USING MOON-REFLECTED TERRESTRIAL RADIO TRANSMISSIONS TO TEST SETI ALGORITHMS. Randall B. Wayth[1] and I. S. Morrison[2], [1]ICRAR-Curtin University, Bentley, Western Australia 6103 Australia, [2]Centre for Astrophysics and Supercomputing, Swinburne University of Technology, John Street, Hawthorn, Victoria 3122 Australia, r.wayth@curtin.edu.au.

Overall Goal(s) and Objective(s): This white paper proposes to use recently deployed low frequency radio telescopes – the Murchison Widefield Array (MWA) and Engineering Development Array (EDA) – in Western Australia's radio quiet Murchison Radio-astronomy Observatory to evaluate new SETI search algorithms in a previously unexplored low frequency range. The moon reflects terrestrial FM and digital TV and radio signals at a level that is ideal for evaluating hardware and new algorithms for SETI. Furthermore, the moon can be used as a passive reflector for signals deliberately beamed in its direction to produce custom-designed far-field test signals for SETI.

Introduction: Historically SETI searches have focused on narrowband signals in the 1-10 GHz frequency range. New low frequency radio telescopes with wideband flexible digital back-ends offer an opportunity to advance SETI in new dimensions of search space: in observing frequency and detection algorithms.

One of the challenges to introducing new signal detection algorithms in SETI is validating and optimizing the algorithms in the absence of suitable test signals. Algorithms can be developed and tested within a simulation environment, but this cannot address all facets of the problem, such as those aspects related to the integration within a practical telescope back-end and real-time operation of the signal processing pipeline. It is possible to inject test signals directly at the telescope antenna or use a nearby terrestrial RFI source or deliberate transmission to provide a signal (normally picked up through an antenna side-lobe) for testing purposes – but this can only provide a near-field source. Satellite downlink signals can provide test signals in a similar way, and provide a better approximation to a far-field source. However, signals captured in this way are typically too high in signal strength to fully exercise SETI detection algorithms that need to be optimized for very low signal-to-noise ratio operation.

Method:

It is proposed that terrestrial radio emissions reflecting off the surface of the Moon can provide a weak source of far-field emissions, ideal for testing SETI algorithms. The distance to the Moon and its low reflectivity to radio waves (~7%) ensure that reflected signals are weak but detectable with current radio telescopes. Such reflected signals can be a significant source of RFI in radio telescope observations when the Moon lies in the telescope's FoV [1], but provide a near ideal test signal for SETI experiments. Experience with the MWA has shown that reflections of broadcast FM radio and digital TV signals are clearly present in the MWA observing band. In a situation where an ET signal carries information, they will necessarily be broadband, and the FM radio and TV signal provide two very different examples of modulation schemes that can carry a message. FM radio has an effective bandwidth of ~100 kHz peaked around the carrier, whereas digital TV signals have a broad and flat spectrum with width ~8 MHz, making them an ideal test source for the new generation of wideband detection algorithms being developed within the SETI community (e.g. [2]).

Furthermore, it is also possible to aim a deliberate transmission at the Moon to produce a test signal with specifically designed parameters and signal strength. As a passive reflector, the Moon offers greater flexibility in signal type than an active reflector such as a geosynchronous satellite, whose downlink frequency band and strength and spectral shape of the signal need to be tightly controlled. Of course, targeting long-range radio transmissions at the Moon can only be done within frequency bands where this is not precluded by regulations. But the practicality of the method has been amply demonstrated by the regular use of "Moon-bounce communications" within the amateur radio community including in the popular 2 meter amateur band (150 MHz), which is in the middle of the MWA's frequency coverage.

Detection of Moon-reflected Earth leakage has already been confirmed with various radio telescopes (e.g. the MWA [1]), where it is treated as a source of RFI.

Technology Requirements:

Moon reflections can provide a powerful and flexible solution to validating and optimizing new SETI algorithms in a frequency range, and with detection techniques, not typically used. Many interesting signal types are already present in reflections of existing leakage radiation including frequency modulated signals (FM radio), wideband digitally modulated signals (digital TV) and narrowband signals (moon bounce amateur radio). The MWA has already demonstrated that it can receive and track FM radio signals reflected off the ISS [3].

In the case of using existing leakage signals, no additional hardware is needed to receive the signals. The MWA already has the capability to record raw voltage data from all telescope's antennas as well as beamforming software to create a voltage beam on a source. In the case of transmitting a specifically designed test signal, this would require access to a transmitting facility that operates in the same band as the observing telescope, ideally located far from the receiver to avoid pollution of the reflected signal with near-field RFI. A small low-cost transportable satellite terminal is expected to provide sufficient up-link power. Alternatively, the worldwide amateur radio community can help provide several types of test signals in the 150 MHz band including narrowband (CW) signals, AM and FM modulated signals and several digital modes.

Data storage and computing resources to support trial SETI programs can be found within existing MWA allocations at the Pawsey supercomputing centre in Perth. In addition, the Breakthrough Listen program intends to supply dedicated hardware. SETI programs on the MWA are expected to be performed largely with commensal observing or with modest amounts of dedicated observing time.

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 applicable to the proposal. The nature of a blind search for ET signals is necessarily a combination of signal processing and large-scale data analysis. Raw radio telescope data has a daunting data rate, and the overall searching task will be enabled by novel and effective use of Big Data Analysis.

References:

[1] B. McKinley et al., "Low-frequency Observations of the Moon with the Murchison Widefield Array", The Astronomical Journal, 145:23, 2013.

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

[3] S. Tingay et al., "On the Detection and Tracking of Space Debris Using the Murchison Widefield Array. I. Simulations and Test Observations Demonstrate Feasibility", AJ 146, 2013