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Space Debris Detection, Tracking and Characterization - SST (1)

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ADVANCED SURVEY RADARS FOR SPACE SURVEILLANCE AND TRACKING APPLICATIONS

Abstract

The increasing overpopulation of resident space objects (RSOs) calls for robust Space Surveillance and Tracking (SST) initiatives. In particular, the threat posed by in-orbit collisions, fragmentations, and satellite re-entries requires efficient methods to build up and maintain a catalogue of space objects. This effort primarily relies on measurements from ground-based sensors. Among these, survey radars play a crucial role by providing angular track, range, and Doppler shift measurements. They do not need prior transit predictions, enabling both orbit refinement and initial orbit determination. Additionally,

advanced data-processing techniques can be leveraged to estimate the shape and potential tumbling motion of observed targets. This work presents the latest advancements in the BI-static RAdar for LEO Survey (BIRALES), an Italian bistatic radar system dedicated to space surveillance. Currently, the system transmitter is the Radio Frequency Transmitter (TRF), while the receiver is a portion of the North Cross of Medicina radio telescope. Several hardware and software enhancements are being implemented to improve the sensor performance. From a hardware perspective, the system is being upgraded to use the entire North Cross radio telescope as receiver, significantly enhancing both sensitivity and field of regard. Additionally, a new transmitting antenna is being installed, further improving detection capabilities. This upgraded configuration will allow adaptive tuning based on target characteristics. Furthermore, a multistatic configuration involving also another radio telescope is under investigation to assess potential improvements in orbit determination accuracy. Concerning the software, a new data processing pipeline has been developed to extract angular track and range rate measurements of the observed targets. This method employs an adaptive beamforming technique coupled with a channelization strategy, ensuring high precision without requiring prior transit predictions. These improvements contribute significantly to catalogue maintenance and SST services. Moreover, methods to analyse radar light curves and micro-Doppler signatures are being explored to derive insights into target tumbling motion and shape. The paper presents numerical simulations conducted to assess the upgraded sensor configuration, demonstrating substantial improvements in both cataloguing capabilities and support to SST services. Additionally, first applications to real case scenarios are discussed, showcasing the sensor contribution in the new configuration to monitor high interest events, like satellite re-entries and fragmentations.