NEXT GENERATION GNSS-R INSTRUMENT

Christopher Ruf[1], Roger Backhus[1], Tim Butler[1], Chi-Chih Chen[2], Scott Gleason[3], Eric Loria[2], Darren McKague[1], Ryan Miller[1], Andrew O'Brien[2], Line van Nieuwstadt[1]

1. Climate and Space Dept., University of Michigan, Ann Arbor, MI USA
2. ElectroScience Lab, The Ohio State University, Columbus, OH USA
3. University Corporation for Atmospheric Research, Boulder, CO USA

ABSTRACT

The science payload on each spacecraft in the CYGNSS constellation is a GNSS-R receiver and antennas designed to receive GPS L1 signals scattered from the Earth surface. The constellation was launched on 15 Dec 2016 and the GNSS-R instruments continue to operate successfully. A next generation version of the receivers and antennas is in development which adds significant measurement capabilities that are expected to enhance the resolution, precision and coverage of current CYGNSS science data products as well as enable some new ones.

Index Terms— CYGNSS, GNSS-R.

1. SUMMARY

Global Navigation Satellite System Reflectometry (GNSS-R) remote sensing uses the existing constellations of navigation satellites (GPS, Galileo, etc.) as the transmitter half of a bistatic radar. The receiver half of the radar is a customized GNSS receiver and associated antennas [1]. A next generation GNSS-R instrument is in development which expands upon the current capabilities of the one used by the NASA CYGNSS mission [2]. The new instrument works with both low (L1/E1) and high (L5/E5) bandwidth signals from GPS and Galileo satellites, whereas CYGNSS works with only GPS L1. The new antenna receives both co-pol (left hand circular polarized) and cross-pol (right hand circular polarized) signals reflected from the surface. CYGNSS measures only the co-pol component. The new receiver is able to simultaneously process scattered signals from many more GNSS transmitters than CYGNSS, which can process up to four [3-5]. The new instrument uses a modular and reconfigurable architecture and the exact number of parallel channels it can support depends on the number of high and low bandwidth signals, the number of co- and cross-pol channels, and the number and range of time delay and Doppler frequency offsets from the specular point values that are measured.

The next generation GNSS-R instrument is expected to enable major improvements over current CYGNSS capabilities in the areas of oceanic and cryospheric climate studies, weather monitoring and prediction, soil moisture and flood inundation mapping, and disaster management [6,7]. The current development effort will raise the technology readiness of the next generation instrument from TRL-4 to TRL-6.

2. INSTRUMENT DESIGN OVERVIEW

The next generation GNSS-R instrument consists of the following sub-systems, each of which is being developed as part of the current effort.

- Zenith navigation antenna and nadir dual frequency science antenna
- RF Front End dual frequency low noise amplifier (LNA) and integrated calibration module
- RF Front End dual frequency analog receiver/signal conditioner/digitizer
- Digital Back End navigation processor

