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A SEARCH FOR NARROW BAND SIGNALS WITH SERENDIP II: A PROGRESS REPORT†

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Abstract—Commensal programs for the Search for Extraterrestrial Intelligence (SETI), carried out concurrently with conventional radio astronomical observing programs, can be an attractive and cost-effective means of exploring the large multidimensional search space intrinsic to this effort. Our automated commensal system, SERENDIP II, is a high resolution 131,072 channel spectrometer. It searches for 0.49 Hz signals in sequential 64,700 Hz bands of the IF signal from a radio telescope being used for an astronomical observation. Upon detection of a narrow band signal with power above a preset threshold, the frequency, power, time, and telescope direction are recorded for later study. The system has been tested at the Hat Creek Radio Astronomy Observatory 85 ft telescope and the NASA-JPL Deep Space Station (DSS 14) 64 m telescope. It is currently collecting data at the National Radio Astronomy Observatory 300 ft telescope.

1. INTRODUCTION

With few exceptions, SETI investigators have had difficulty obtaining substantial amounts of dedicated telescope time[1]. In an effort to overcome this problem, the Berkeley SETI program has developed an automated instrument, SERENDIP (an acronym: Search for Extraterrestrial Radio Emission from Nearby Developed Intelligent Populations), which does not require any dedicated radio telescope time[2]. SERENDIP operates by automatically searching for narrow band signals in data which are being collected as part of the ongoing astronomical observing program. Any such signals detected are noted, along with relevant observational data, for further study.

The advantages of this method of data acquisition include very low operation cost per unit observing time, negligible impact on observing schedules, large volume data collection, and a randomized search strategy. A commensal SETI program such as this is not free to choose observing frequencies and sky coordinates. However, in view of the plethora of postulated frequency regimes for interstellar communication and the large number of potential sites for civilizations which have been suggested, this is not necessarily a disadvantage.

In this paper, we describe our new system, SERENDIP II, and our initial operations with this unit.

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2. SYSTEM PARAMETERS AND OBSERVATIONS

The SERENDIP II hardware has been discussed in detail by Werthimer *et al.*[3], and is only briefly summarized here. An overall block diagram is shown in Fig. 1. The intermediate frequency centered at 205 MHz from the radio telescope passes through the front end which splits the signal into quadrature components and converts it to baseband by two mixers and a programmable frequency synthesizer (local oscillator). Each component then passes through a seven pole low pass filter and is digitized by an eight bit analog to digital converter at a sample rate of 64,701 Hz. Each component has 2^{16} samples stored in ram thus requiring 128 kb of memory.

For every 65 kHz band, the array processor computes a 65536 point complex fast Fourier transform (FFT) using 16 bit block floating point arithmetic, thus dividing the band into 65536 channels, each 0.98 Hz wide, giving a total bandwidth of 64701 Hz. The array processor calculates the power spectrum derived from the complex FFT and combines adjacent bins of the power spectrum to regain lost power when a peak falls between two bins[4]. The two resulting power spectra are scanned for peaks above a previously chosen threshold. Upon detection of a peak, civil time, telescope co-ordinates, bin number, power, intermediate frequency, and synthesizer frequency are recorded on disk for off-line data analysis. The frequency synthesizer in SERENDIP II then steps 50 kHz along the band to process the next power spectrum, allowing a 15 kHz overlap between adjacent power spectra.

Test runs using SERENDIP II were performed in

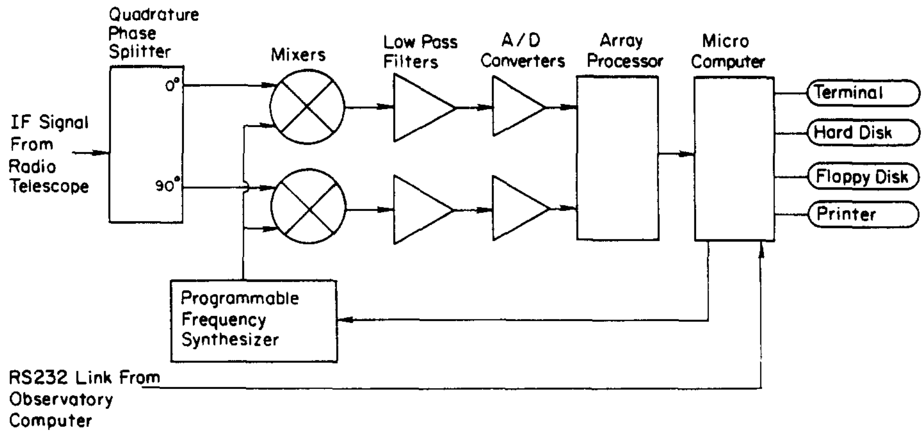

Fig. 1. A block diagram of the SERENDIP II system.

