An Experimental setup for a Radio Dynamic Zone

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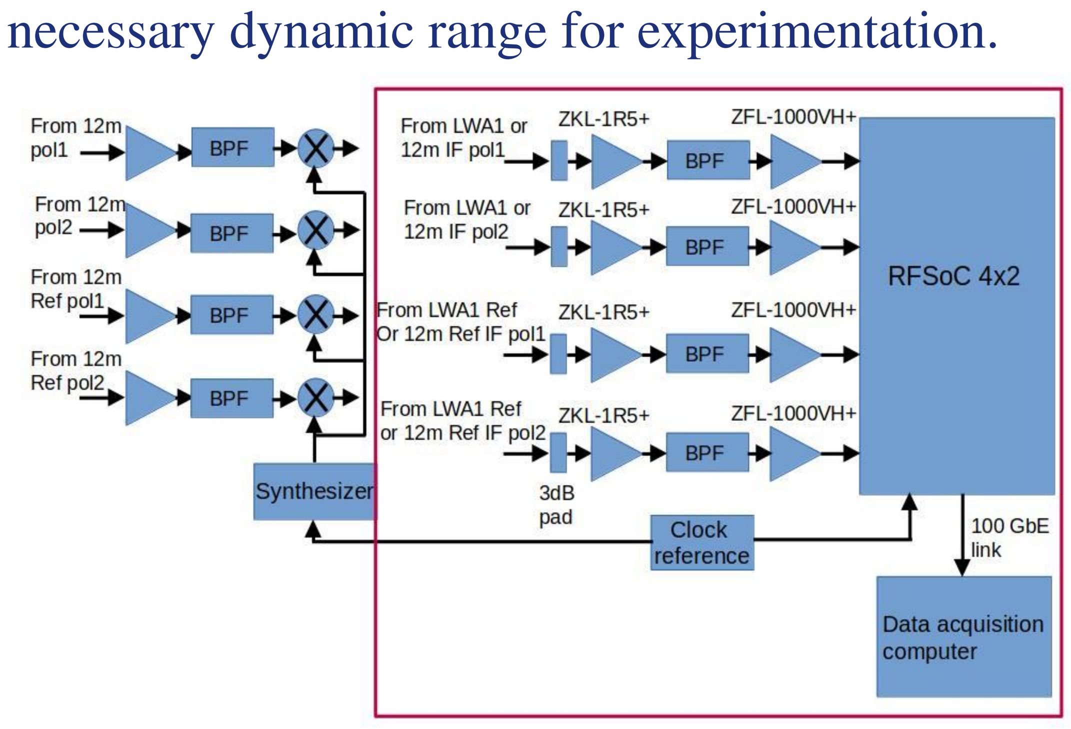
Abstract

Radio Dynamic Zones where the spectrum is shared between active transmitting services and passive services such as radio astronomy, is a suggested spectrum management model for the future [1]. An effective radio receiver under such conditions would require a high dynamic range and advanced Radio Frequency Interference (RFI) mitigation. With the intention to design such a receiver, we developed an initial experimental setup consisting of a 4-channel voltage recording system. The system and the results from tests performed on the system are presented in this poster. We also present our efforts to use the system to collect data for RFI mitigation research and develop high dynamic range receivers.

A 4-channel voltage recording system

Our initial experimental setup consists of a 4-channel voltage recording system (see Fig. 1). Such a system will allow off-line development of RFI mitigation techniques both in the voltage and correlation domains. We digitize the signals using 14-bit analog-to-digital converters (ADCs) in the RFSoC 4x2 FPGA board. The digitized data is transported to the acquisition computer through a 100 GbE link. The analog part of the system is designed to operate over a 10 - 1000 MHz radio frequency (RF) range. Plugin units such as bandpass and notch filters make the operation possible over the required RF frequency range. These plugin units are also helpful to achieve the necessary dynamic range for experimentation.