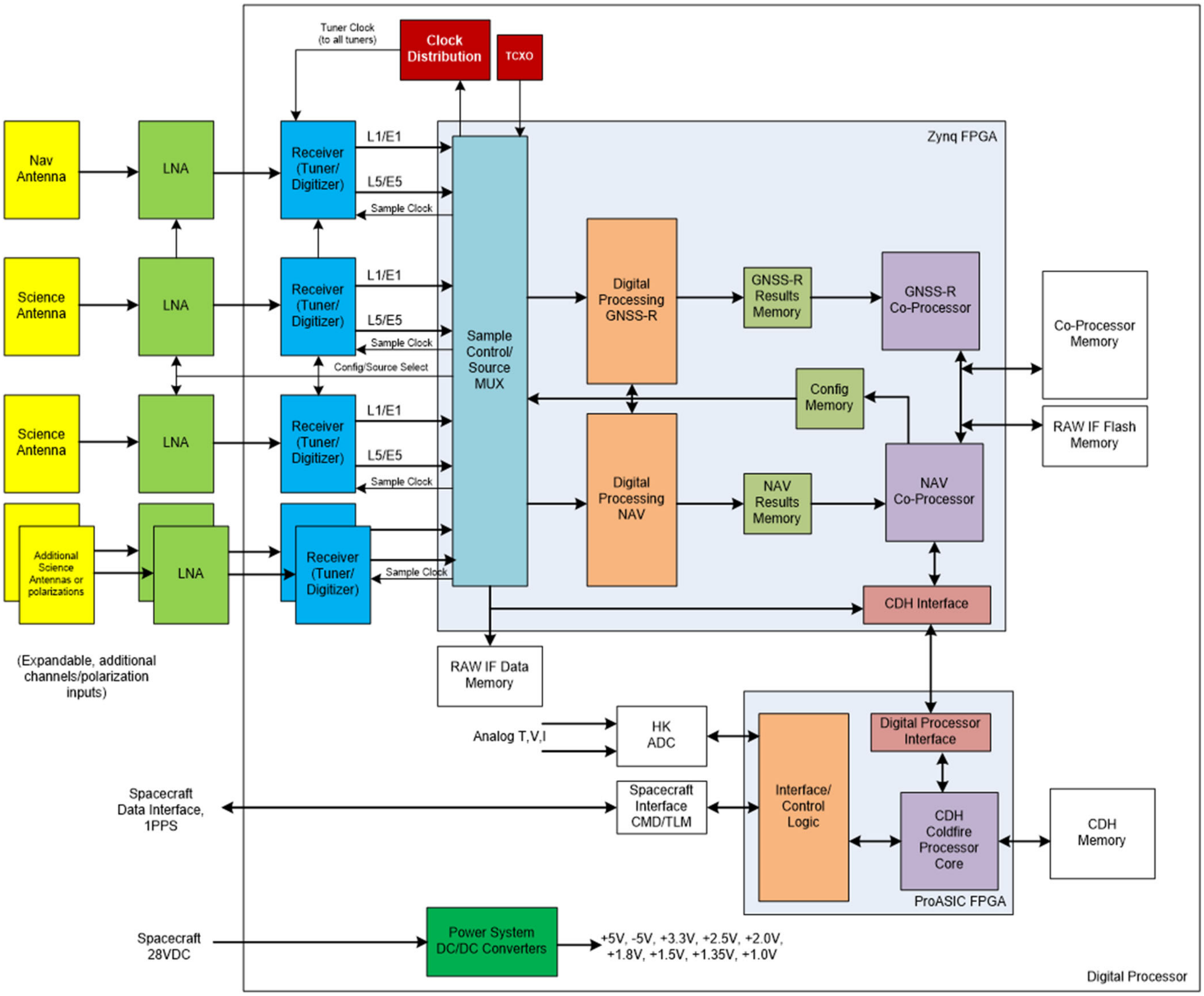

Figure 1. Next generation GNSS-R instrument functional block diagram.

- Digital Back End GNSS-R processor
- Digital Back End control & data handling/bi-directional digital interface to spacecraft
- Power supplies and power conditioning for instrument subsystems/power interface to spacecraft

A functional block diagram of the entire system is shown in Fig. 1 in its fully populated modular configuration using five antennas, fiver RF daughterboards, and five LNAs. This could, for example, correspond to a configuration with one zenith navigation antenna and two nadir science antennas, each having a co- and cross-polar output channel.

3. DIGITAL SIGNAL PROCESSING ARCHITECTURE

The digital signal processing (DSP) architecture on the Zynq system-on-chip (SOC) is divided into two parts. First, the FPGA programmable logic contains low-level signal conditioning and correlator banks. This low-level processing is divided into narrow- and wideband digital processing channels that are used to process received GPS and Galileo signals separately based on their bandwidth. Second, the ARM cores run the primary signal processing software (SPSW), which control receiver operations and processes correlator bank outputs. Common correlator resources are shared to track the direct path GNSS signals to form navigation solutions as well as the reflection path signals to form delay-Doppler maps (DDMs) science measurements. The processor provides a substantial performance improvement over the current generation of instruments, such as the one used by the CYGNSS instrument. The additional performance increases the amount of reflections that can be tracked, increases the bandwidth of available GNSS signals, and provides new opportunities to implement onboard processing algorithms. These algorithms, including precision orbit determination and enhanced coherent reflection processing modes, could significantly impact the science value of GNSS-R measurements. A Command and Data Handling (CDH) subsystem operating on a separate radiation tolerant processor serves as a robust system monitor and interface between the receiver and external interfaces.