February 1986 at the University of California's 85 ft telescope at Hat Creek Radio Astronomy Observatory. In Fig. 2 we show a histogram of power taken at 1400 MHz. For comparison, the theoretical values are given. The peak on the right tail of this graph comes from a 60 Hz interference component in our instrument which we have subsequently removed.

We implemented and tested the current SERENDIP II software at the NASA-JPL 210 ft DSS 14 telescope in a commensal mode with the Berkeley Pulsar Group. An example of events over a 10σ threshold (10^{-5} false alarm rate) at DSS 14 is shown in Fig. 3 with higher power events indicated by larger dots. These data were taken at 2250 MHz. The density of events across the spectrum is not uniform because the anti-alias filter is not perfectly flat. We have fixed this problem in our later work by scaling the spectrum before it is thresholded.

The SERENDIP II system is currently operating at NRAO's 300 ft telescope in Greenbank, W. Va, again with the Berkeley Pulsar Group. At present, only a limited amount of data is available. In Fig. 4 we show the galactic locations thus far observed and for which we have processed the data. In Fig. 5 is shown a plot of events over threshold from 825 to 826 MHz. The density of events is spread homogenously over frequency and time except for a series of events about 825.06 MHz. The source of these events has not been identified but it is clearly terrestrial. Although these events can be easily seen by eye, it is not a simple task to devise an automated program which will pick out even this simple level of interference. The complexity of the task is made more obvious in Fig. 6 where we have simply expanded the scale of the events near 825 MHz. It is obvious from the figure that these events drift in frequency and hence cannot be deleted simply by developing a pattern recognition scheme based on a high density of events at a single frequency.

At this juncture in our program we are concentrating on developing and testing schemes which will

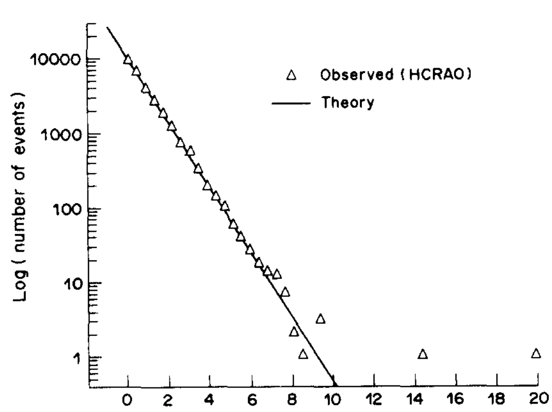

Fig. 2. Histogram of power from HCRAO at 1400 MHz. The large tail at high power is 60 Hz line noise which has been subsequently removed.

