

Abstract

DE-LEO is an angle-based signal processing approach proposed to mitigate Low Earth Orbit (LEO) satellite interference affecting radio telescopes operating near the **1420 MHz hydrogen line**. The project addresses increasing radio frequency interference caused by large LEO satellite constellations, especially near the telescope boresight where interference becomes strongest. The proposed solution divides satellite motion into three boresight regions (**5°, 15°, and 45°**) and applies adaptive filtering intensity based on interference severity at each angular region. MATLAB simulations were performed using angle-dependent antenna gain, thermal noise, white noise, and modeled LEO interference signals. The results demonstrated significant interference suppression while preserving the received signal behavior. Optimization analysis identified an effective filtering intensity near **0.22**, balancing interference reduction and filtering penalty.

Background

Radio telescopes operating near the 1420 MHz hydrogen line are increasingly affected by radio frequency interference (RFI) due to the rapid growth of LEO satellite constellations. The large number and continuous movement of these satellites have made interference mitigation a major challenge in modern radio astronomy. Since the interference strength varies with the satellite’s angular position relative to the telescope boresight, adaptive mitigation strategies are required. Previous studies have identified SatTrack-defined boresight regions at (5°, 15°, and 45°) as critical angular positions for interference analysis.

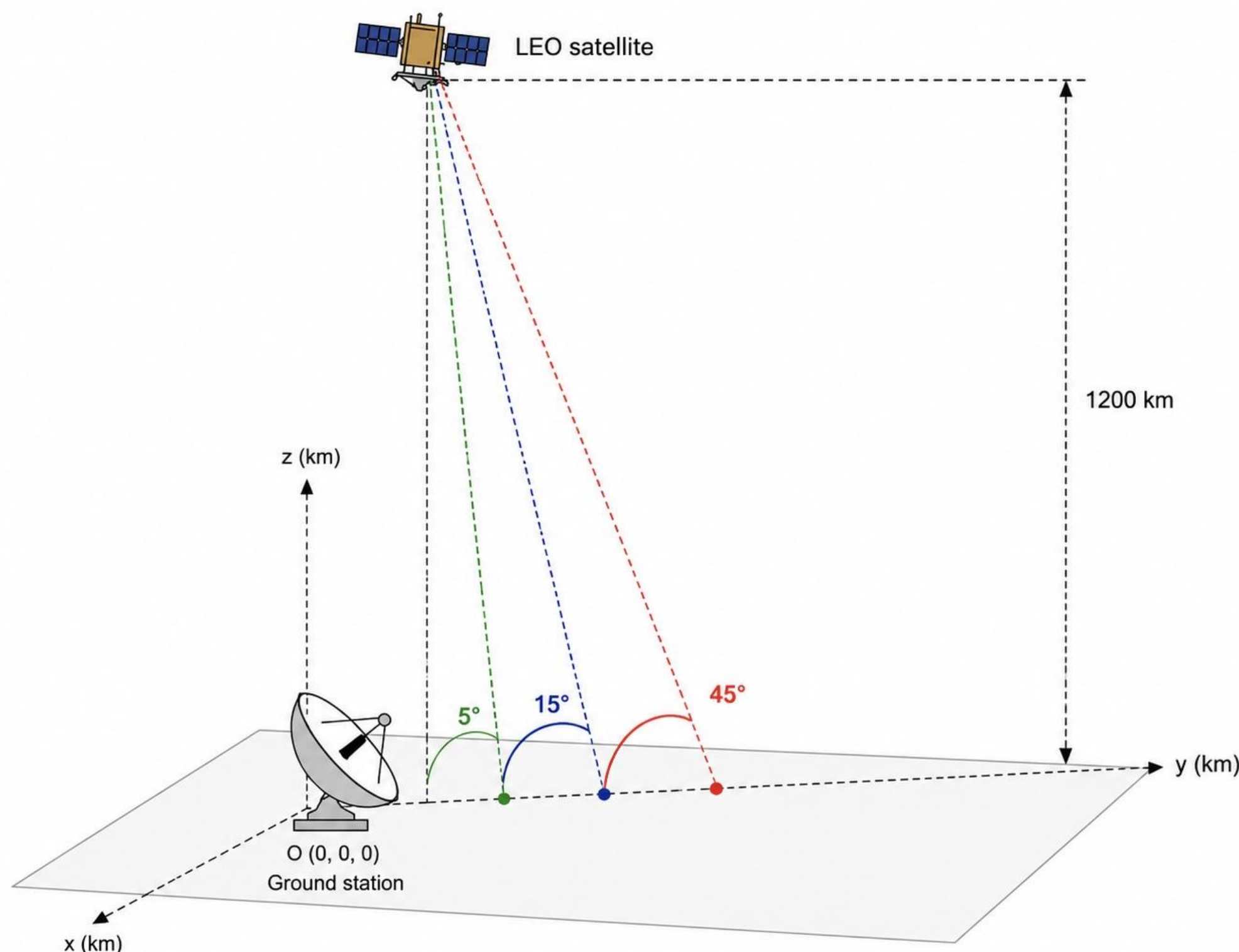


Figure 1. Geometric relationship between the radio telescope and LEO satellite at different boresight angles [1].

System Model

- **Signal Framework:** Defines the input as a composite of the received astronomical signal, dynamic LEO interference, and aggregate random noise.
- **Adaptive Mitigation:** Implements an Angle-Dependent Filter that scales suppression intensity in real-time based on the satellite’s spatial position.
- **Segmented Excision:** Operates across three intensity zones to balance RFI Rejection with Spectral Integrity.
- **Signal Optimization:** Applies a Moving Average Filter to smooth the mitigated signal and reduce residual noise.

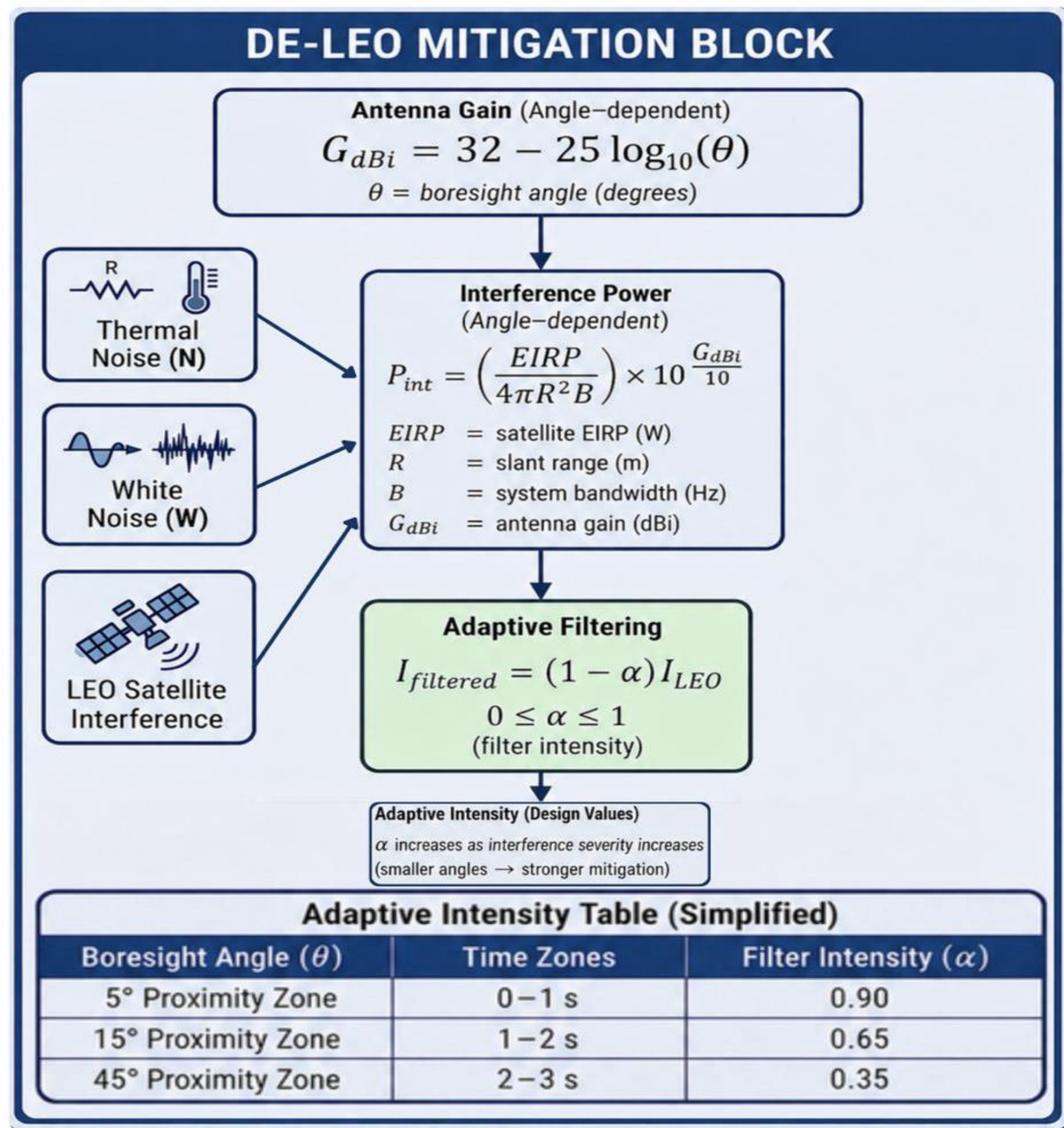


Figure2. DE-LEO Block Diagram.

