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Reducing Electromagnetic Interference in Telescopes Through Signal Filtering

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Abstract

This project aims to reduce electromagnetic interference (EMI) in radio telescopes through digital signal filtering.
A 50 Hz sine wave representing a clean astronomical signal was simulated and combined with artificial interference from GSM (200 Hz), LTE (300 Hz), and WiFi (400 Hz), which can degrade the accuracy of telescope data.
To suppress the interference, three Butterworth band-stop filters were designed, each targeting a specific frequency.
MATLAB simulations demonstrated a 96% reduction in noise power, with the filtered output closely matching the original signal.
This software-based approach enhances radio telescope performance without the need for physical shielding, offering a practical solution for modern radio astronomy.

Introduction / Background

In recent years, the field of radio astronomy has faced increasing challenges due to the increase in radio frequency interference (RFI) caused by human interventions.
Telescopes designed to capture signals often encounter interference from nearby telecommunications towers, electronic devices, and other sources of electromagnetic radiation. This interference can severely impact the quality and reliability of collected astronomical data. Maintaining the purity of received signals is critical for accurate observation and interpretation. Therefore, developing methods to filter out unwanted signals without affecting the desired astronomical information has become increasingly important.
To address this, a Butterworth Band-Stop Filter was selected for this project because of its ability to effectively remove unwanted interference within a specific frequency range while preserving the integrity of surrounding signals. This filter is known for Controlled Attenuation in the Stopband and Stability and Simplicity.

System Model / Methodology

Figure 3. Flow chart

Goal of the system:
The code aims to remove radio frequency interference (RFI) caused by GSM, LTE, and WiFi signals from a clean astronomical signal.
Main components:
Original signal: A simulated clean astronomical sine wave (50 Hz).
Interference: Simulated RFI from common sources: GSM at 200 Hz, LTE at 300 Hz, WiFi at 400 Hz.
Filtering process: Three cascaded Butterworth Band-Stop filters, each designed to remove one interference band.
Process flow:
Signal Generation: Create the clean 50 Hz sine wave.
Add Interference: Combine the signal with GSM, LTE, and WiFi noise.
Filtering Stage:
Filter 1: Removes 200 ± 10 Hz (GSM).
Filter 2: Removes 300 ± 10 Hz (LTE).
Filter 3: Removes 400 ± 10 Hz (WiFi).
Output: Final filtered signal with minimal distortion and noise removed.
Filter type used:
Butterworth Band-Stop Filter – chosen for its smooth response and ability to reject unwanted frequencies without introducing ripples.

Proposed Solution / Main Idea

In this project, we propose a signal filtering system designed to reduce electromagnetic interference (EMI) affecting radio telescope data.Our approach involves simulating noisy astronomical signals and applying a digital Butterworth Band stop filter to suppress unwanted high-frequency interference while preserving the essential low-frequency signals from celestial sources.The method demonstrates a significant improvement in signal clarity, ensuring more accurate astronomical observations without the need for physical shielding materials.

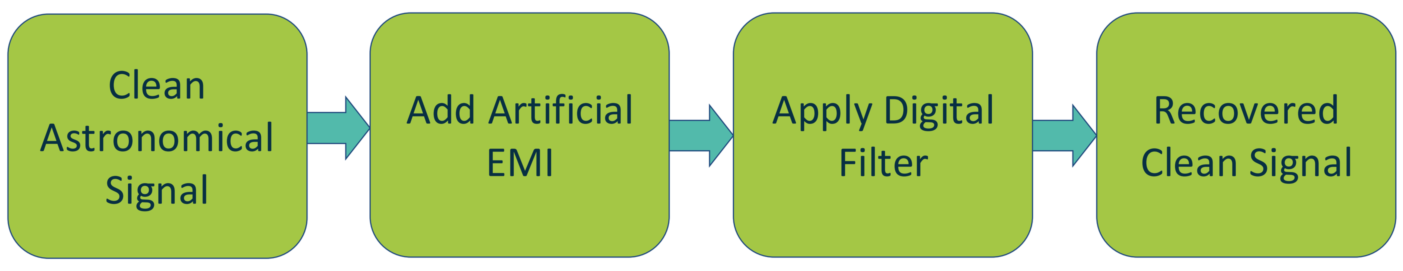

Figure 1. Signal Filtering Process Flow

Results / Simulation / Discussion

A MATLAB simulation was conducted to evaluate filtering on a noisy astronomical signal. A 50 Hz sine wave was generated to represent clean telescope data and was corrupted with simulated interference from GSM (200 Hz), LTE (300 Hz), and WiFi (400 Hz).

