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Hawaii Fast Radio Burst Outrigger Station

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Abstract

A hybrid array of radio telescope antennas is planned for deployment on the Big Island of Hawaii to serve as an outrigger station to the CHIME FRB telescope located in British Columbia. The array will consist of ten 6-meter dishes and twelve log periodic antennas designed to operate in the 400 to 800 MHz band. This paper summarizes the early stages of preparation and tests conducted to date.

1 Introduction

Academia Sinica Institute of Astronomy and Astrophysics (ASIAA) is currently working to deploy an antenna array in Hawaii to serve as an outrigger station for the CHIME FRB[1] telescope in British Columbia. This outrigger station will provide additional localization precision to the CHIME data set which is an important parameter in understanding the nature of FRB events. The Hawaii outrigger station will be setup to view the same portion of the sky as CHIME and will continuously digitize and store the 400 to 800 MHz data in a ring buffer from each antenna. When CHIME detects an FRB event it will broadcast a trigger which will tranfer the ring buffer data to disk memory. The data will be sent to the CHIME facility for offline correlation processing.

2 Site Survey

The Hawaii outrigger array will match CHIME's 400 to 800 MHz observing band. Radio frequency interference (RFI) sources in this band are numerous. Narrow band voice and telemetry can be digitally removed by blanking those specific frequency channels but one of the several challenges is to maintain signal linearity within the analog chain prior to digitization. A single strong interferer can cause nonlinearity in the frontend low noise amplifier (LNA) and compromise the entire band. In addition to narrow band RFI, the 400 to 800 MHz regime permits commercial broadcast of digital TV and 4G LTE internet communications. These transmissions occupy significant bandwidth where blanking would discard a large fraction of our overall 400 MHz bandwidth.

In order to provide maximum sensitivity and bandwidth a site with low RFI is desirable. An RFI survey of Hawaii island was conducted using a vehicle with a magnetic mount antenna and LNA, refer to Figure 1. An extended band from 200 to 1200 MHz was monitored on a Keysight FieldFox N9918A spectrum analyzer.

Figure 1. Monopole antenna and LNA mounted to top of vehicle. The output of the LNA was connected to a portable spectrum analyzer inside the vehicle.

Relative measurements were compared with two of the results shown in Figure 2 and Figure 3 with associated latitude and longitude coordinates. Based on these results we focused our efforts in the Pahala region of the Big Island which is approximately 1.5 hour drive from our base office in Hilo.

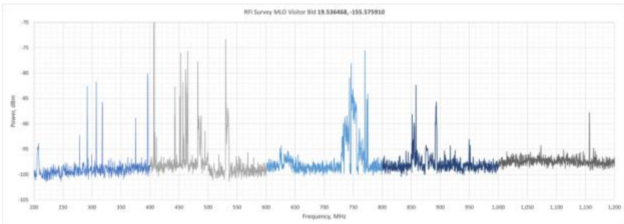

Figure 2. RFI spectra from 200 to 1200 MHz captured at Maunaloa observatory, 19.536468N, 155.575910W.

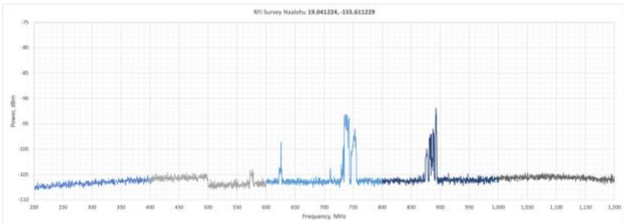

Figure 3. RFI spectra from 200 to 1200 MHz captured at Naalehu, 19.041224°N 155.611229°W.

3 Antenna

The primary antenna array will consist of ten 6-meter diameter parabolic dishes design to operate in C-band (4 to 8 GHz) with an F/D of 0.38. Using a typical efficiency value of 65%, the gain and 3 dB beam width at 600 MHz is 29.6 dB and 5.8 degrees. A photo of our first dish constructed in Hilo is shown in Figure 4. The receiver is located at the prime focus and will be described in a later section.

Figure 4. Construction of first 6-meter dish. The receiver is located at the prime focus. Optical fiber and DC power is routed along the lower feed leg.

The secondary array will consist of twelve log period antennas designed to operate in the 400 to 800 MHz band and are shown in Figure 5.

Figure 5. Log periodic antennas with gain of 9.1 dBi and beam width of 35 degrees.

4 Instrumentation

The receiver for the 6-meter dishes consists of a dual polarization clover leaf assembly with integrated LNAs [2] shown in Figure 6.

Figure 6. Clover leaf feed consists of two pairs of opposing petals forming a pair of orthogonal dipole antennas. The radio signals collected by the 6-meter dish is focused onto the feed.

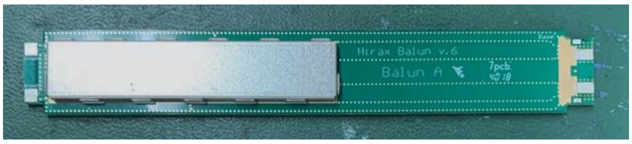

Figure 7. LNA provides differential to singled-ended gain of 40 dB and noise temperature of 25K.

