Interference Localization and Mitigation in Synthetic Aperture Radars Using Variable Space-Frequency Filter

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Introduction

Radio Frequency Interference (RFI) in Synthetic Aperture Radar (SAR) is a daunting challenge that affects the SAR sensing reliability and its image quality. To ensure that SAR remains a powerful tool for Earth observation, this work presents an effective two-dimensional tunable attenuation space-frequency (azimuth-range) filtration applied on raw SAR data.

Aims

- **SAR data modelling**: using SEMUS [1] framework for emulating RF-level spaceborne raw SAR level-0 data.
- **RFI data modelling:** generation and injection of arbitrary RF Interference into raw SAR data, creating contaminated data.
- **RFI localization in raw data:** using the power profile and the estimated spectral characteristics of the interference to locate interferer's position.
- **RFI mitigation:** using customized complex 2D azimuth-range tunable attenuation BSF to eliminates RFI with minimal data loss.
- **Image formation:** Using SEMUS to focus the raw SAR data into level-1.

Methodology

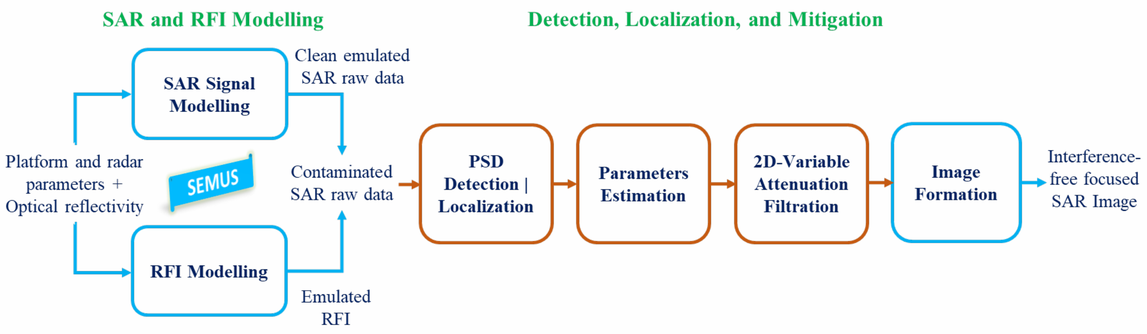

Figure 1: The detailed architecture of the proposed localization and mitigation approach.

A tunable 2D-space-frequency filtration technique is introduced. The variable filter attenuation follows the power profile of the interfering signal. The filter is directly applied on the raw RF signal, by accurately estimating azimuthal location of the interferer as the satellite scans the underlying swath.

Simulated results are obtained using a public open-source spaceborne SAR emulator, SEMUS, for generating emulated clean and contaminated SAR raw data. The filtration framework is successfully tested on real-life interference events on the TerraSAR-X satellite raw data.

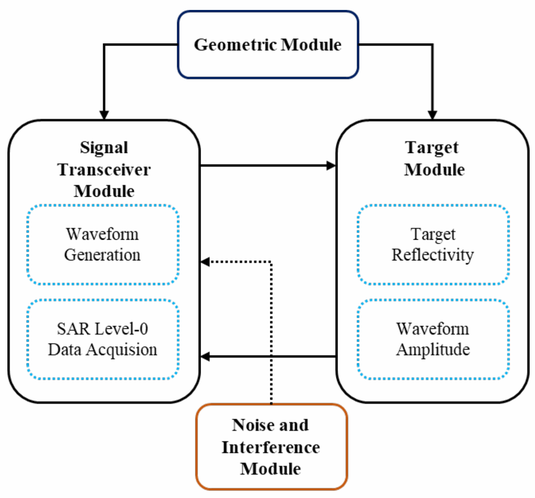

Figure 2: SEMUS interaction block diagram.

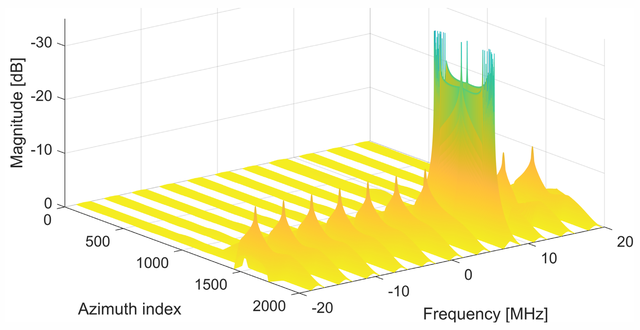

Figure 3: Magnitude response of the proposed tunable attenuation 2D complex BPF.

Implementation and Results

- An L-band satellite is utilized to generate the SAR unfocused data using SEMUS for fast processing.
- Using the proposed approach, the generated RFI signal is injected into level-0 SAR unfocused data before applying the image formation process [2].