Three Butterworth band-stop filters were applied, each targeting one of the interfering frequencies. A 6th-order Butterworth low-pass filter (cutoff at 100 Hz) was also tested to isolate the 50 Hz signal from 200 Hz interference.

Before filtering, noise accounted for approximately 25% of the total signal power. After filtering, it dropped to just 1%, indicating a 96% reduction.

Simulation plots show the noisy signal was visibly distorted, while the filtered output closely matched the original. The Butterworth filters effectively removed narrow-band interference while preserving signal integrity, confirming their suitability for EMI suppression in radio telescope applications.

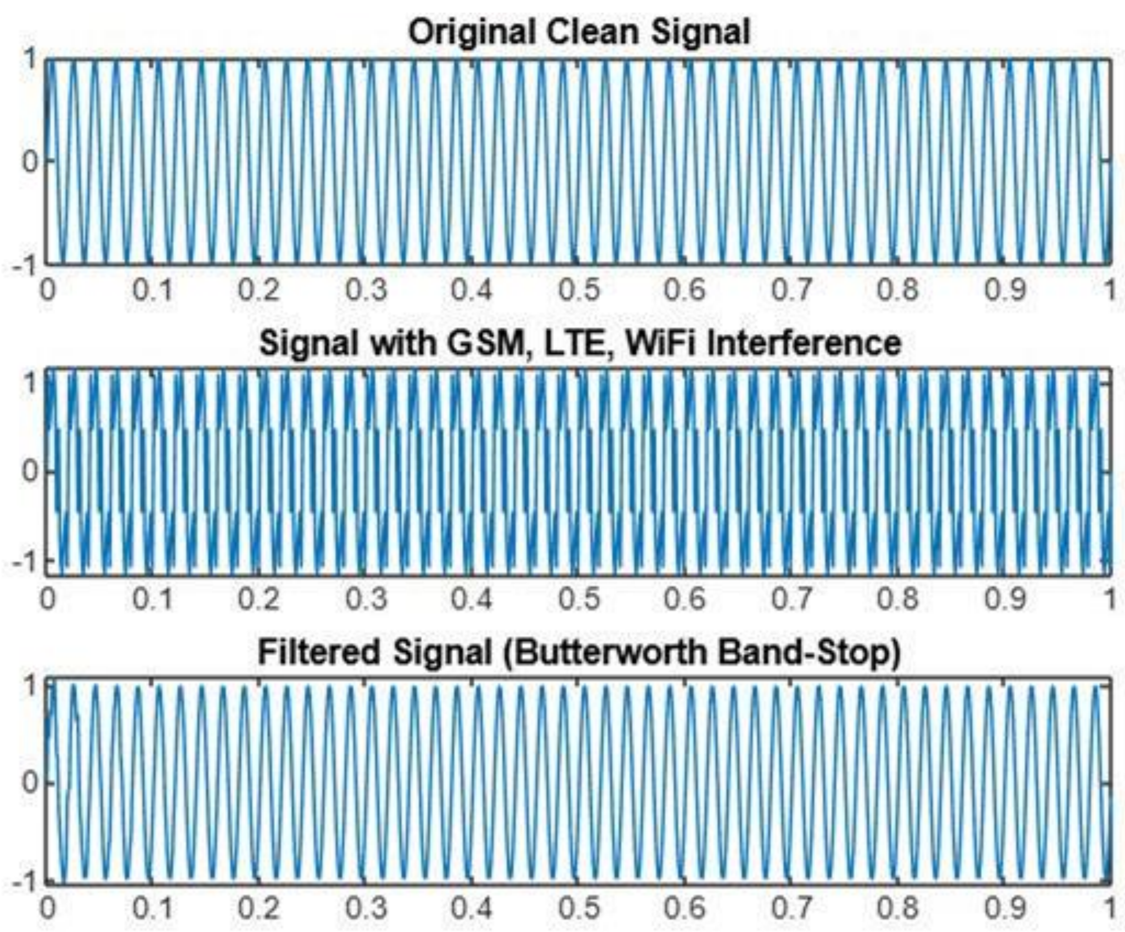

Figure 2. MATLAB simulation of signal filtering to reduce electromagnetic interference.

Conclusions

In this project, we implemented digital Butterworth band-stop filters to minimize electromagnetic interference (EMI) from GSM, LTE, and WiFi signals in radio astronomy applications. Our solution effectively reduced unwanted noise and enhanced the clarity and accuracy of astronomical signals. This software-based approach improves the performance of radio telescopes and offers potential for future development in other advanced signal processing fields.

References