Two Element Broadband Radio Interferometer: Exploring the SKA-Low Frequency Band at Gauribidanur Radio Observatory

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Project Overview

This project was to set up two elements of Log-Periodic Dipole Antenna arrays and the front-end electronics and back-end receiver at Gauribidanur Radio Observatory(GRO) [**77.428 E 13.603 N**]. The antennas are operated in the frequency range of 150 MHz to 350 MHz, which explores the SKA-LOW frequency band. We conducted a single baseline interferometry to observe the Sun and Galactic Plane Transit.

Introduction

- Radio interferometry using Eight broadband Log-Periodic Dipole Antennas operating between 150-350 MHz frequency exploring the SKA Low Band.
- Antenna Array in East-West orientation along with front-end electronics and back-end receiver at Gauribidanur Radio Observatory.
- Antenna array response simulated using CST Software.
- Remote Data Acquisition System via Oscilloscope along with automation for remote operation
- Successful monitoring of solar and galactic plane transits, evidenced by distinct fringe patterns and phase plots.

SKA-Low

Square Kilometer Array-Low is an array of antennas to be installed in radio-quiet locations in West Australia. Our Setup at GRO explores the SKA Low-Frequency Band and aims to conduct supporting experiments in future.

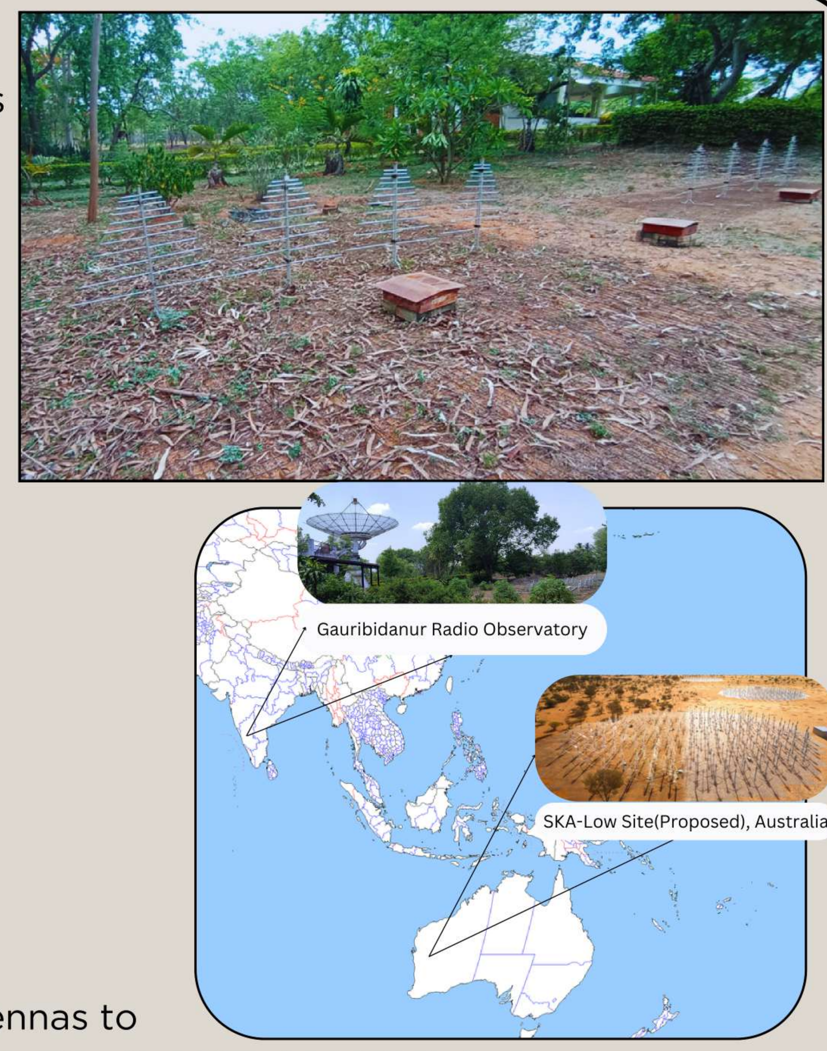


Fig. 1 : *LPDA Array @ Gauribidanur Radio Observatory, India and SKA-Low Site, Australia*