4. INSTRUMENT SUB-SYSTEM TESTING

The new antennas have been tested while mounted on a CYGNSS spacecraft mock-up in a compact range anechoic chamber at the ElectroScience Lab of the Ohio State University (see Fig. 2). This is done to evaluate the effectiveness of new antenna design details intended to reduce near field coupling to the spacecraft and improve antenna performance. The new LNA has undergone full environmental testing. Vibration testing is shown in Fig. 3. The RF front end sub-systems are realized as daughterboards, one for each LNA input channel, which are integrated with the larger digital back end motherboard. The integrated receiver is shown in Fig. 4 with three of the daughter boards installed. A maximum of five daughterboards can be accommodated.

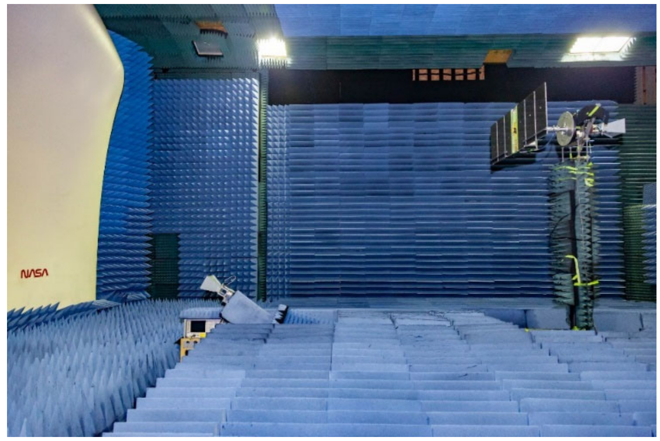

Figure 2. Anechoic chamber testing of the new antenna while mounted on a spacecraft mock-up.

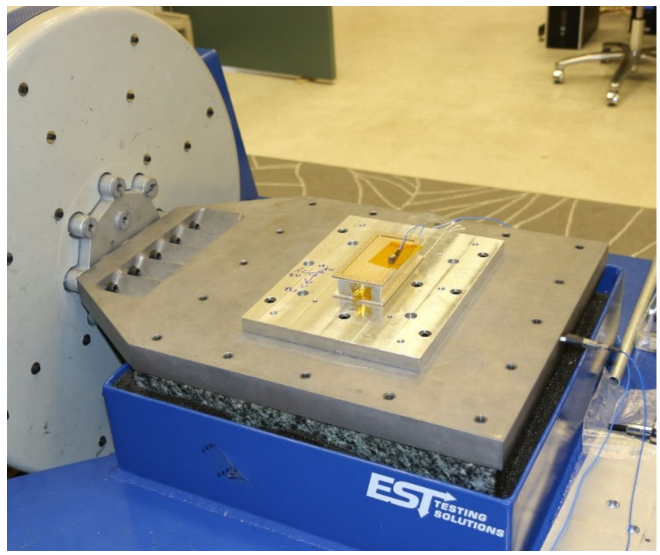

Figure 3. Vibration testing of the new low noise amplifier/integrated calibration module sub-system

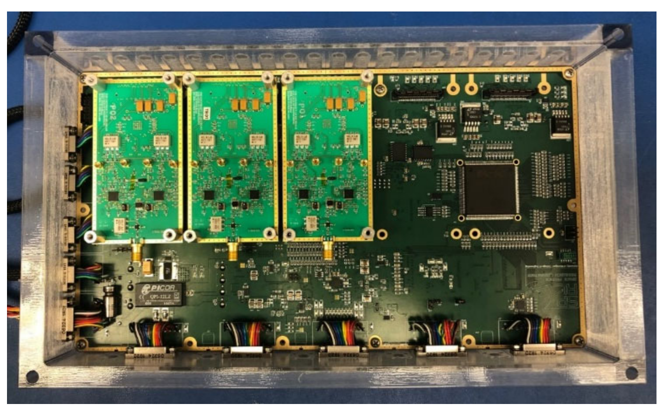

Figure 4. Next generation GNSS-R receiver shown with three RF front end daughter boards installed.

5. CONCLUSIONS

The IGARSS presentation will provide an overview of the next generation GNSS-R instrument design and the latest results of its testing and end-to-end performance characterization.

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