National Aeronautics and Space Administration

Enhancing CRABS search capabilities for Galactic FRBs

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Objectives

The exciting discovery of the Fast Radio Burst, FRB, 200428 from SGR 1935+2154 by California RAdio Burst Sensors, CRABS, justifies the need for a deeper FRB search obtainable with an improved instrument. Improving the instrument's sensitivity, duty cycle, RFI rejection and the candidate event selection aimed to expand the CRABS search capabilities for galactic FRBs. A discovery of yet another FRB source in our Galaxy would be an extremely important event for the astrophysics community and would deepen our understanding of the FRB phenomena and shed light on the energy transfer processes feeding these bursts.

Background

Fast radio bursts, FRBs, were discovered in 2007. They are a type of radio transients, possibly the most energetic ones known to humans. A lot of effort has been devoted to uncover the sources of the extragalactic, millisecond- duration FRBs. On April 28, 2020 the FRB200428 with a fluence of 1.5 ± 0.3 Mega-Jansky milliseconds was discovered by CRABS/STARE2 telescope and for the very first time localized to a local magnetar SGR1935+2154 [1,2]. The construction of the telescope was supported by 2018 President's and Director's Fund award. The radio array consists of three sensors located at OVRO and Goldstone in California, and near Delta, Utah. It was commissioned and began operation in November of 2019. Each sensor has a full sky view and covers the frequency range from 1.28 GHz to 1.53 GHz with 2048 channels of 122 kHz each. CRABS is sensitive to fast, dispersed radio transients above a fluence detection threshold of 300 kJy ms1/2 with 65.536 μs time resolution and 1.84 steradian effective field of view. Unlike other instruments, CRABS was specifically designed to be sensitive to extremely rare and extremely bright fast radio transients like FRBs from our Galaxy.

Approach and Results

DSS-13 site at Goldstone, where one of the CRABS sensors is located, is known for its intense wide-band RFI from a nearby military base. The sensor deadtime due to RFI is about 25%. This urged us to improve the sensor sensitivity and RFI protection. The Utah sensor was unstable and often went off line on the hot days. The hardware and firmware upgrades were due to improve the stability of the FPGA board and increase the telescope duty cycle. Since the hardware upgrads were needed, a decision was made to replace the Low Noise Amplifiers, LNAs, with the Front End Boards, FEBs, as they work together.

The LNAs and FEBs installed at CRABS sensors were originally designed for Deep Synoptic Array, (DSA), project, see Figure 1, [3]. Minor modifications were made to the schematics to adopt the design for CRABs sensors: the internal attenuation was tuned for each CRABS site; manual noise calibration option was added. The main systems of the new FEB board are: 1280-1530 MHz bandpass filter; 23 dB amplification stage, laser diode driver with control loop; power, LNA current and temperature monitoring circuits and 32 kHz generator. The signal from FEB is sent to the FPGA board over the optical fiber. The FPGA board was not changed during this upgrade. All three CRABS stations were upgraded over the duration of the project. New LNAs at Delta sensor mounted at the antenna feeders are shown in Figure 2, while Figure 3 shows new FEBs installed. The upgrade resulted in lowering the system temperature from about 66K for the old system to about 30-35K for the new sensors, boosting the system sensitivity. An example of the system temperature plot from Goldstone Sensors after the upgrade is shown in Figure 4. Some hardware repairs were also performed at the time of the upgrade.

As the upgrades and repairs were in progress, CRABS detected a solar flare on May 7, 2021, confirming operational status of the upgraded sensors. Figure 5 shows the spectrum registered by OVRO and Delta CRABS sensors. Goes X flux confirms the flare in X-ray [4].