Antenna Design and Instrumentation

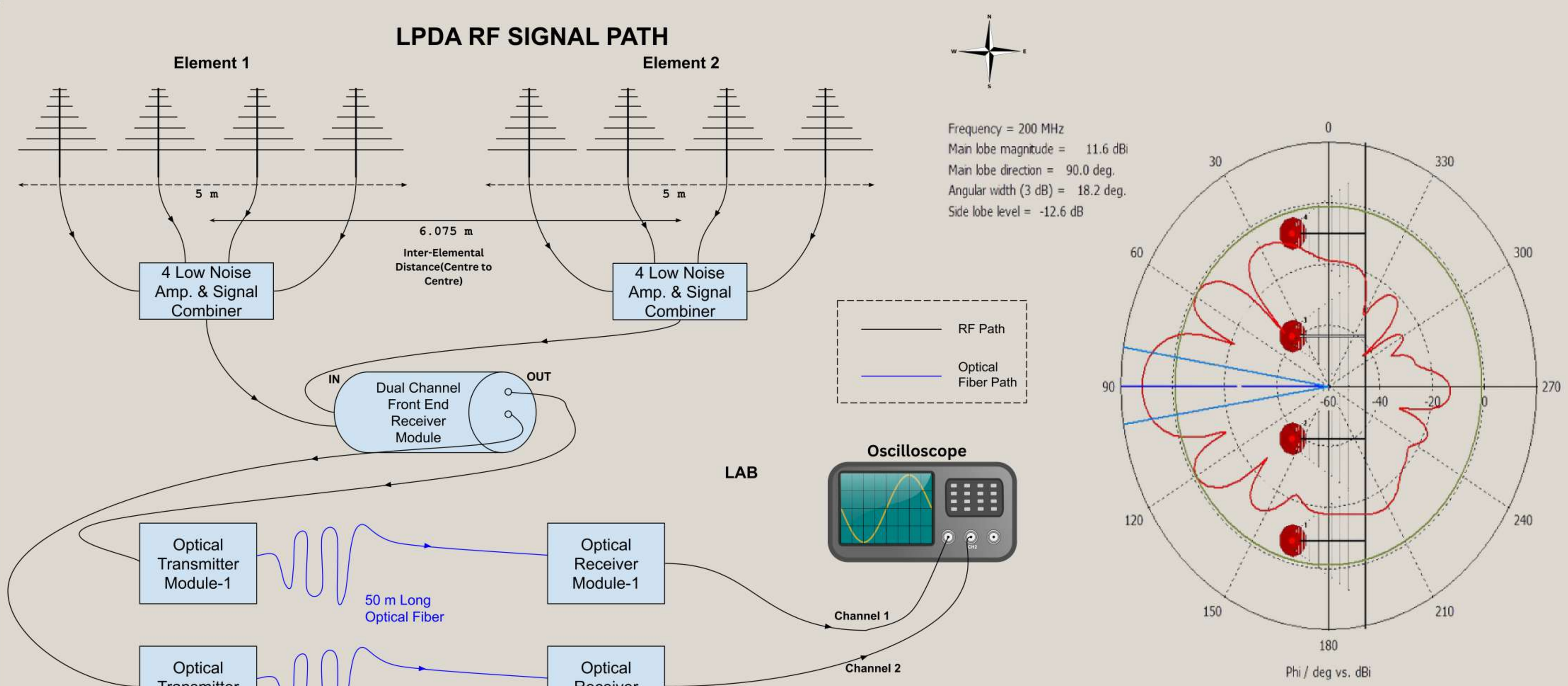
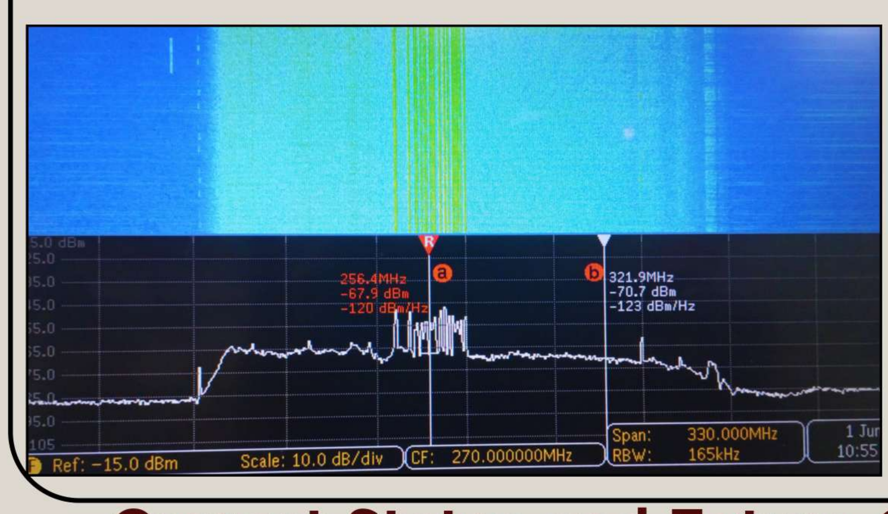


