Current and Nascent SETI Instruments in the Radio and Optical: SERENDIP V.v, OSPOSH and HRSS

Andrew Siemion[1], Dan Werthimer[1], Henry Chen[2], Jeff Cobb[1], Jim Cordes[3], Terry Filiba[1], Adam Fries[1], Andrew Howard[1], Eric Korpela[1], Matt Lebofsky[1], William Mallard[1], Laura Spitler[3], Mark Wagner[1] [1]University of California, Berkeley (siemion@berkeley.edu), [2]University of California, Los Angeles, [3]Cornell University

Here we describe our ongoing efforts to develop high-performance and sensitive instrumentation for use in the search for extra-terrestrial intelligence (SETI). These efforts include our recently deployed Search for Extraterrestrial Emissions from Nearby Developed Intelligent Populations Spectrometer (SERENDIP V.v) and two instruments currently under development; the Heterogenous Radio SETI Spectrometer (HRSS) for SETI observations in the radio spectrum and Open Source Pulsed Optical SETI Hardware (OSPOSH) for SETI observations in the optical band. We will discuss the basic SERENDIP V.v instrument design and initial analysis methodology, along with instrument architectures and observation strategies for OSPOSH and HRSS. In addition, we will demonstrate how these instruments may be built using low-cost, modular components and programmed and operated by students using common languages, e.g. ANSI C.

SERENDIP V.v

In July of 2009 we commissioned SERENDIP V.v, the newest iteration of the three-decade old Search for Extra-Terrestrial Radio Emissions from Nearby Intelligent Populations program [1]. This project utilizes a high performance field programmable gate array (FPGA)-based spectrometer to perform a high sensitivity sky survey effort on the 7-beam Arecibo L-band Feed Array (ALFA) at Arecibo Observatory. This survey will search for narrow-band signals in a 200 MHz band surrounding 1420 MHz. The SERENDIP V.v spectrometer analyzes time-multiplexed signals from all seven ALFA beams, commensally with other telescope users, effectively observing 2 billion channels across seven 3 arcminute beams.

OSPOSH

The pulsed optical SETI program at UC Berkeley searches for nanosecond scale optical light pulses, possibly transmitted intentionally by a powerful pulsed laser operated by a distant intelligence. The search rests on the observation that humanity could build a pulsed optical transmitter (using, for example, a NIF-like laser and a Keck Telescope-like optical beam former) that would be detectable at interstellar distances. When detected, resultant nanosecond-long pulses would be a factor of $\sim$1000 brighter than the host star of the transmitter during their brief flashes [2]. Such nanosecond-scale optical pulses are not known to occur naturally from any astronomical source [3].

Our current optical pulse search [4] utilizes UC Berkeley's 30-inch automated telescope at Leuschner Observatory in Lafayette, California. The detector system consists of a custom-built (wholly from off-the-shelf components) photometer, with three photomultiplier tubes (PMTs) fed by an optical beamsplitter to detect the concurrent arrival of incoming photons. This "coincidence" detection technique improves detection sensitivity by rejecting spurious signals seen in only one PMT. The PMTs have a rise time of 0.7 ns and roughly flat sensitivity for $\lambda = 300$–650 nm. The signals are fed to three high speed amplifiers, three fast discriminators and a coincidence detector. The use of a coincidence circuit significantly reduces the false alarm rate from spurious and infrequent pulses observed in individual PMTs.

Our next generation optical SETI instrument—Open Source Pulsed Optical SETI Hardware (OSPOSH) is based on the same front-end optics and photodetectors as the original Berkeley OSETI instrument, but adds a flexible digital back-end based on the Center for Astronomy Signal Processing and Electronics Research (CASPER) [5] DSP instrument design system (Figure 1). The programmable FPGA-based digital back-end will allow us to improve sensitivity by implementing sophisticated real-time detection algorithms, capture large swaths of raw sampled voltages for diagnostics or centroiding and perform efficient rejection of interference based on pulse profiles.

HRSS

Until recently, the level of technology and engineering expertise required to implement a SETI instrument was quite high. As a result, SETI programs have been limited to a handful of institutions.