Proposed Solution

DE-LEO applies a fixed filter with **adaptive intensity** to mitigate LEO satellite interference affecting radio telescopes operating near the **hydrogen-line** observation band.

System Description:

- Satellite motion divided into three **boresight angular regions**
- Filter intensity adapts according to interference severity at each **region**:
 - 5° → $\alpha = 0.90$ → High Interference → **Strongest suppression**
 - 15° → $\alpha = 0.65$ → Moderate Interference
 - 45° → $\alpha = 0.35$ → Low Interference → **Lightest suppression**

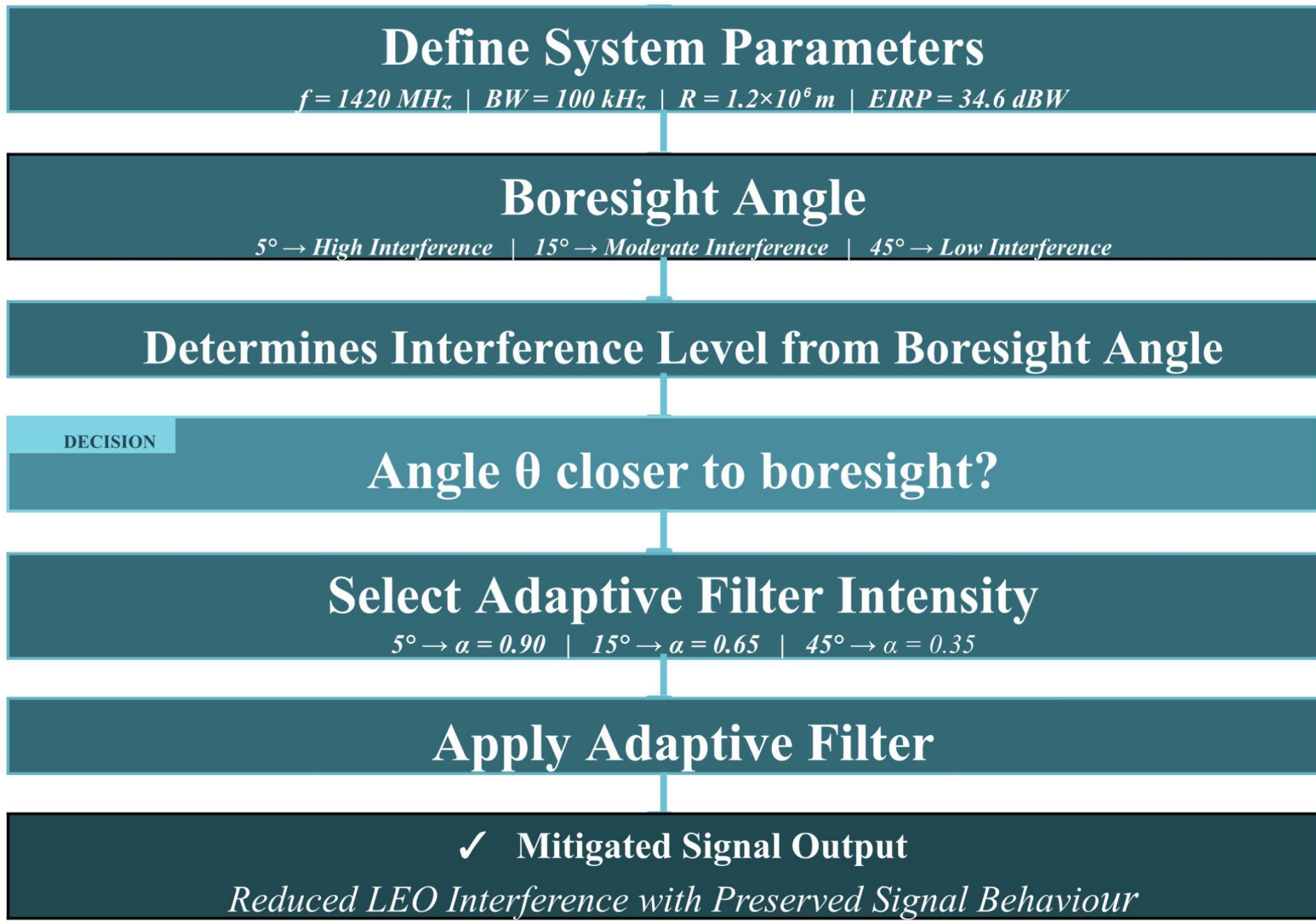


