation was conducted in April 2015 coincident with a pass of the International Space Station (ISS) as shown in Figure 2.

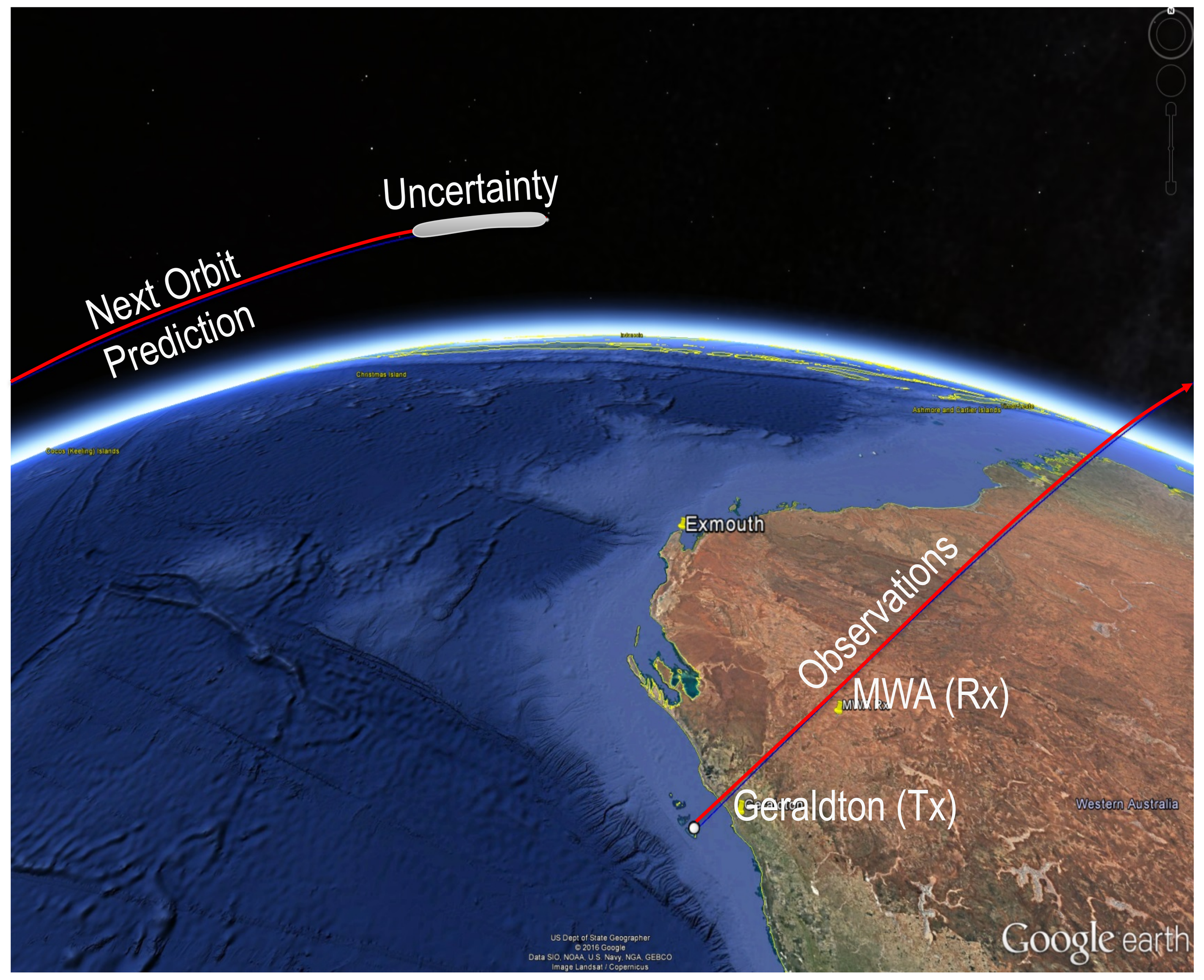

Figure 2– Visualization of the ISS overflight over Western Australia, along with predictions for the next orbit and uncertainty.

As well as collecting reflected signals from the ISS and other objects (e.g., Figure 5), transmitted reference signals were able to be extracted. These transmissions had been diffracted from Geraldton (300+ km away) and Perth (600+ km away).

