Ionospheric Correction and Enhancement of Radio Signals for PNU Radio Telescope

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Abstract

This project aims to improve PNU Radio Telescope signals at 1420 MHz using MATLAB to reduce ionospheric effects and radio frequency interference (RFI) through adaptive filtering and ionospheric correction based on TEC and Kp-index data. A comparison between LOFAR and the PNU Radio Telescope was also conducted to evaluate signal processing performance. The results showed improved signal-to-noise ratio (SNR) and radio observation quality.

Introduction / Background

Radio astronomy plays an important role in studying celestial objects and understanding the universe through radio-frequency observations. One of the most important frequencies in radio astronomy is the hydrogen line at 1420 MHz, which is widely used to observe neutral hydrogen in the Milky Way galaxy.

Before reaching ground-based radio telescopes, radio signals travel through the ionosphere, a layer of Earth's atmosphere containing free electrons and ionized particles. These particles affect electromagnetic waves and introduce signal distortion, phase shift, delay, and scintillation noise, reducing signal quality and observation accuracy.

This project investigates the influence of ionospheric disturbances on radio signals using real observational data from the PNU Radio Telescope. MATLAB-based signal processing techniques, including RFI filtering and TEC-based ionospheric correction, were applied to analyze and improve the received signals.

System Model / Methodology

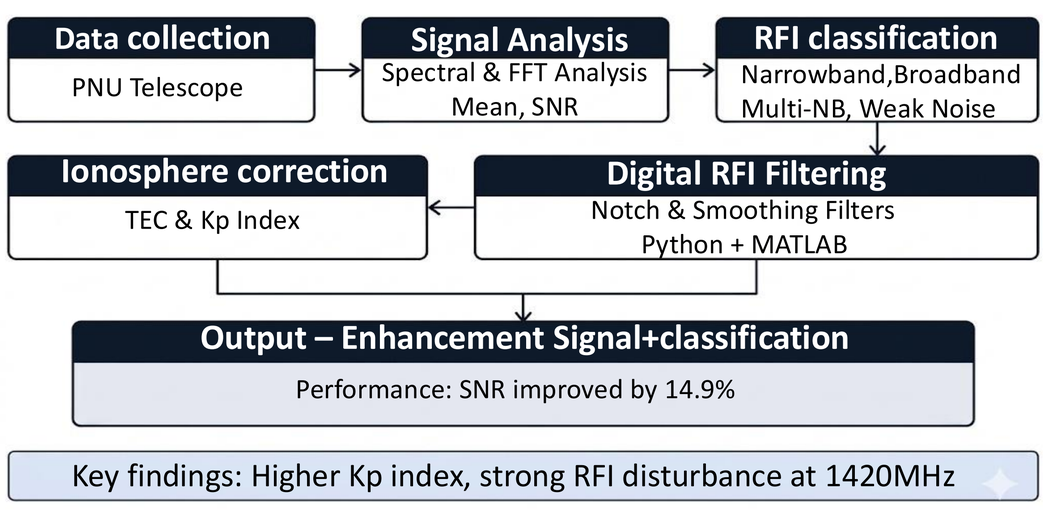
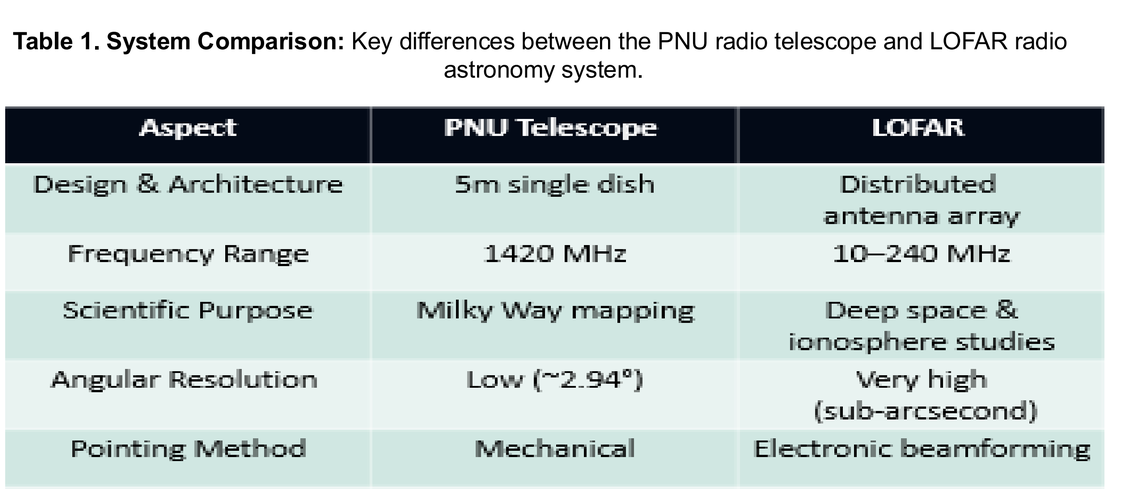