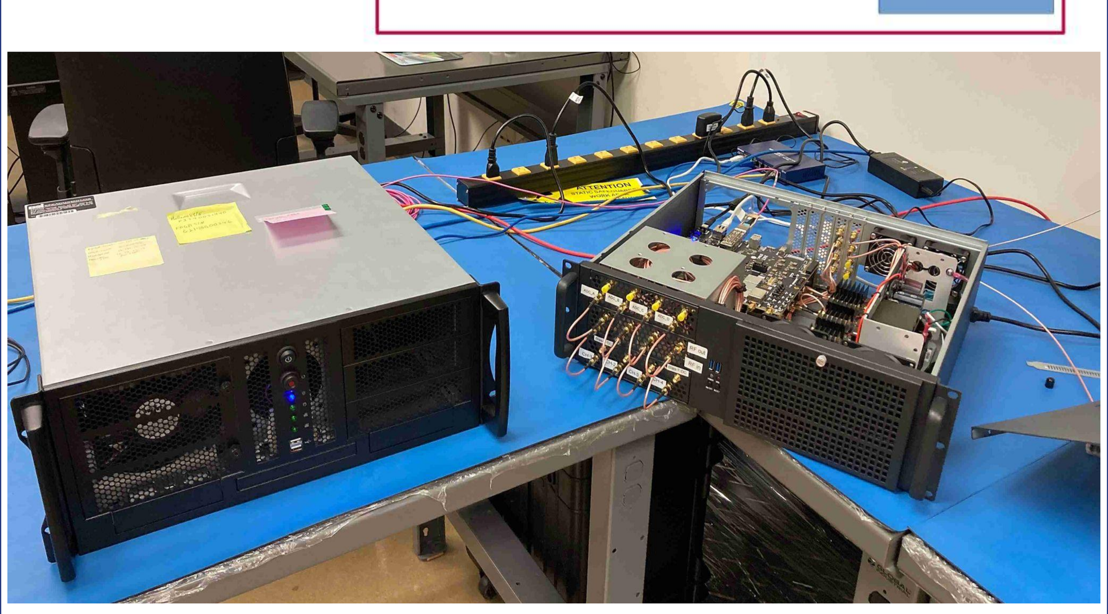


Figure 1: (top) A block diagram of the 4-channel voltage recording system. The blocks within the redbox have been realized. The blocks outside the redbox intend to interface the system with the 12m telescope at Arecibo. (Bottom) Image of the integrated voltage recording system.

Results

There are two modes of operation. In mode 1, the system can bandpass sample signals with a bandwidth of up to 24.6 MHz and record the voltages to a solid-state disk for up to 2 hours. The lab test results from this mode are shown in Fig. 2. In mode 2, the system can sample signals at 245.76 MHz and transport the data to the acquisition computer memory. Using a Graphic Processor Unit, we will use this mode to process data in real-time for the next generation experimental setup. Fig. 3 shows the lab test results.