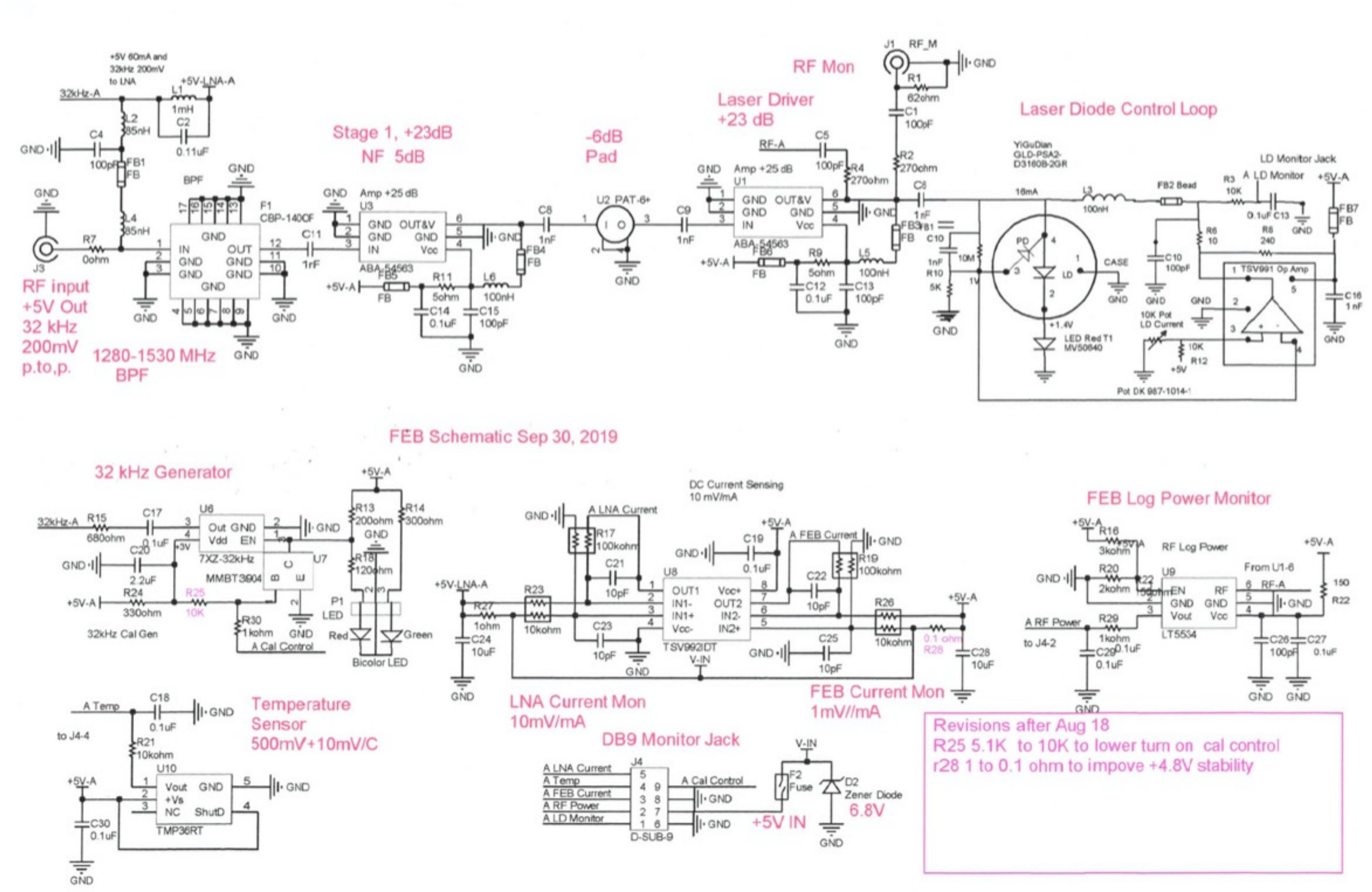

Figure 1. FEB board wiring diagram

Figure 2. Upgraded LNAs installed at Delta CRABS station.

