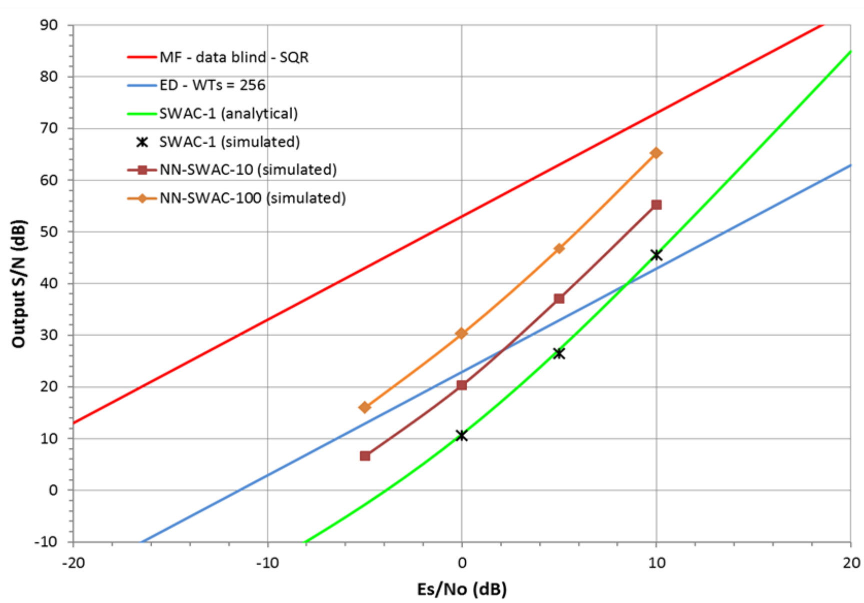
REAL-TIME WIDEBAND BLIND SIGNAL DETECTION FOR SETI. I. S. Morrison[1], [1]Centre for Astrophysics and Supercomputing, Swinburne University of Technology, John Street, Hawthorn, Victoria 3122 Australia, imorrison@swin.edu.au.

Overall Goal(s) and Objective(s): This white paper calls for the development and validation of an efficient GPU-based implementation of a new wideband SETI detection algorithm known as Symbol-wise Autocorrelation (SWAC). This algorithm is computationally demanding but offers improved sensitivity over other wideband detectors for a number of signal formats of relevance to interstellar communications and hence SETI. This is accomplished even while the algorithm is "blind" to the specific signal parameters – a necessary feature for the SETI application. The ultimate goal would be real-time execution of SWAC so it can routinely augment the narrowband detection capabilities in real-time SETI signal processing pipelines used in current and future radio telescopes.

Introduction: The current real-time signal processing pipelines used by the SETI Institute (ATA) and Breakthrough Listen (GBT and Parkes) are tailored to the detection of narrowband sources. Data-sets not containing such a source are discarded, despite the possibility they may contain other signal types to which the existing pipeline is insensitive. Although narrowband searches have been far from exhaustive, the lack of success to date across all SETI programs suggests there may be no "low hanging fruit" of strong narrowband sources, and it is time to extend detection capabilities to include wideband signal formats at low power spectral densities.

Method: One recently proposed algorithm that shows good promise is Symbol-Wise Autocorrelation (SWAC) [1] [2] [3]. For certain signal classes, SWAC can approach the detection sensitivity of matched filtering, while offering "blind" detection in the sense that precise knowledge of the signal carrier frequency and modulation parameters is not required. SWAC provides superior sensitivity to conventional autocorrelation with randomly modulated signals. It also strongly outperforms basic square-law energy detection, providing the added advantage of a built-in 'null reference' to aid detection (the absence of which is a key weakness of energy detection).

Implementations of SWAC have been developed in MATLAB for simulation purposes [2] [3], and also in Python for off-line cloud-based processing of stored data sets. Neither of these implementations has been computationally optimized. The SETI pipelines developed by the SETI Institute and Breakthrough Listen follow the recent trend towards GPU-based processors for radio astronomy back-ends, and this trend is expected to continue with any SETI pipelines implemented for the SKA and its pre-cursors (MWA, ASKAP, MeerKAT). To augment existing narrowband capabilities, it is proposed to implement a computationally efficient version of SWAC that can be readily integrated into existing GPU pipelines. It is further proposed that this extended pipeline be rigorously validated, first using test vectors generated by simulation



Evaluation of SWAC sensitivity through simulation shows that advanced variants can outperform energy detection (blue curve) and approach the performance of matched filtering (red curve).

software, then using Moon-reflected test signals (initially existing Earth leakage, then purpose-designed test transmissions [4].