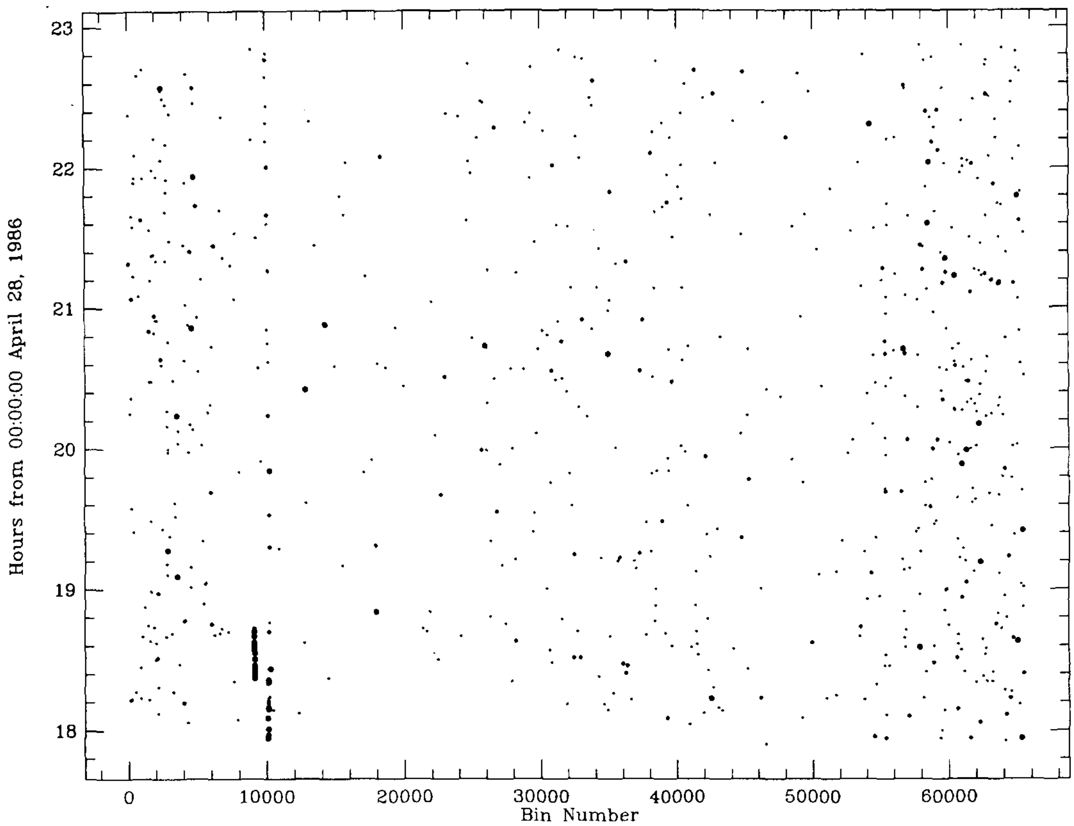

Fig. 3. Events over 10σ threshold from DSS 14 at 2250 MHz. Larger power is represented by larger dots. Note the density inhomogeneity over bin number.

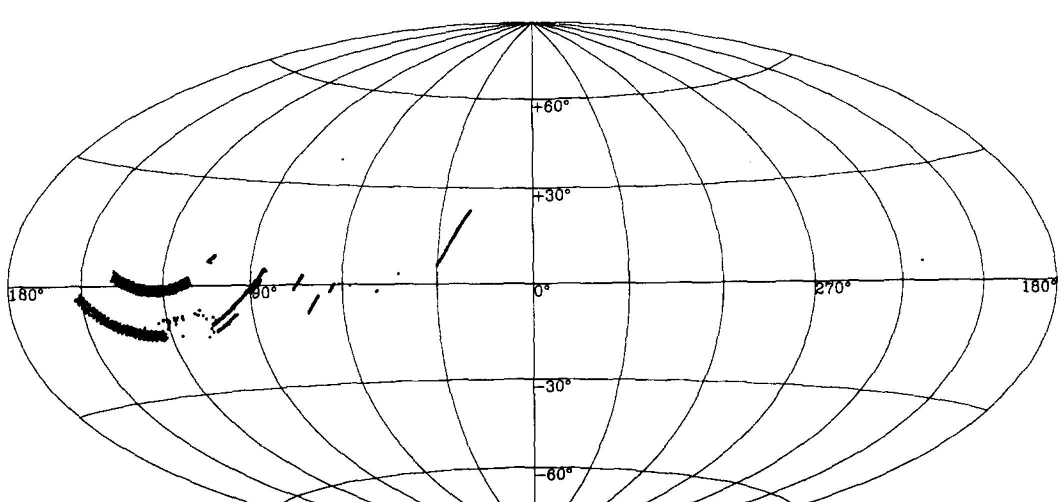

Fig. 4. Galactic locations of events over 11σ threshold at 825 MHz. This is only a limited amount of data that has been processed from NRAO.