Table 1. System Comparison: Key differences between the PNU radio telescope and LOFAR radio astronomy system.

Aspect	PNU Telescope	LOFAR
Design & Architecture	5m single dish	Distributed antenna array
Frequency Range	1420 MHz	10–240 MHz
Scientific Purpose	Milky Way mapping	Deep space & ionosphere studies
Angular Resolution	Low (~2.94°)	Very high (sub-arcsecond)
Pointing Method	Mechanical	Electronic beamforming
Cost & Complexity	Low-cost, simple	High-cost, complex

Proposed Solution / Main Idea



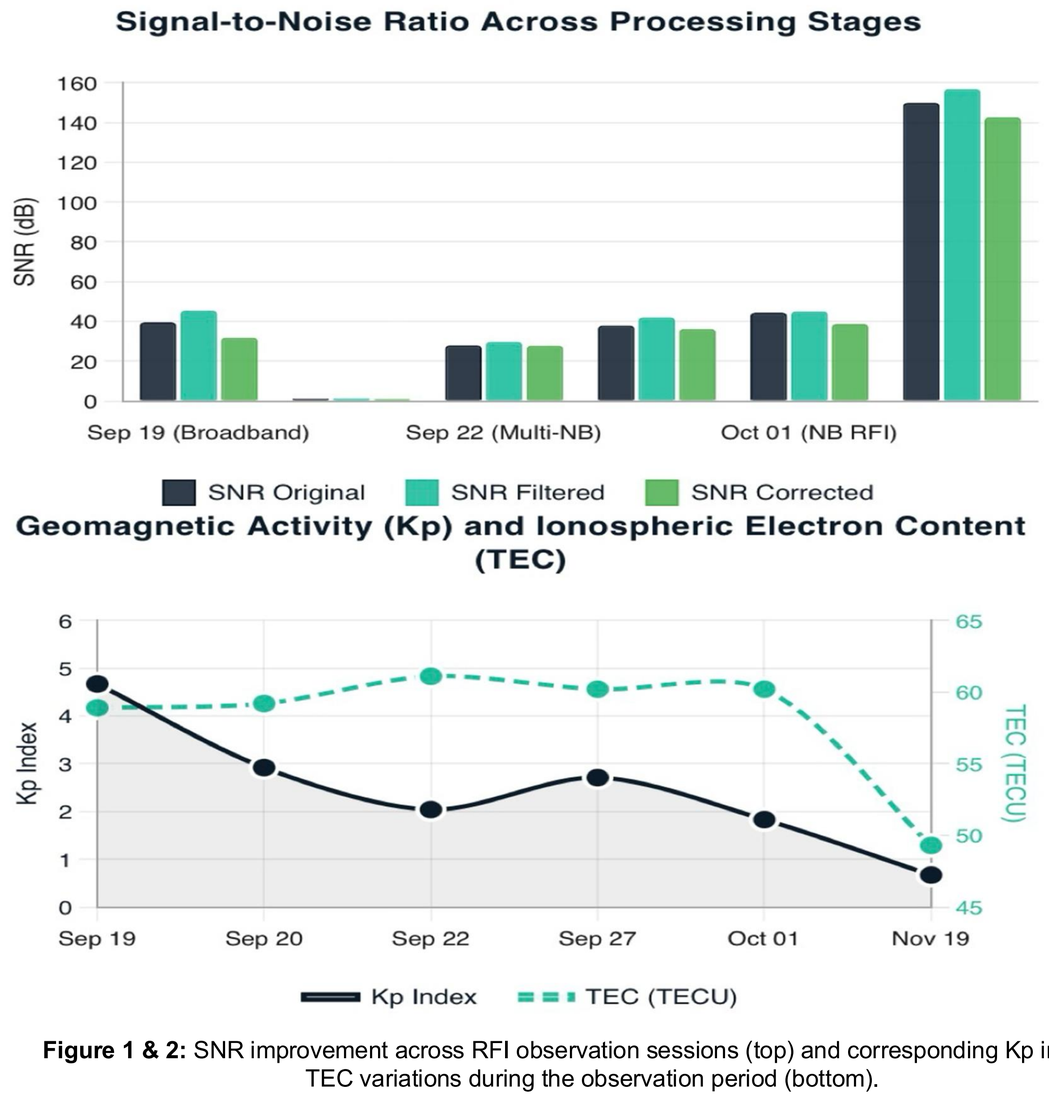


Figure 1 & 2: SNR improvement across RFI observation sessions (top) and corresponding Kp index vs. TEC variations during the observation period (bottom).

Results / Simulation / Discussion

- Processing Pipeline: Developed a MATLAB-based tool for RFI filtering and ionospheric phase correction at 1420 MHz.
- Signal Enhancement: Observed signal-to-noise ratio (SNR) improvement of up to 14.8% after digital filtering.
- Phase Calibration: Estimated ionospheric phase shifts using TEC-based observational data from Riyadh for signal correction.
- Environmental Impact: Results suggested a correlation between atmospheric distortion and elevated Kp index levels.
- Performance: The pipeline improved signal clarity by reducing noise and phase distortion, supporting more reliable radio telescope signal analysis.