The Heterogenous Radio SETI Spectrometer we are developing will take advantage of the high bandwidth capabilities of a high-speed analog-to-digital converter (ADC) paired with a FPGA to digitize, packetize, and transmit coarse channelized spectral regions to flexible, off-the-shelf CPUs and graphics processing units (GPUs)

Table 1: HRSS Costs Compared To Other SETI Spectrometers

SETI Spectrometer	**Bandwidth**	**Beams**	**Pol's**	**Cost**	**Normalized Cost** per MHz/beam/pol
SERENDIP V.v deployed at Arecibo & JPL	200 MHz	1	1	\$40K	\$200
HRSS first 125 MHz dual pol bands	125 MHz	1	2	\$9K	\$40
HRSS additional 125 MHz dual pol bands (after the first 125 MHz)	125 MHz	1	2	\$3K	\$15

[1] Costs are for components only and do not include labor.

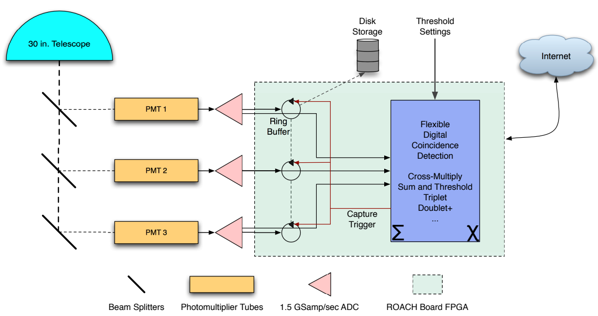

Figure 1: Schematic diagram for the proposed digital backend for OSPOSH. An optical telescope feeds three photomultiplier tubes (PMTs) using optical beamsplitters. The PMT outputs are digitized directly using fast 1.5 Gsamp/sec ADCs and fed into the ROACH Virtex-V FPGA for processing. Voltage samples are fed into a deep 4 Gb DRAM ring buffer in parallel with a programmable event trigger that results in the readout of the ring buffer and capture of raw event data including pulse profiles and possible information content. The digital logic for the instrument is fully reconfigurable and compatible with the CASPER open-source instrument design tool flow.

for fine spectroscopy. The complete instrument system, including digitization and packetization hardware, digital signal processing (DSP) algorithms, and control software, will be made publicly available for students and researchers worldwide. This architecture will not only provide for economical entry into cutting edge SETI research (Table 1), its use of standard C programming on CPUs and GPUs will enable the DSP instrument internals to be accessible for students with only modest instrumentation experience. The HRSS architecture is highly scalable and inexpensive, paving the way for future spectrometers with very high bandwidth (many GHz) covering multiple beams simultaneously.

Acknowledgements The Berkeley SETI projects are funded by grants from NASA and the National Science Foundation, and by donations from the friends of SETI@home. We acknowledge generous donations of technical equipment and tools from Xilinx, Fujitsu, Hewlett Packard, Sun Microsystems, Atmel.

References

[1] D. Werthimer, D. Ng, S. Bowyer, and C. Donnelly. The Berkeley SETI Program: SERENDIP III and IV Instrumentation. In G. S. Shostak, editor, *Progress in the Search for Extraterrestrial Life.*, volume 74 of *Astronomical Society of the Pacific Conference Series*, pages 293–+, 1995.

[2] A. W. Howard, P. Horowitz, D. T. Wilkinson, C. M. Coldwell, E. J. Groth, N. Jarosik, D. W. Latham, R. P. Stefanik, A. J. Willman, Jr., J. Wolff, and J. M. Zajac. Search for Nanosecond Optical Pulses from Nearby Solar-Type Stars. *The Astrophysical Journal*, 613:1270–1284, October 2004. doi: 10.1086/423300.

[3] A. B. Howard and P. Horowitz. Is there RFI in pulsed optical SETI? In S. A. Kingsley & R. Bhathal, editor, *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, volume 4273 of *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series*, pages 153–160, August 2001.

[4] M. Lampton. Optical SETI: The Next Search Frontier. In G. Lemarchand & K. Meech, editor, *Bioastronomy 99*, volume 213 of *Astronomical Society of the Pacific Conference Series*, pages 565–+, 2000.

[5] A. Parsons, D. Backer, D Werthimer, and M. Wright. A New Approach to Radio Astronomy Signal Processing: Packet Switched, FPGA-based, Upgradeable, Modular Hardware and Reusable, Platform-Independent Signal Processing Libraries. In *USNC-URSI, National Meeting, Boulder, CO*, 2006.