We constructed time series image data using traditional beamforming (Figure 3). Sky visibilities are then calculated from the power in each direction's beam.

However with the direct transmitted signals delay-Doppler processing can be employed. Using this targets are found by searching for delayed and Doppler shifted copies of the direct signal in the surveillance signal; by comparing both time of arrival and frequency of arrival differences the target's bistatic-range and relative velocity can be calculated. This resulted in a large improvement in SNR over purely imaging (Figure 6).

Results

Using the radar detections of the ISS (Figure 4), Bayesian statistical methods were used for initial orbit determination, which capture the uncertainty in the estimated orbit (Figure 2).

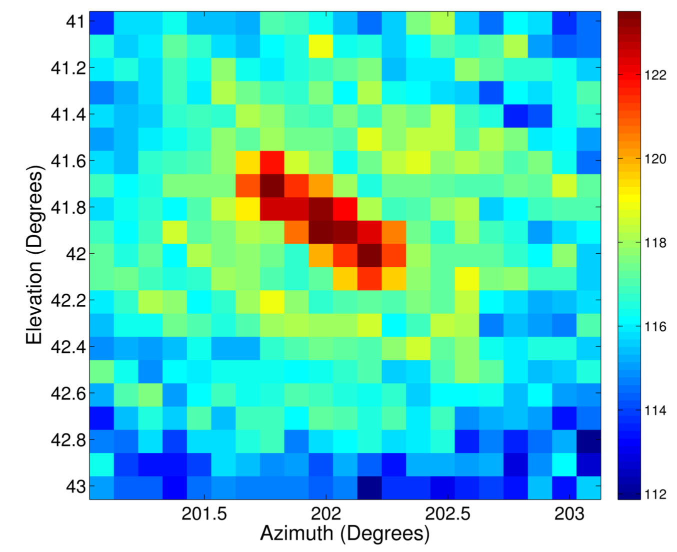

Figure 3 – One second of ISS passing across the sky.

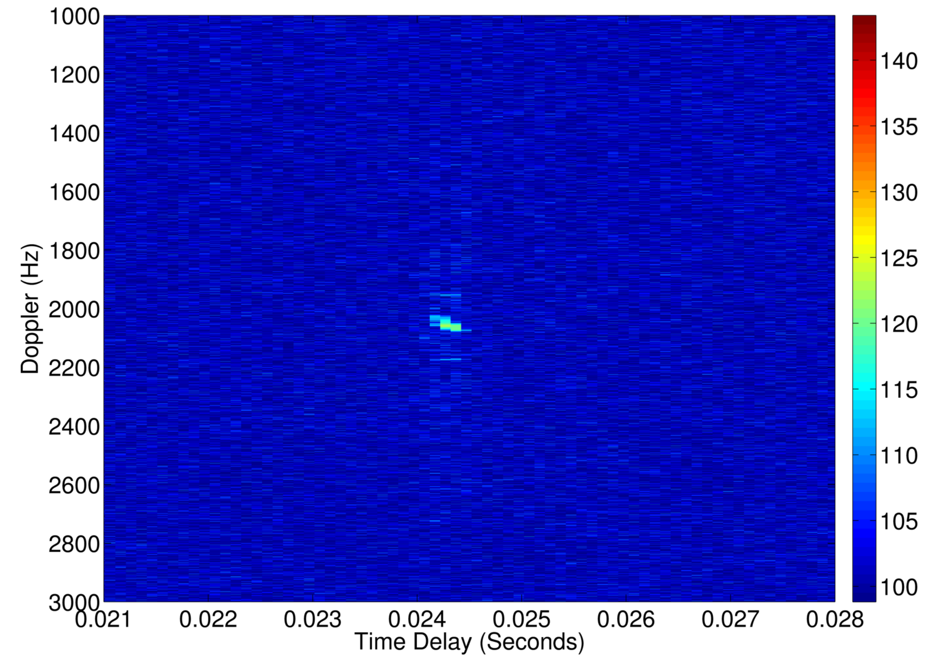

Figure 4 – delay-Doppler ISS detection using Geraldton Transmitter. 1 s CPI.