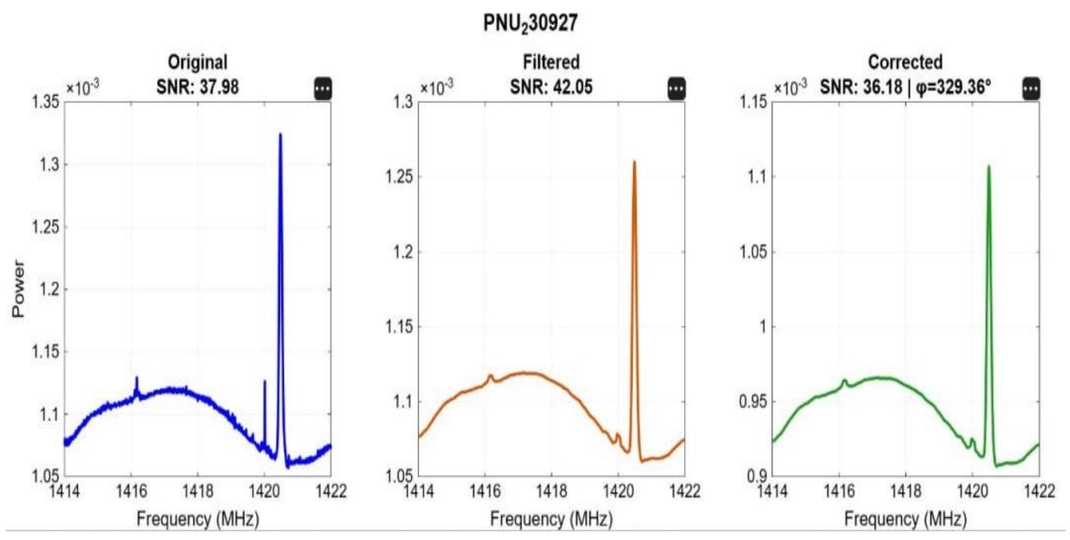


Figure 1. Signal Processing Stages: Original, filtered, and phase-corrected radio signals after RFI mitigation and TEC-based correction.

Table 2: Validation of PNU ionospheric results in comparison with global regional TEC and stability characteristics.

Region	TEC Range(TECU)	Phase Stability	Validation Status
Equatorial	High(40-100+)	Low (High Fluctuations)	Expected High Activity
Polar	Variable	Very Low (Intense)	Strong Disturbances
Mid-Latitude(Saudi)	15-35(Quiet)	High Stability	Regional Baseline
Our Results(PNU)	49.3-61.1	3.57 - 5.93 rad	Physically Valid

Conclusions

In this project, a MATLAB based signal processing pipeline was developed to analyze and enhance 1420 MHz radio telescope observations affected by ionospheric disturbances and radio frequency interference. The implemented TEC based ionospheric correction and digital filtering techniques demonstrated measurable improvement in signal quality. Validation against published ionospheric studies confirmed physically consistent phase and SNR behavior, supporting reliable PNU radio telescope signal analysis.

References:

ElectroSpace II Competition 2026

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