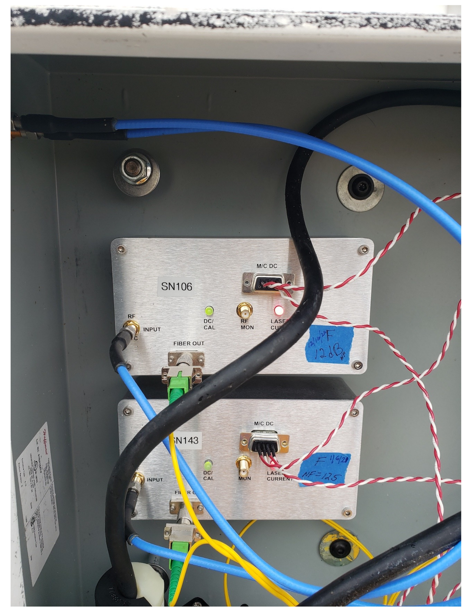

Figure 3. New FEBs installed at Delta CRABS station.

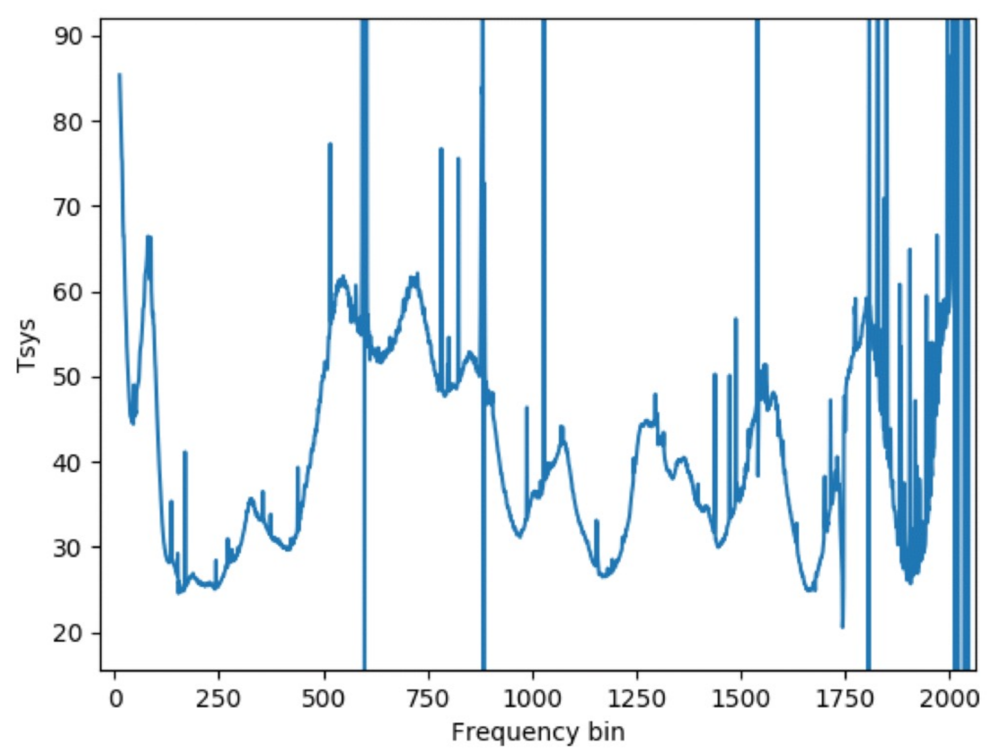

Figure 4. System temperature for Goldstone CRABS sensor as a function of the frequency. The relevant operating frequency range is 1280-1530 MHz. Spikes on the plot is a digital artifact or a local RFI, filtered out during the data processing.