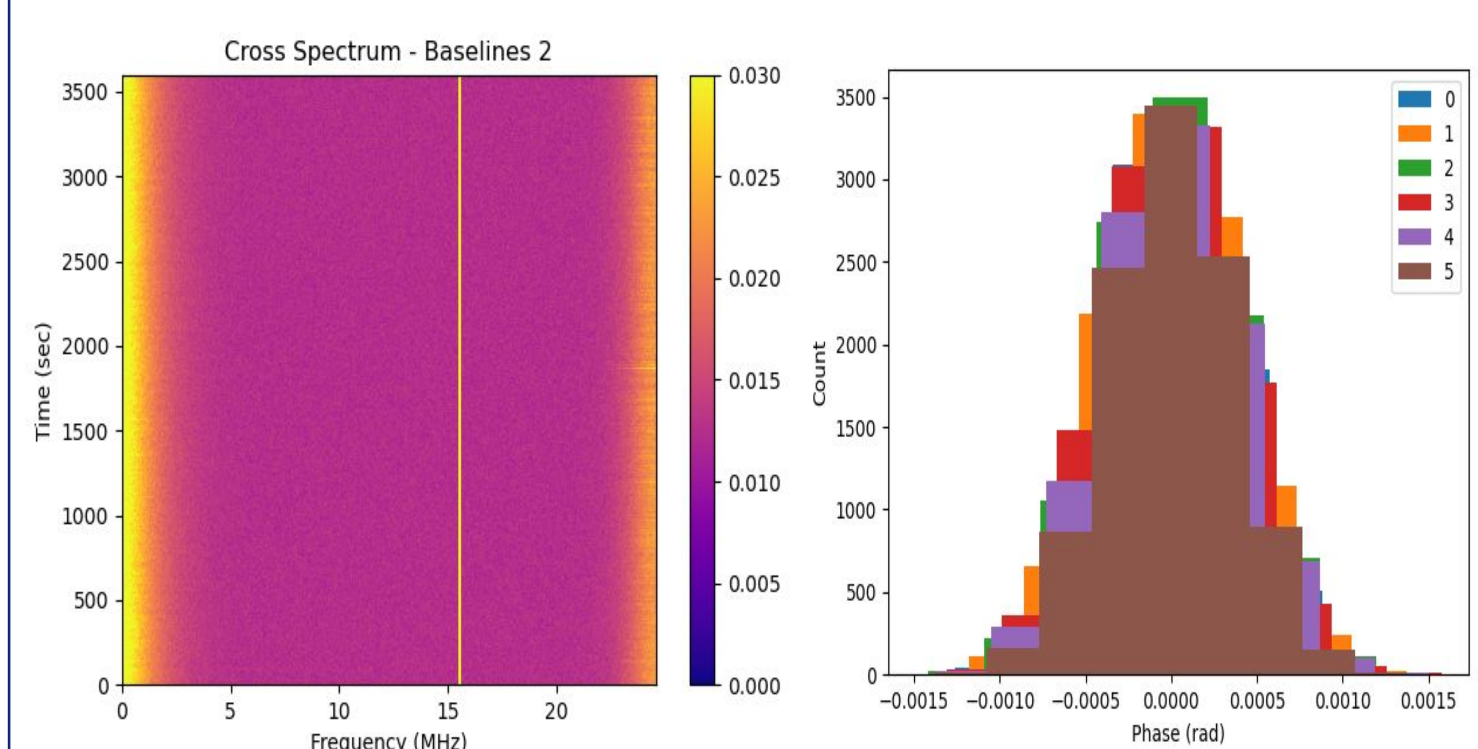


Figure 2: (Left) The cross-correlation amplitude between ADC0 and ADC1 for a correlated noise input for 1 hour. The mean cross spectral values were subtracted from each frequency channel. The higher correlated power near 15.6 MHz is due to a tone injected along with the noise. (Right) A histogram of the phase of all cross-correlations for 1-hour duration. These plots demonstrate the stability of the amplitude and phase of the cross-products over 1 hour.

