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IMPROVING GENERIC GNSS RECEIVER PERFORMANCE WITH INTERMEDIATE FREQUENCY ADAPTIVE ANTI-JAMMING TECHNOLOGY

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ABSTRACT

Jamming attacks can severely disrupt Global Navigation Satellite Systems (GNSS) performance, posing significant threats to the resilience of Positioning, Navigation and Time (PNT) service. To mitigate jamming influence, extensive anti-jamming technologies, such as multiple antenna arrays or robust baseband processing algorithms, are conducted. However, these methods are typically employed in specialized GNSS receivers, as they require extra antenna or modification of baseband algorithms. Massive off-the-shelf GNSS receivers, widely used in personal devices, communications, and reference stations, rely on Intermediate Frequency (IF) anti-jamming filters. However, these filters have limitations that they are effective for specific jamming signals and cause GNSS signal distortion. Due to diverse and variable jamming conditions in real environments, there is still an urgent demand of adaptive jamming countermeasures for generic GNSS receivers in the market. This thesis aims to improve the anti-jamming performance of generic GNSS receivers without altering antenna or baseband structure. To achieve the purpose, the following key issues have been addressed.

To understand the jamming intensity that a generic receiver can withstand, the theoretical impact of diverse jamming signals on the GNSS receiver is investigated. The theoretical investigation derives the tracking threshold for a generic receiver and then develops an effective Carrier to Noise Density Ratio (C/N0) model for different jamming signals. Based on the developed model, the theoretical J/S thresholds are formulated, indicating the J/S level that the generic receivers can withstand. The tests results verify the theoretical analysis that the Jamming to Signal ratio (J/S) thresholds for most types of jamming attacks are 35~40 dB. The J/S threshold can serve as a baseline to evaluate the effectiveness of the anti-jamming method in this thesis.

To mitigate jamming impact on generic GNSS receivers, an Adaptive Jamming Mitigation (AJM) algorithm is proposed to detect, identify, filter, and monitor various jamming attacks. A metric of Differential Cumulative energy Spectrum Power (DCSP) II is formulated to detect jamming signals and identify jamming types. Additionally, a configurable ANF equipped with a check unit is developed. The ANF adaptively configures parameters based on identified jamming types to achieve higher C/N0 performance, while the check unit assesses changes in jamming conditions. Test results demonstrate the proposed AJM algorithm can effectively mitigate jamming signals with J/S over 41 dB, surpassing the J/S thresholds of generic receivers.

To reduce GNSS signal distortion caused by IF anti-jamming filter, a GNSS restoration algorithm is proposed based on Frequency Domain Adaptive Filtering (FDAF) plus Signal Prediction aided Reference Spectrum Model (SPRSM) equalizer. FDAF is the first step to smooth the spectrum after the AJM processing. Then, a SPRSM equalizer is developed to compensate for the distorted signals using the empirical spectrum and GNSS predictions. Theoretical analysis and simulations demonstrate that the GNSS restoration algorithm can reduce the signal distortion, empowering IF anti-jamming filters to counter jamming signals with 45 dB~57 dB of J/S, significantly improving the anti-jamming margin of GNSS receivers.

Finally, a hybrid anti-jamming approach, integrating the AJM algorithm and GNSS restoration algorithm, is developed. Real data experiments validate the capability of the hybrid approach in

mitigating various jamming signals with 48~56 dB of J/S, far exceeding the J/S thresholds of generic GNSS receivers. Therefore, this approach can enhance the performance of GNSS receiver under jamming conditions significantly. Notably, the proposed hybrid approach requires no modifications of antenna structures or baseband algorithm, making it readily applicable to massive generic GNSS receivers in the market.