Figure 3. DE-LEO Processing Flowchart

Simulation Results

► Time-Domain Analysis (Figure 4):

- **Pre-Mitigation:** Severe Leo interference appears near the 5° boresight region due to peak antenna gain , with high-amplitude fluctuations >5 that completely mask the weak astronomical signal.
- **Post-Mitigation:** The DE-LEO algorithm adaptively suppresses interference amplitude across all angular regions to stabilize the signal while preserving its natural astronomical characteristics.

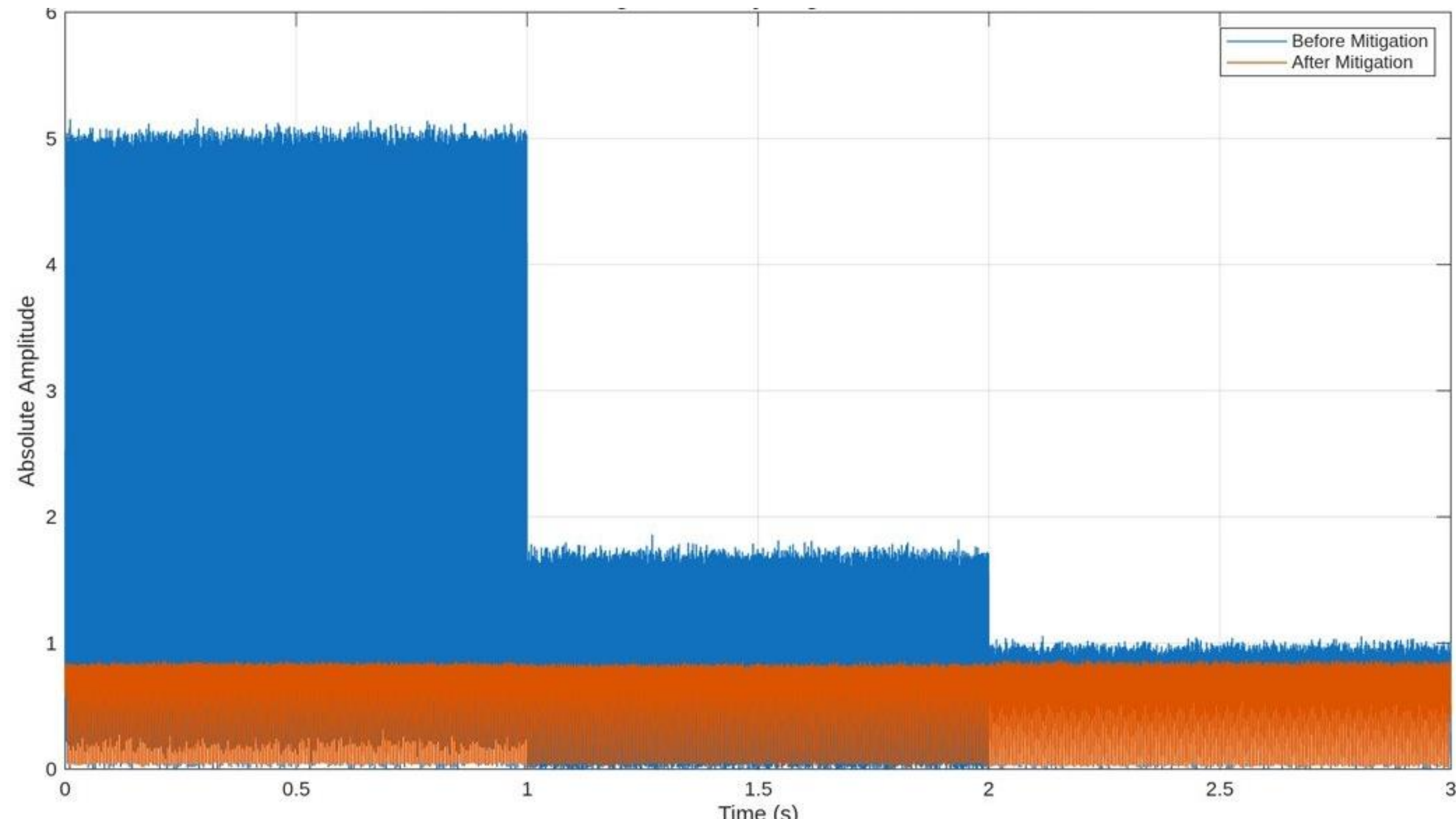


Figure 4. Received Signal Before and After Adaptive LEO Interference Mitigation (3x10^6 scale)