Fig. 2 & 3 : *Signal Flow Path from Antenna to Oscilloscope via Coaxial and Optical Fiber(**Left**) and 2D Farfield Directivity Beam Pattern of Antenna Array(**Right**)*

- The array of all eight antennas was simulated over CST Software: Overall directivity of about **12 dBi main lobe** and **18°(3 dB)** Beam in the sky.
- The front-end electronics, which amplifies the weak electrical signal and combines the signals from four antennas forming a single beam of each element, removes the FM Band, followed by a series of amplifications and attenuation and gets converted into optical to be transmitted over a 50 m long optical fiber.
- The Back-End Receiver has a photodiode-based receiver to convert it back into electrical and an amplifier to compensate for any transmission power loss. It is then monitored on a digital oscilloscope.
- All the electronics mentioned were developed in-house at Electronics Engineering Group, Raman Research Institute.



Weak voltage signals from the antennas after passing through amplifiers to boost up the signal, band pass filter to allow just the desired frequency range and we observe the spectrum in the spectrum analyzer.(Fig. 4) where the filter response (**cyan region**) and the satellite signals(**green lines**) can be seen

Fig. 4: *Frequency Spectrum and Spectrogram on Spectrum Analyzer*

Remote Data Acquisition System and Results

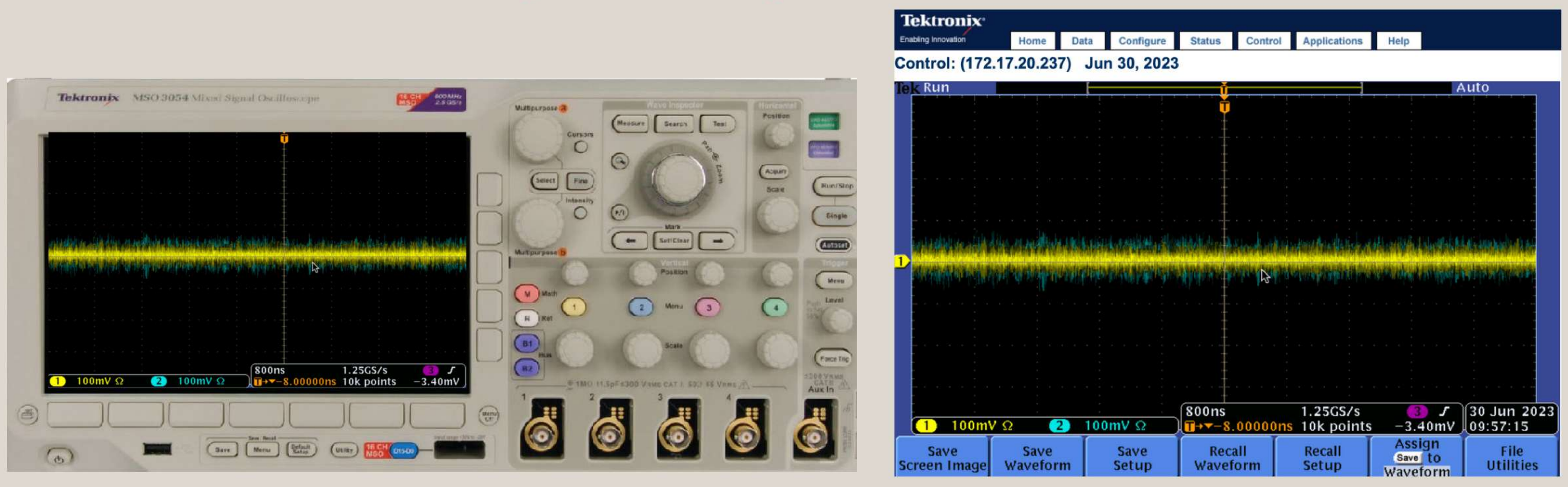


Fig. 5: *Digital Oscilloscope as a Signal Monitoring and Data Acquisition System(Tektronix MSO3054)*

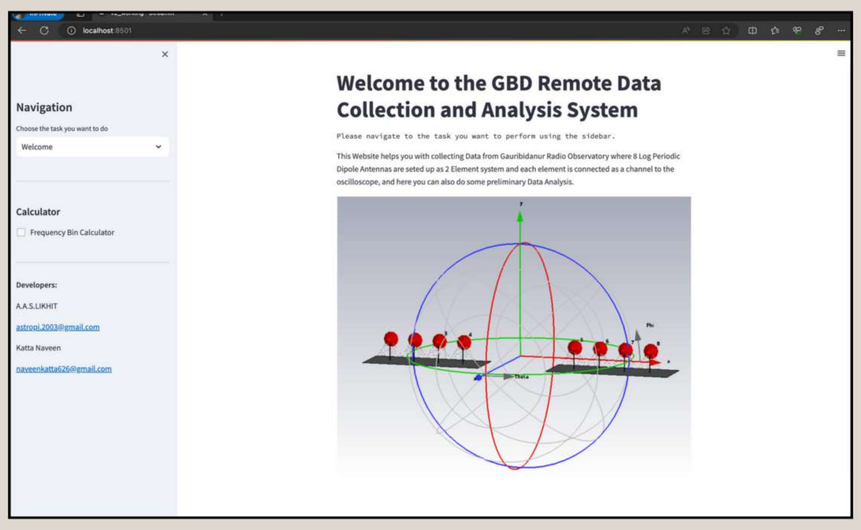


Fig. 6: *Web Interface developed for Automated Data Acquisition, Analysis and Download using Python Package* ***Streamlit****.*

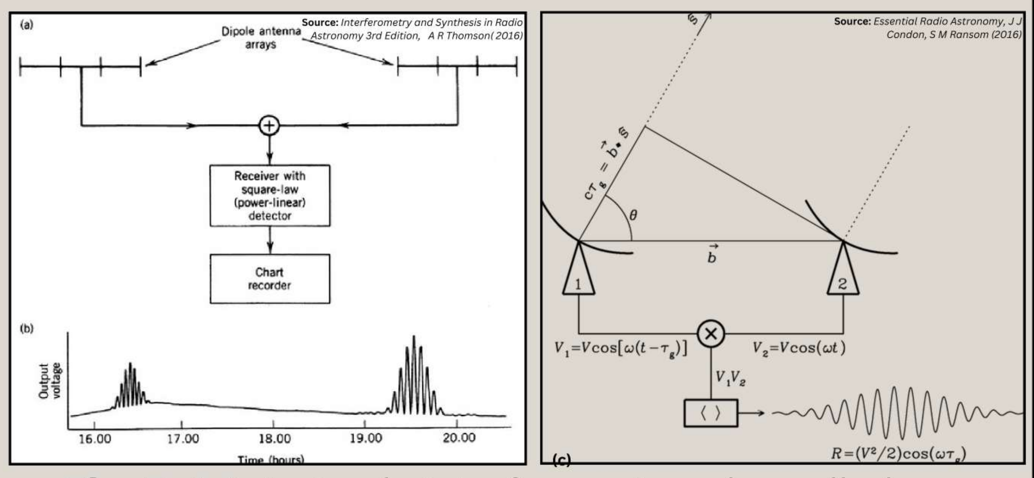


Fig. 7: (a) *A simple interferometer, also called an adding interferometer, in which the signals are combined additively.* **(b)** *Record from such an interferometer with east–west antenna spacing.* **(c)** *Multiplying Interferometer, where signals are multiplied and combined* ***(Our results are of a multiplying interferometer)***