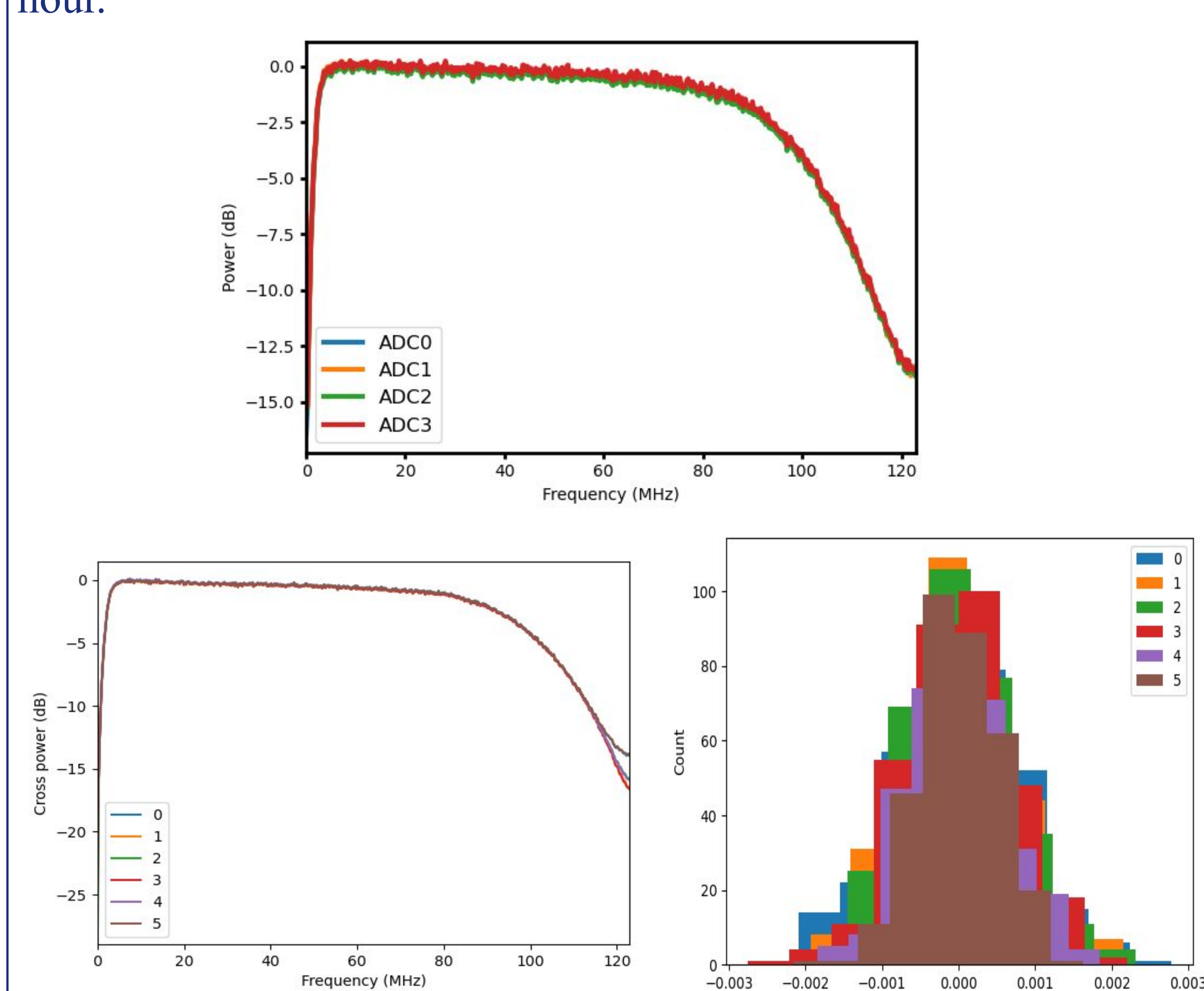


Figure 3: (Top) Self-spectra obtained from the 4 ADC outputs in mode 2, which provides a maximum bandwidth of 122.9 MHz. The input to the system for this data set was a correlated noise with ~100 MHz bandwidth. (Bottom-left): Amplitude of the six cross-spectra vs frequency. (Bottom-right): Histogram of the phase of the cross-spectra (after removing the mean phase) obtained from 10 sec data.

We are currently preparing to connect the system to the DLITE telescope at Malabar, Florida, to collect data for developing RFI mitigation techniques. DLITE consists of four LWA antennas operating over 20 to 80 MHz. We plan to connect one of the LWA antenna outputs to the two channels. The other two channels will be connected to a dual-polarized reference antenna.