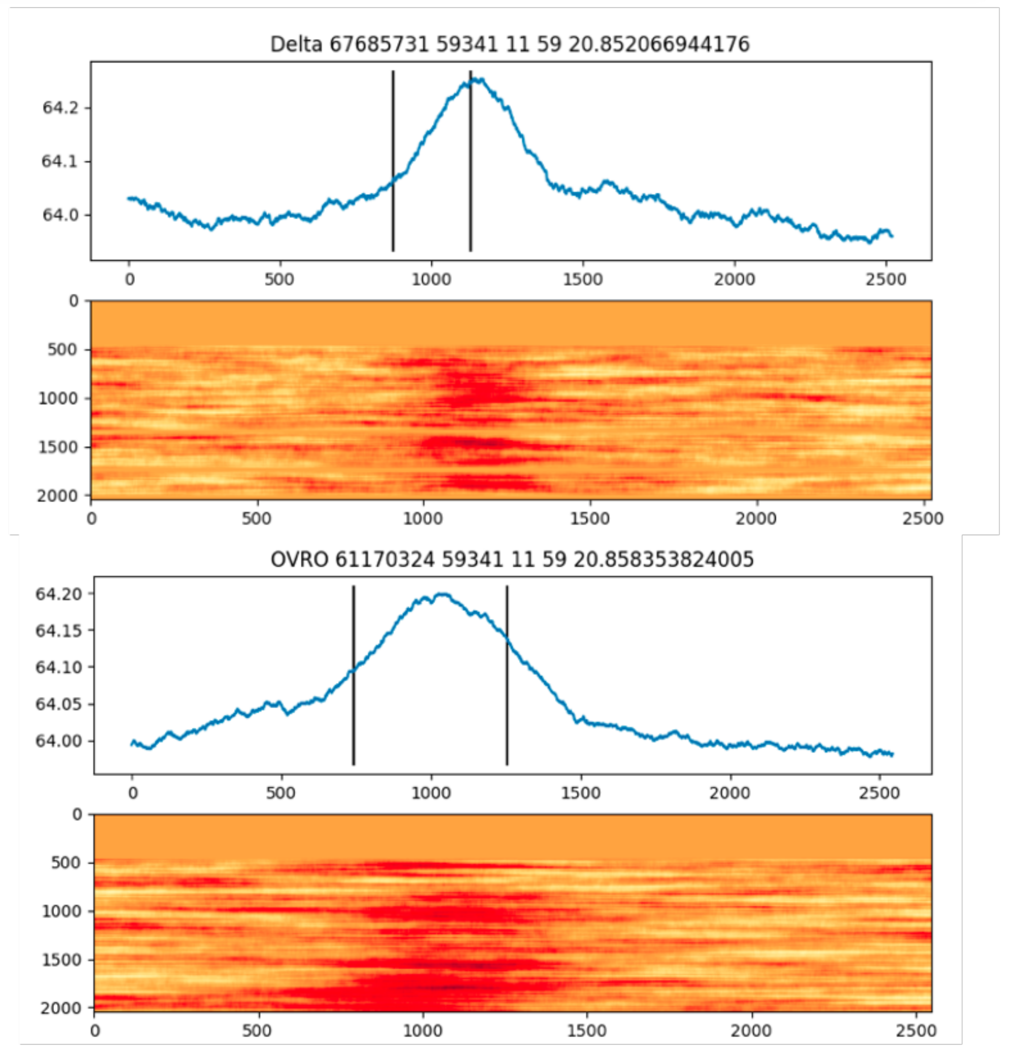

Figure 5. Solar flare registered at Delta and OVRO sites. Upper plots – time series. Lower plots – frequency spectrum. Note: Y-axis corresponds to frequency bins 1530-1280 MHz.

Significance/Benefits to JPL and NASA

The completed upgrade reduced CRABS/STARE2 system temperature from 66K to about 30-35K, increasing the sensor sensitivity correspondingly. The ungraded CRABS telescope continues to monitor the sky 24/7 in search for another FRB from our own galaxy maintaining NASA leadership in the field of Fast Radio Bursts – probably the most violent events known to humans.

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