Plots and Results

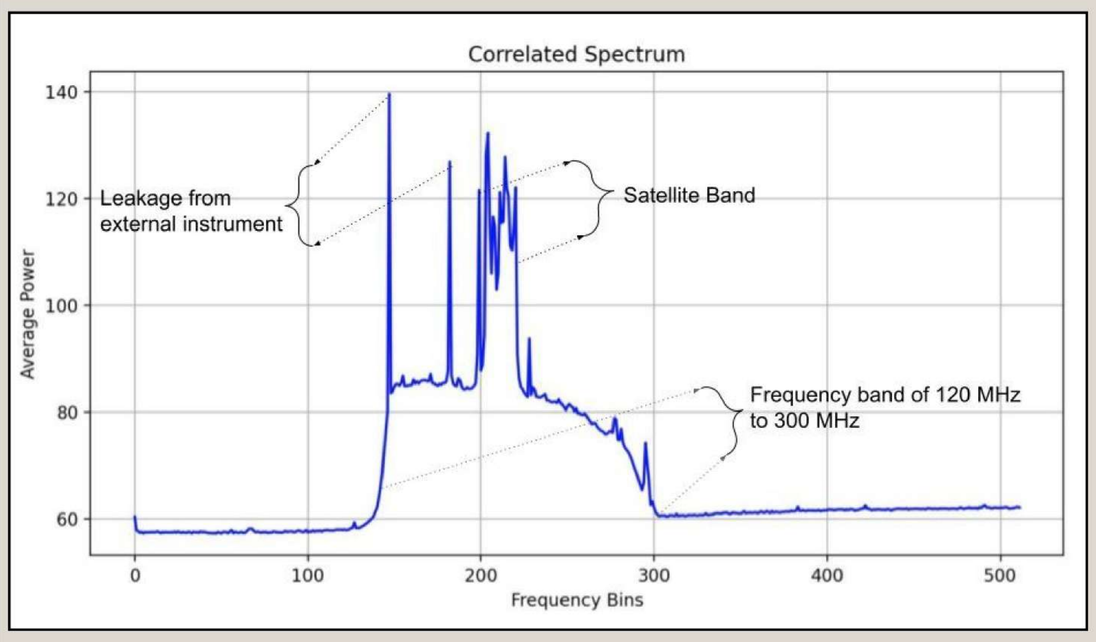


Fig. 8: *Correlated Spectrum Observed (one frequency bin represents 1.22MHz Bandwidth of Frequency)*