The detection performance of the SWAC algorithm has already been proven through MATLAB simulations. The practicality of its use has been confirmed through off-line processing of observational data from the ATA, as part of the IBM/SETI Institute Spark@SETI project. However, in neither case was there any attempt to create code capable of making detections in real time.

Technology Requirements: Design of a "fast SWAC" algorithm began in 2015 and initial coding experiments in the CUDA language for NVIDIA GPUs have recently commenced at Swinburne University. The focus to date has been "basic SWAC", which is the simplest and lowest sensitivity version of the algorithm. There remains considerable work to implement the full algorithm and achieve robust real-time operation.

Even an efficient GPU implementation may demand a higher compute load than can be accommodated by existing processing hardware. In the short-term this may limit the search parameter space and/or maximum sensitivity. Any such limits should evaporate over time as GPU performance increases as per Moore's law.

Development of GPU CUDA code can be undertaken using existing hardware (several GPU-based servers are available within Swinburne University, for example). Once operational, the code would be made available for integration into existing and future GPU-based telescope back-ends.

Other Enabled Scientific Opportunities: The generic wideband signal detection capabilities of SWAC make it very effective for detecting and categorizing sources of broadband RFI – which could be of benefit to all radio telescope users.

Additional Information:

(A) This paper responds to Question 3 of the *Alien Mindscapes* article: How can we detect intelligent life?

(B) Big Data Analysis is not directly applicable to the implementation phase of the tool proposed, which can be developed and tested using relatively small datasets of simulated and observed telescope data. However, in its operational phase, the developed tool will generate new high-level data products that can serve as additional search inputs to Big Data Analysis tools.

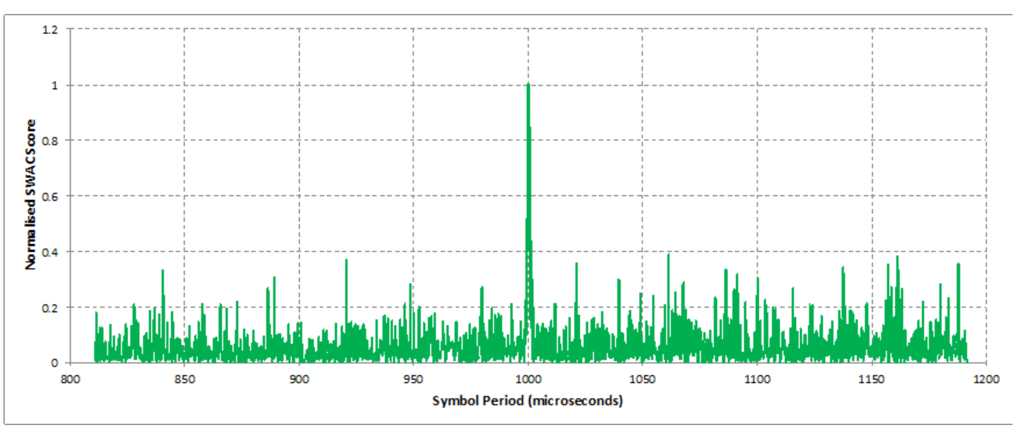
References:

[1] I.S. Morrison, "Detection of Antipodal Signalling and its Application to Wideband SETI", Acta Astronautica, vol. 78, 2012.

[2] I.S. Morrison, "Evaluation of Symbol-Wise Autocorrelation for the setiQuest Project", Final Report, SETI Institute, 2011.

[3] I.S. Morrison, "Constraining the discovery space for artificial interstellar signals", PhD dissertation, University of New South Wales, 2017 (available at http://www.unsworks.unsw.edu.au/primo_library/libweb/action/dlDisplay.do?vid=UNSWORKS&docId=unsworks_46149).

[4] R. Wayth & I.S. Morrison, "Using Moon-Reflected Terrestrial Radio Transmissions to Test SETI Algorithms", SETI Institute Workshop white paper, February 2017.



SWAC detection of the GPS downlink signal in ATA data centered on 1575 MHz (signal entering through antenna side-lobes).