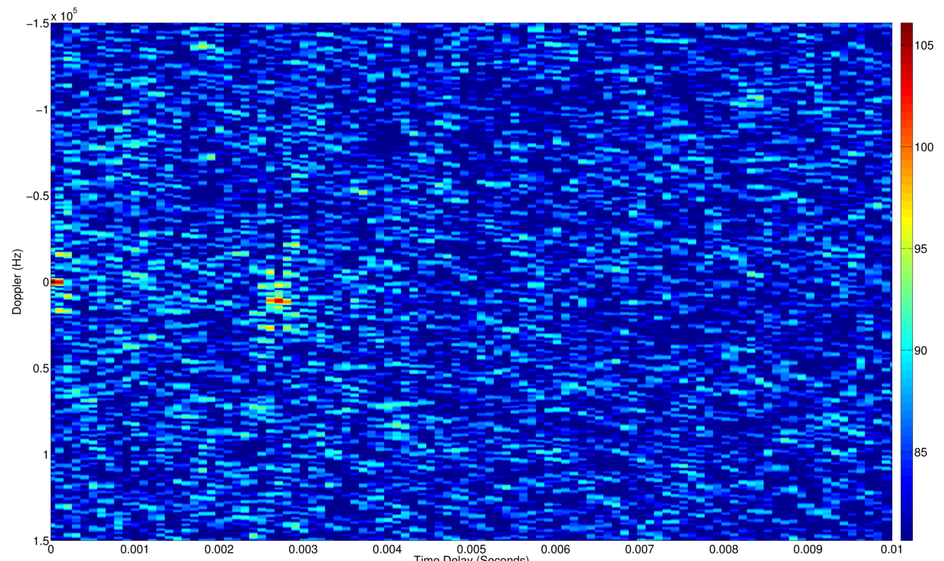

Figure 5 – delay-Doppler meteor detection using Geraldton Transmitter. 20 ms CPI.

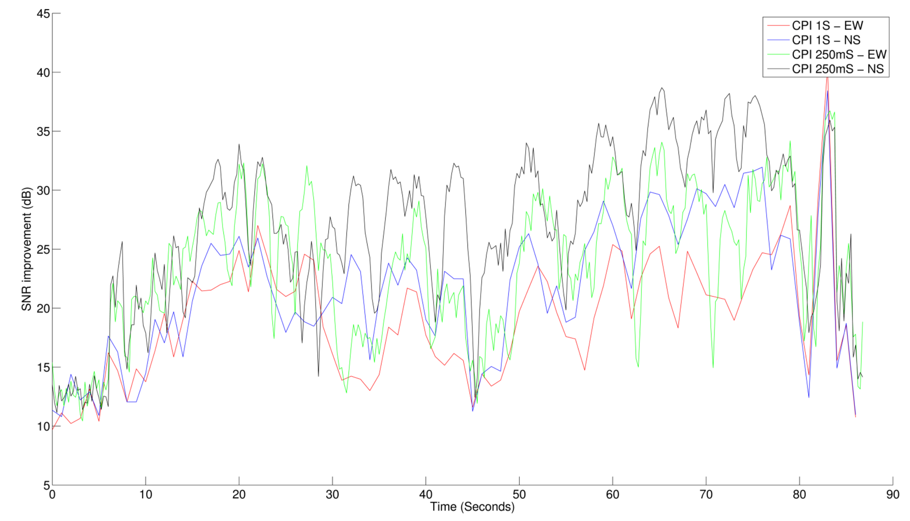

Figure 6 - SNR improvement achieved with delay-Doppler processing

Future Work

The results presented here are very preliminary and it is envisaged that significant performance improvements will be achieved through refinements in signal processing and experimental design. More trials are being planned that will collect high SNR FM transmissions from multiple spatially distributed transmitters simultaneously with the MWA collection.

Furthermore, VHF digital TV emissions will be recorded in a dedicated collection.

Conclusion

We built upon previous work using the Murchison Widefield Array to collect reflections of terrestrial broadcast signals from objects in orbit. The results presented here demonstrated the ability to accurately perform delay-Doppler processing in a full passive radar configuration. Delay-Doppler processing both provided the final two dimensions of the six dimensional state vector, and improved the detectability of the objects (through a SNR enhancement) over the previously employed angle-only approach. With the data collected in this experiment there would have been a very high probability of being able to reacquire the object using a narrow field-of-view secondary sensor on the next orbital pass.

Acknowledgement

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