RFI Mitigation for 3.3 GHz CH Observations with the Arecibo 12m Telescope

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Introduction

- CH 3.3 GHz lambda-doublet transitions trace CO-dark molecular gas undetectable via conventional 12CO observations.
- Pilot observations with the Arecibo 12 m telescope detected CH toward several Galactic center locations.

Challenge: Observations affected by strong radio frequency interference (RFI).

Solution: Developing a multi-antenna RFI mitigation system operating near 3.3 GHz.

- Post-correlation adaptive RFI cancellation & automated excision of contaminated data.
- Signals amplified, filtered, and digitized via RFSoC 4x2 ADCs; digital filtering reduces bandwidth to ~15 MHz (~1400 km/s).
- Supports voltage recording up to 1 hour; GPU-accelerated offline processing for algorithm development.
- Real-time GPU-based cross-correlation system in development for live post-correlation mitigation.

Goal: Present the design and development status of the RFI mitigation system at the Experimental Astronomy Lab, UCF.

A Reconfigurable System for Adaptive Cancellation of RFI

System Design (Fig. 1)

- **Hardware setup:**
  - Three dual-polarized reference antennas (3.1–3.4 GHz) and the electronics required to interface with Arecibo 12m telescope.
  - Each path: Low-Noise Amplifier → 3.18–3.35 GHz cavity bandpass filter → downconverted to ~140 MHz Intermediate Frequency (IF)
- **Digitization & data acquisition:**
  - Two RFSoC 4x2 boards, each with four ADCs, record voltage data to a server.
  - Board 1: 12m telescope + one reference antenna.
  - Board 2: Remaining two reference antennas.
  - ADC sampling: 245.76 MHz; digital FIR filter bank reduces bandwidth to ~15 MHz.
  - Outputs requantized to 16-bit, packetized, and transmitted via a 100 GbE interface to a server. (~7.9 Gbps total)

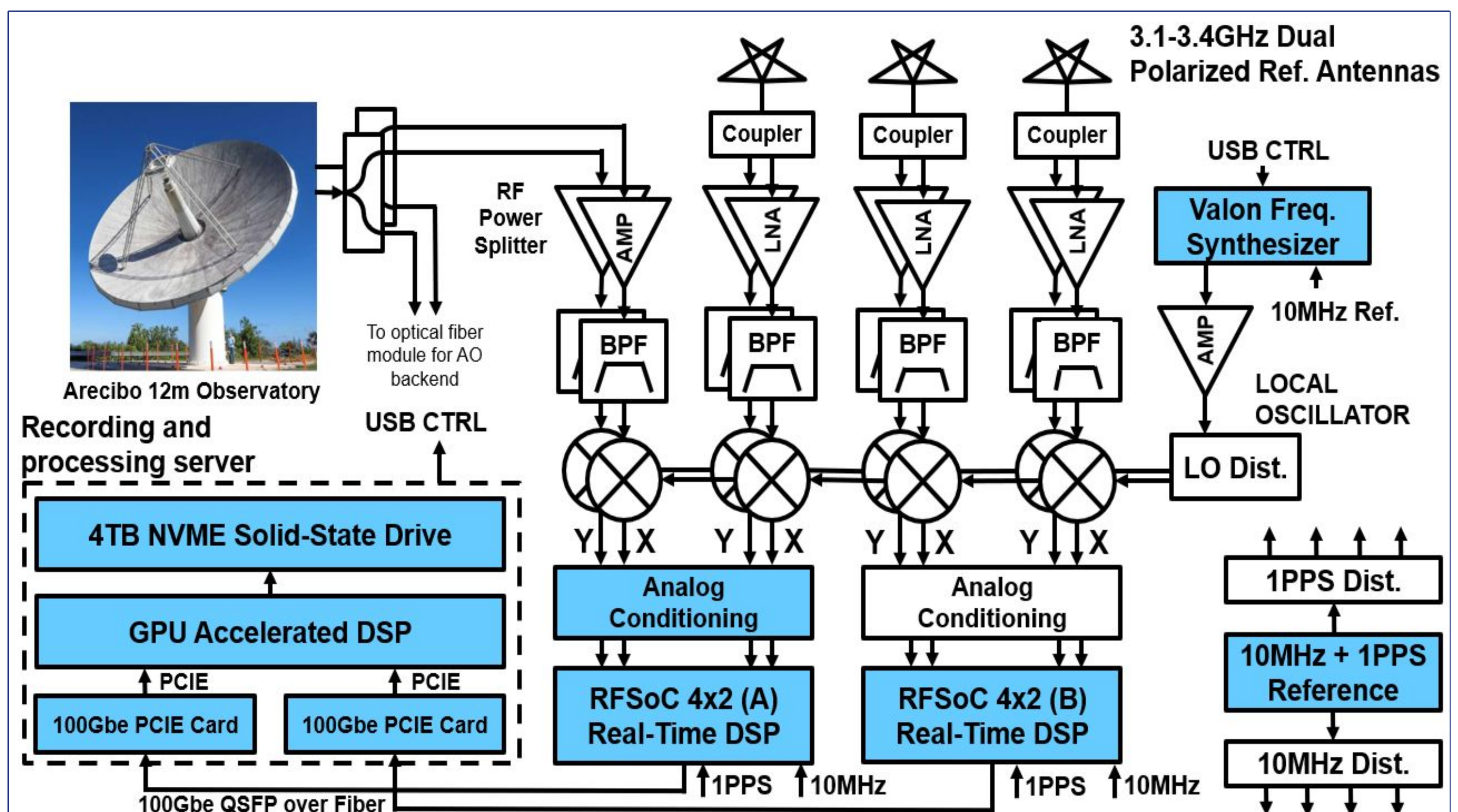

Fig. 1: A simplified block diagram of the reconfigurable system being developed for RFI mitigation research. The hardware, firmware, and software components highlighted in blue have been completed, integrated, and are currently undergoing lab testing