The LNA for the log periodic antennas consists connectorized components packaged in a shielded metal enclosure, see Figure 1, with a gain and noise temperature of 47 dB and 32K.

The RF signals collected by the antennas are transmitted over fiber optic links to the digital backend processor ICE boards [2] shown in Figure 8. Each ICE board assembly consists of four 4-core 8-bit ADCs capable of digitizing 16 analog inputs at 800 Msps. We have two ICE board assemblies to process 32 analog inputs.

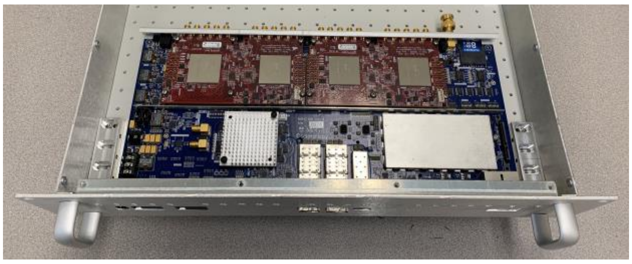

Figure 8. ICE mother board (blue) with two data acquisition daughter boards (red). This board assembly is currently being packaged into an EMI chassis to prevent radiation.

The ICE mother board utilizes Xilinx K7 FPGA to provide real-time functions built around the KOTEKAN framework [1].

5 Preliminary Test Results

We have selected a site in Pahala and are awaiting approval for a construction permit to assemble the ten 6-meter antennas. In the mean time we have performed tests using the log periodic antenna system with a calibrated RFI survey shown in Figure 9. Though RFI is present the level is low enough to allow for linear operation of our analog system without compromise in sensitivity. Using a pair of antennas, we were able to detect strong phase fringes as the sun drifted through the beam of the fixed antenna pair.

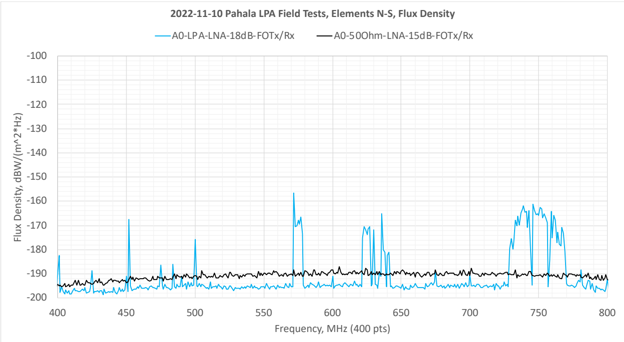

Figure 9. RFI flux density measured at Pahala site, 19.249722°N 155.468611°W, using log periodic antennas.

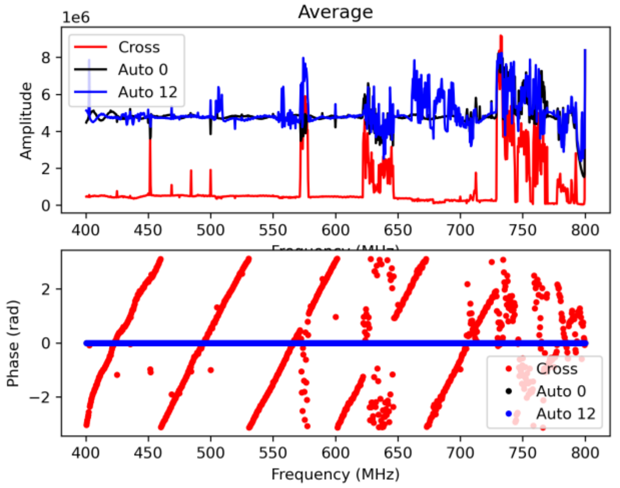

Figure 10. Cross correlation amplitude and phase detection on the sun using a pair of log period antennas space by 18-meters in the E-W direction. Integration time was 2.684 seconds.

5 Summary

We have located an RFI quite site in the Pahala region of the Big Island of Hawaii and successfully demonstrated a scaled down version of the final system using low gain log periodic antennas, LNAs, fiber link, and the digital backend ICE boards. We await the completion of the construction permit after which we will begin assembly of the 6-meter dishes, cable trenching, installation of power and communication infrastructure.

Acknowledgments

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References

[1] M. Amiri *et al*, "An Overview of CHIME, the Canadian Hydrogen Intensity Mapping Experiment" APJ, vol. 261, No.2, Jul. 27 2022, doi: 10.3847/1538-4365/ac6fd9.

[2] M. Deng *et al.*, The cloverleaf antenna: A compact wide-bandwidth dual-polarization feed for CHIME, International Symposium on Antenna Technology and Applied Electromagnetics, ISBN:978-1-4799-2225-3, doi: 10.1109/ANTEM.2014.6887670.