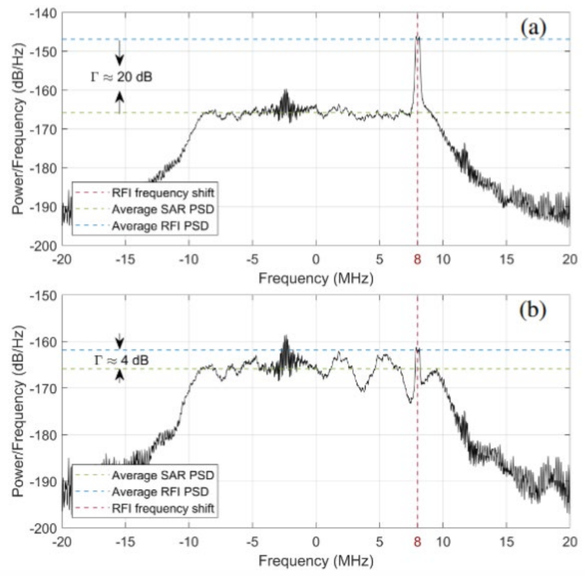

Figure 4: PSD of SAR raw data before and after RFI removal.

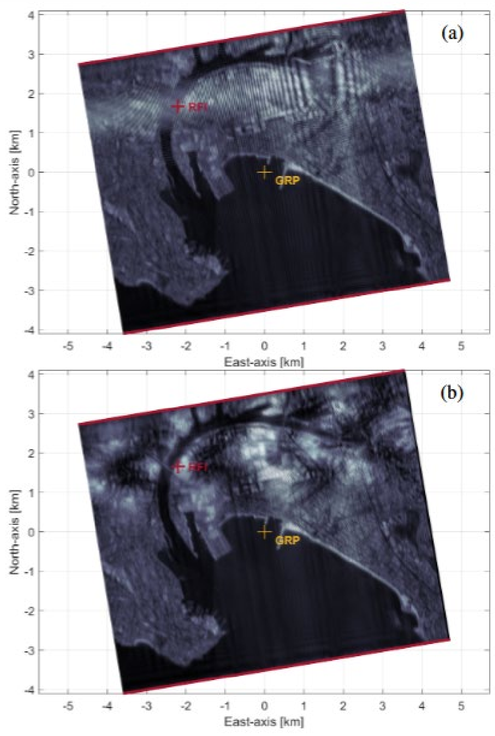

Figure 5: Focused SAR image, processed with RDA, resulting from a simulated contaminated SAR raw data with simulated RFI, before and after filtration.

- Finally, the proposed approach is tested on real TerraSAR-X raw data from the German Aerospace Center (DLR) to mitigate an actual RFI on SAR image above Los Angeles in October 2015 [2,3].

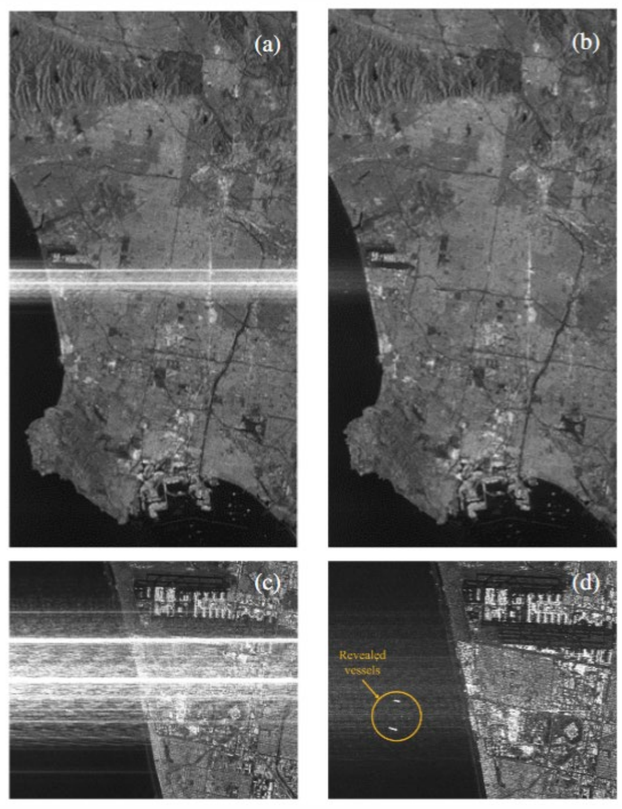

Figure 6: An actual TerraSAR-X image analyzed by our team. (a) and (b) are respectively the original contaminated images and the filtered image after applying the proposed filtration approach, (c) and (d) are a zoomed-in version revealing ships.

References

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[2] N. Hendy, A. Al-Hourani, T. Kraus, M. Schandri, M. Bachmann, H. M. Fayek, "2D-Azimuth-Range RF-level Variable Smoothing Filtration with Single Receiver Power localization for RFI Mitigation in Spaceborne SAR," in 2024 IEEE International Geoscience and Remote Sensing Symposium, 2024.

[3] M. Schandri, T. Kraus, A. Hourani, N. Hendy, F. Kurnia., and M. Bachmann, "Analysis of Radio Frequency Interferences in TerraSAR-X Products," in EUSAR 2024, 2024.

Acknowledgment

To SmartSat CRC for funding my PhD and my internship, and to the German Aerospace Center (DLR) and the European Space Agency (ESA) for their invaluable collaboration and support throughout this project.

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