High Dynamic Range Receiver system

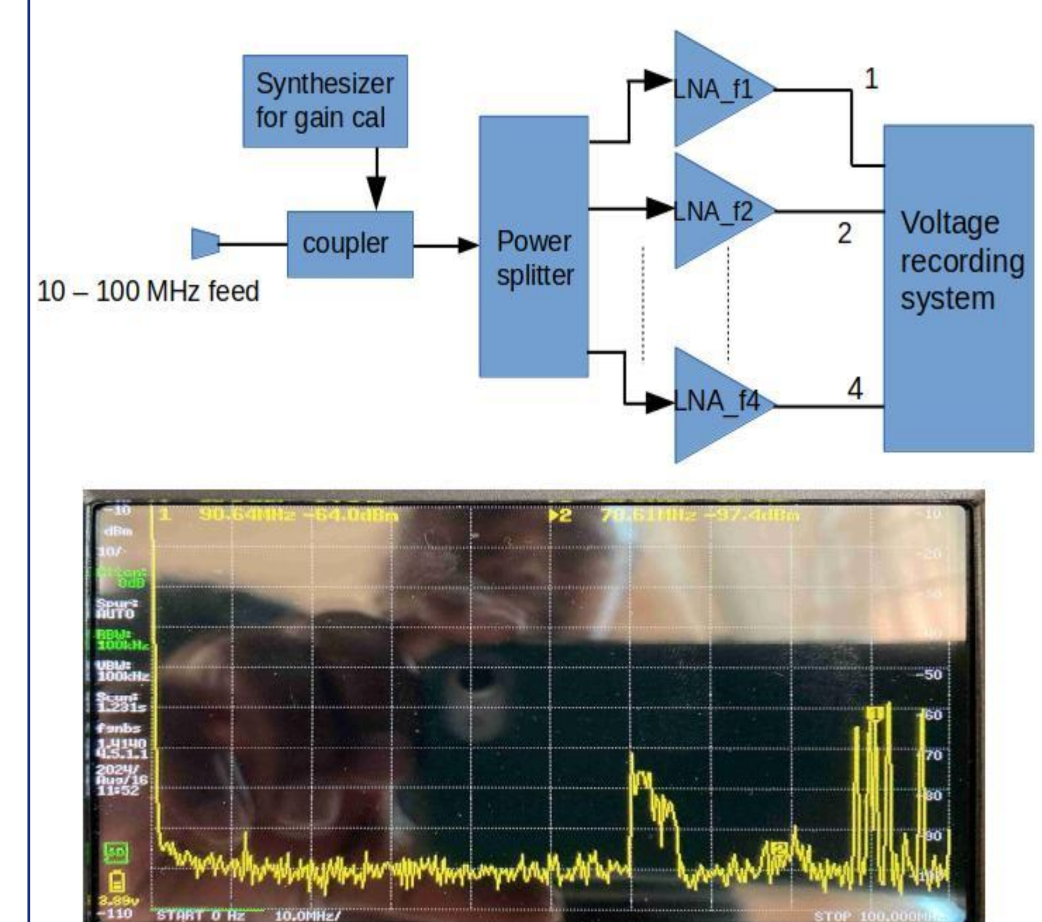


Figure 4: (Top) A concept of the high dynamic range receiver system under experimentation. We aim to develop the system over 10 to 100 MHz bandwidth. (Bottom) A spectrum in the 10 to 100 MHz frequency range from the RFI survey made at UCF.

Generally, two design aspects are to be considered to achieve the required dynamic range for radio astronomy observations: (1) the linearity of the analog system and (2) spurs and distortions in the ADC [2]. To achieve the highest possible dynamic range, we plan to divide the frequency range into sub-bands immediately after the feed, with a low-noise amplifier (LNA) tuned to each sub-band (see Fig. 4). Signals from each sub-band are then processed separately.

References

[1] M. Zheleva, C. R. Anderson, et al., “Radio Dynamic Zones: Motivations, Challenges, and Opportunities to Catalyze Spectrum Coexistence”, IEEE Communications Magazine, 61, 6, February 2023, pp. 156 - 162, doi:https://doi.org/10.1109/MCOM.005.2200389

[2] D. A. Roshi, “Noise Figure Analysis of a 0 - 2.5 GHz directly digitized radio astronomy receiver system”, CARSE report, July 2024, https://carseuprm.org/resources/publication-rscs/

Acknowledgements

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