- **Observation requirements:**
  - Velocity coverage: ~1000 km/s (~11 MHz) near 3.335 GHz. Local Oscillator (LO) tunable for different spectral lines.
  - Velocity resolution: ~1 km/s (~11 kHz) near 3.335 GHz; offline GPU processing uses 4096-point FFT to compute all cross-spectra from 8 data streams with resolution of 15 kHz.
- **Synchronization:**
  - GPS-disciplined 10 MHz reference clock is used for both the FPGA and LO, along with a PPS (pulse-per-second) signal
  - Data acquisition server time is synchronized to GPS time through the Network Time Protocol (NTP)

Test Results & Status

- Hardware, software, and firmware development (blue blocks in Fig. 1) is complete or near completion.
- **Lab testing:** Correlated noise injected into all eight FPGA inputs.
- **Data processing:** Self- and cross-correlation spectra were computed from the recorded voltages using the offline processing software (Fig. 2).
  - Upper-left & lower-right: self/cross-spectra from each FPGA board.
  - Lower-left & upper-right: cross-correlations between boards.

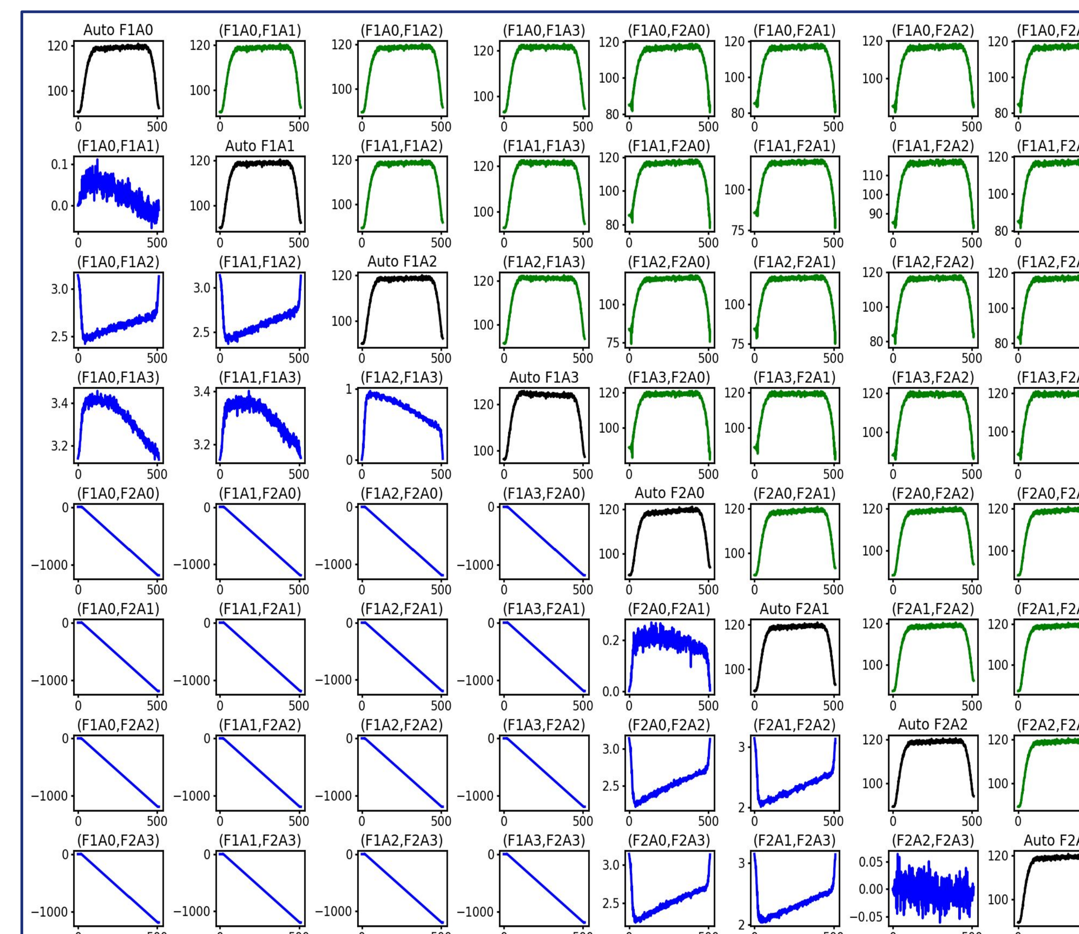

Fig. 2: Correlation matrix obtained by injecting correlated noise into all eight system inputs. Self-correlations, cross- correlation amplitudes, and phases are shown in black, green, and blue, respectively. The x-axis spans a 30.72 MHz frequency range, with correlation amplitudes (in dB) and phases (in radians) on the y-axis

- **Observation:** Phase ramp indicates pipeline delay mismatch in FPGA firmware.
- **Next steps:** Resolving pipeline delay issue to ensure accurate cross-correlation.

References

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