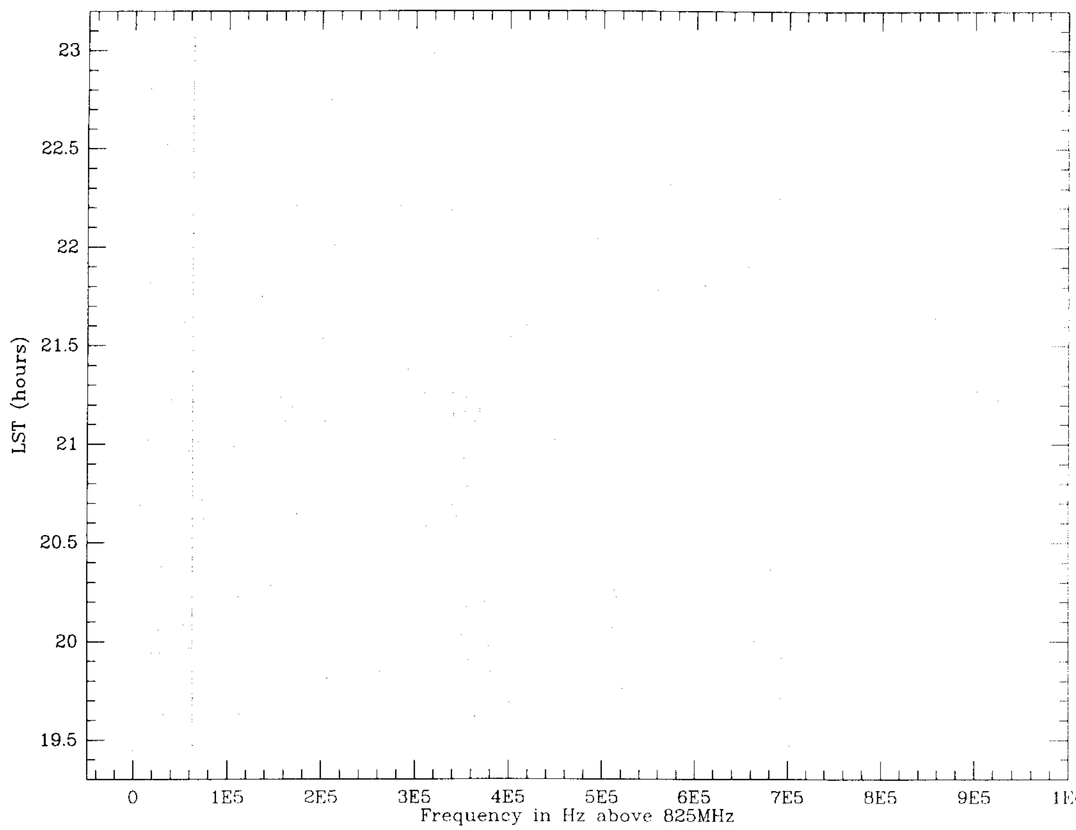

Fig. 5. Events over 11σ threshold from NRAO at 825 MHz. Note the closely spaced series of events near 825.06 MHz.

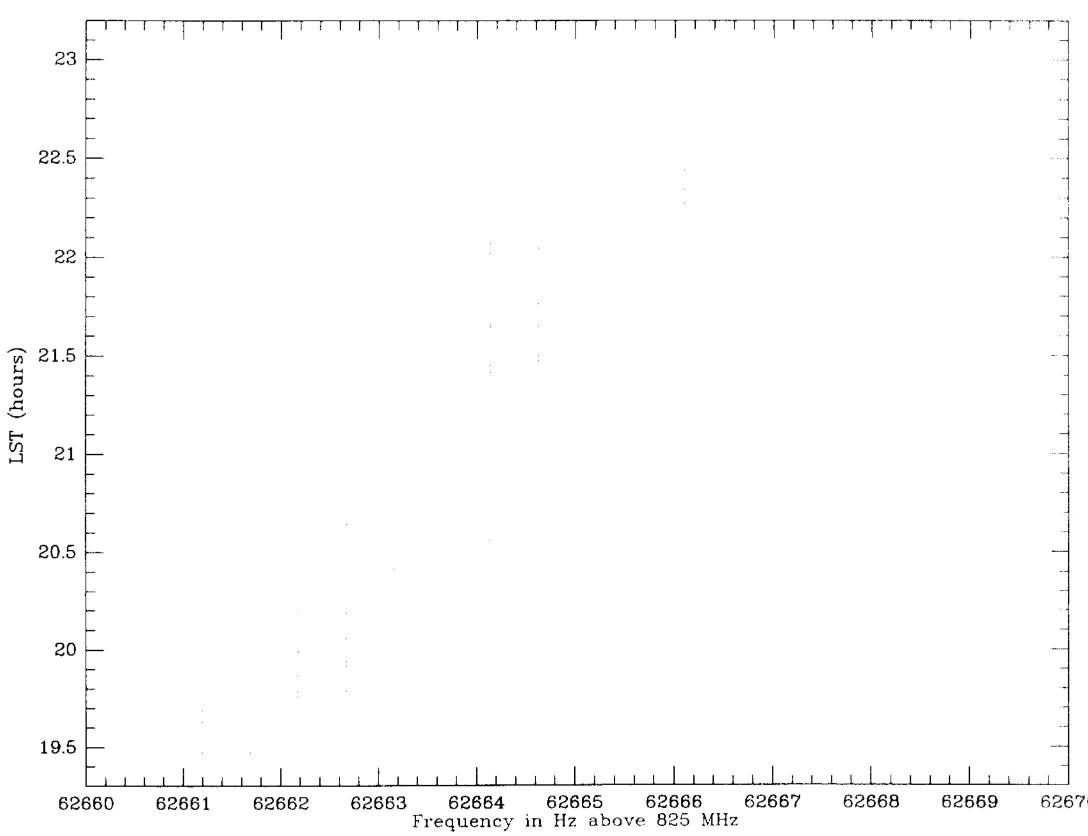

Fig. 6. The series of events from Fig. 5 can be seen to drift in frequency in this magnification about 825.06 MHz.

reduce the number of events which are false alarms, without substantially increasing the likelihood of overlooking a potentially valid signal.

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