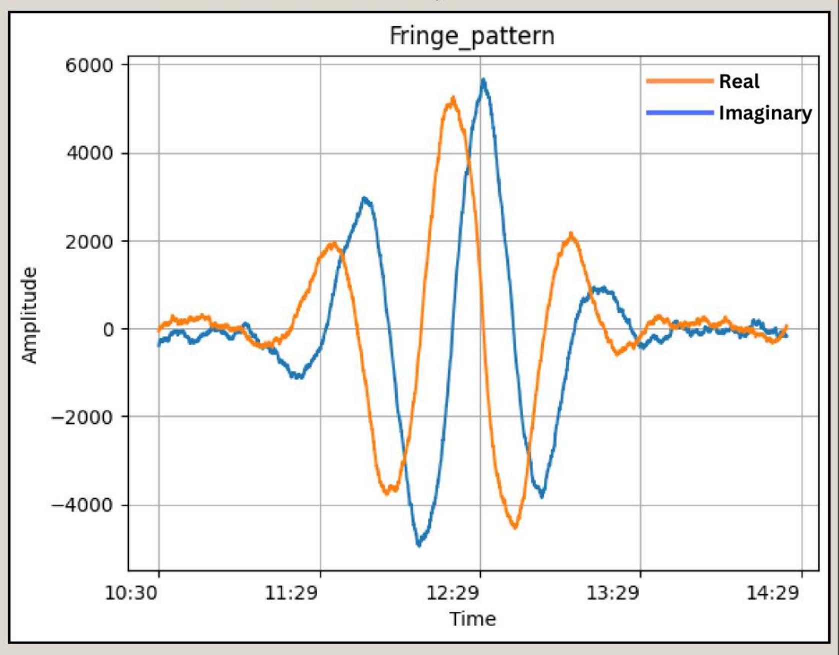


Fig. 9: *Fringe Pattern of Sun as on 11th July 2023*

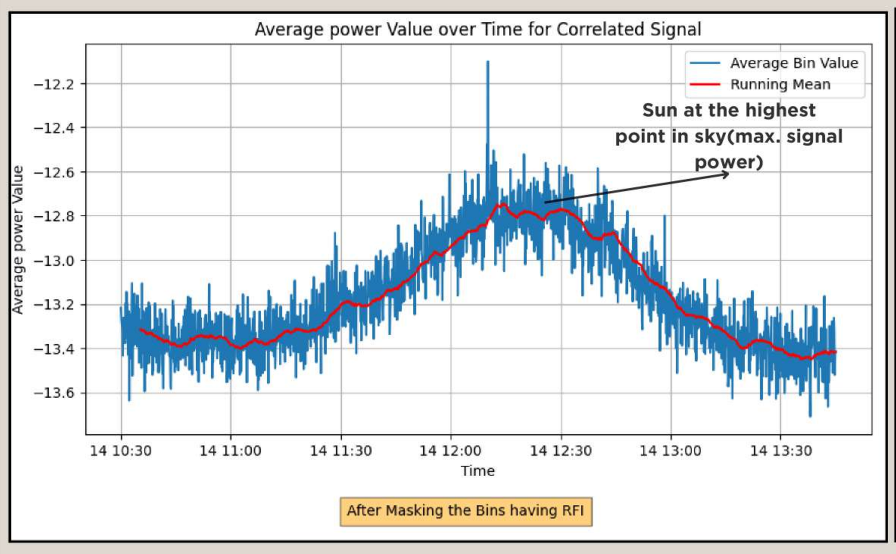


Fig. 10: *Variation of average power across all frequencies over time, revealing the Solar Transit Observation.*

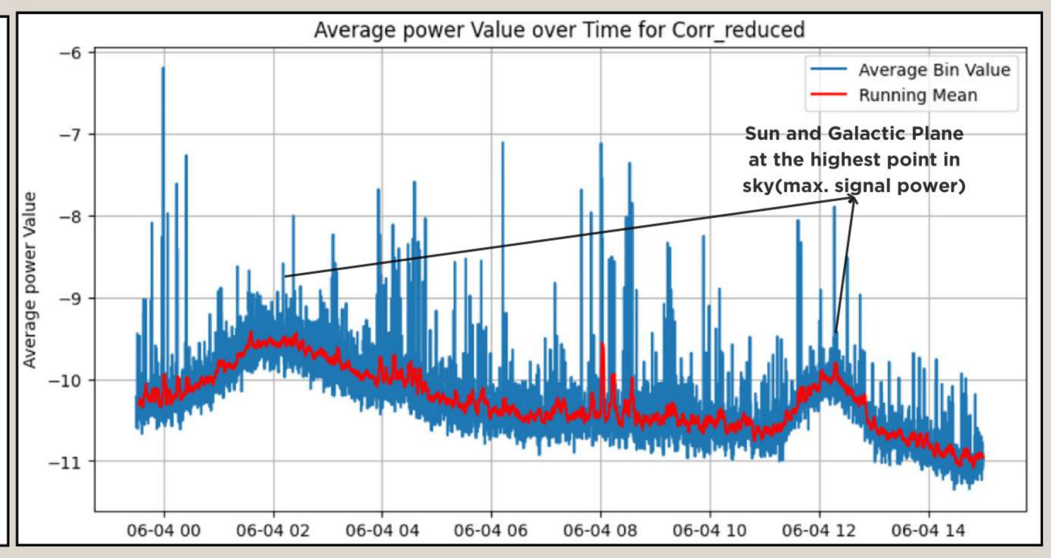


Fig. 11: *Variation of average power across all frequencies over time during the 17-hour robust observation of the sky on June 4, 2023, revealing both Galactic Plane Transit and Solar Trasit.*