- Figure 5: Shows significant interference suppression across all angles, achieving a **36 dB** reduction at the critical 5° boresight region.
- Figure 6: Identifies the optimal filtering balance at $\alpha \approx 0.22$, successfully minimizing residual interference while preventing signal penalty.

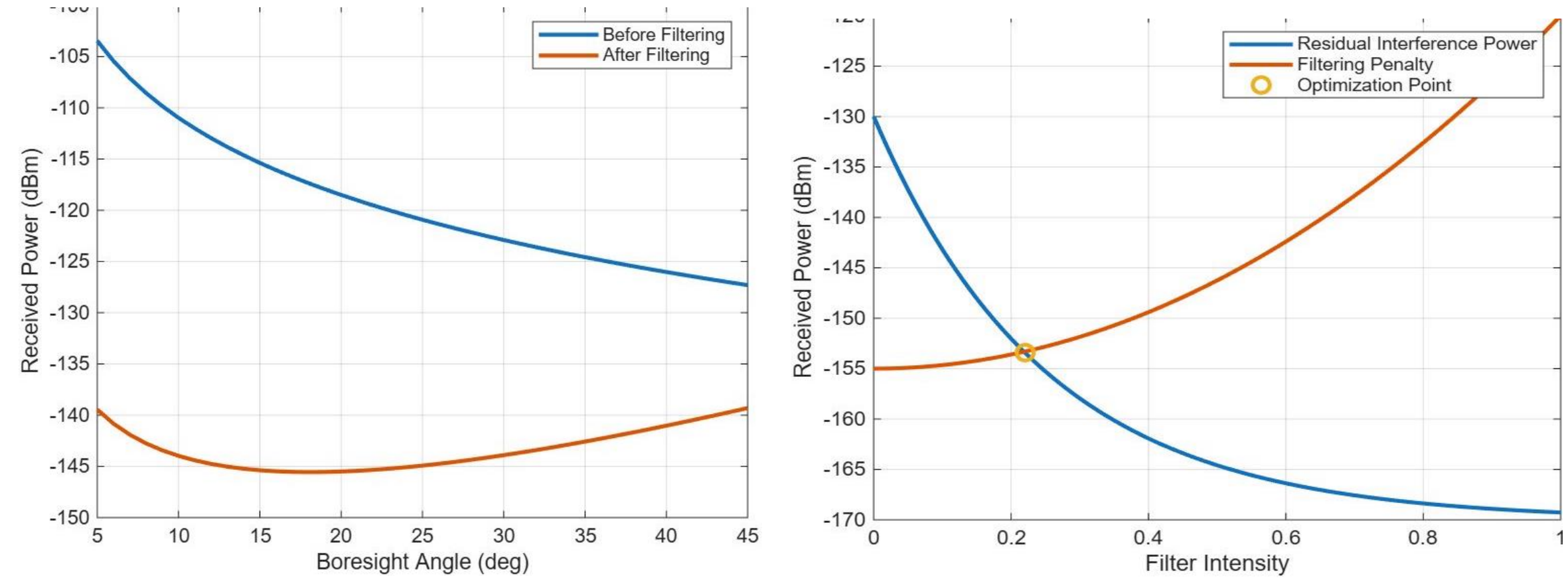


Figure 5. Interference Power vs Boresight Angle

Figure 6. Adaptive Mitigation Optimization Curve

Conclusions

Table 1. Interference mitigation performance at 5°, 15°, and 45°.

Angle (°)	Before Mitigation (dBm)	Reduction (dB)	After Mitigation (dBm)
5°	-103.45	36	-139.45
15°	-115.38	30	-145.38
45°	-127.31	12	-139.31

The findings show that the DE-LEO approach successfully decreased RFI at all evaluated angles. At 5°, the greatest interference suppression of 36 dB was attained.

Contact



ElectroSpace II Competition 2026

Acknowledgments

King Abdulaziz City for Science
and Technology (KACST)

Reference