Common Radio Frequency Interferences Spectroram

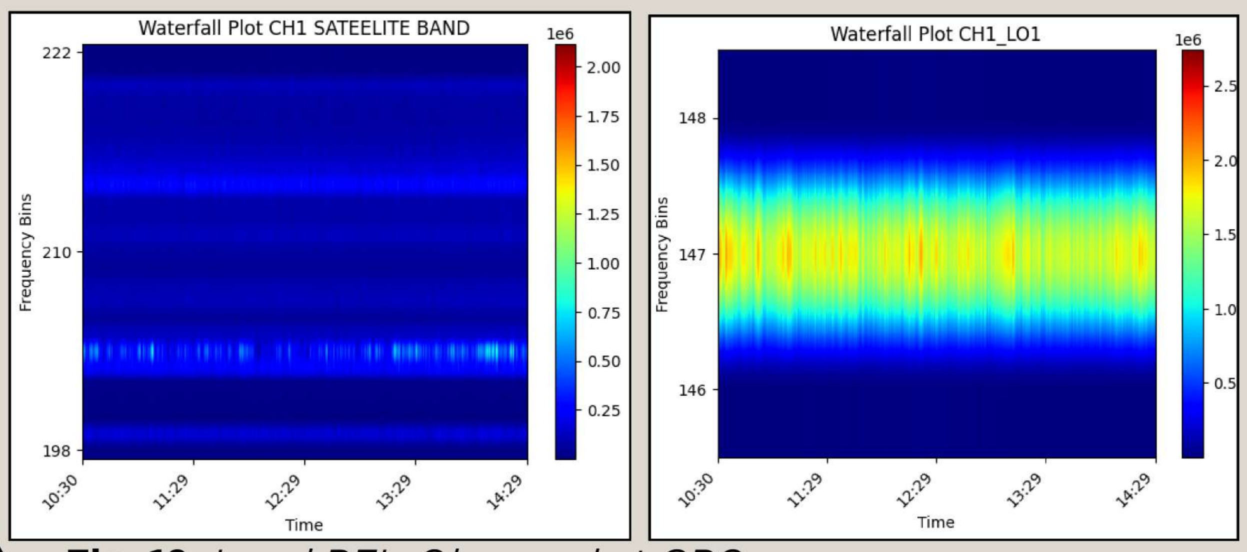


Fig. 12: *Local RFIs Observed at GRO*

- We found a constant RFI, which was quite dominant due to Satellite Signal in the range of 240 MHz to 270 MHz.
- Also, a local RFI of frequency oscillates between 180 MHz and 220 MHz in a day, which we found to be due to leakage from a local external instrument.

Current Status and Future Goals

- The antennas have been actively well-functioning for the last six months at GRO, and we are observing solar transit and obtaining fringes daily.
- Our setup will monitor radio frequency interferences (RFI) at the observatory.
- We aim to select the best observational band in our frequency range.
- As our frequency band explores the SKA-Low band(**50-350 MHz**), we aim for further expansion for the SKA-Low band at Gauribidanur Radio Observatory.

References

- "Innovative Web Tool for Remote Data Acquisition and Analysis: Customized for SKA Test LPDA Setups at Gauribidanur Radio Observatory", Agastya et. al. (Upcoming Manuscript for more about Web Interface)
- "Increased Number of Independent Beam for SKA-Low Tile Processing Module", a talk by Sahana Bhattramaki.(2024)
- "A Simple Radio Interferometer for characterizing the SKA Low Digital Receivers", a talk by Abhishek R.(2024)

Scan for details on Web-Interface

Acknowledement

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