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Author: Ms. Silvia Urbinati
University of Rome "La Sapienza", Italy

Dr. Paolo Marzioli
Sapienza University of Rome, Italy
Prof. Fabio Santoni
Sapienza University of Rome, Italy

INNOVATIVE TDOA-BASED LAUNCHER TRACKING WITH SOFTWARE-DEFINED TECHNOLOGIES AND SYNCHRONIZATION: AN ANALYTICAL STUDY

Abstract

With the growing market of small satellites and the cost reduction of new launchers, efforts are increasingly being made to minimize the cost of putting commercial and experimentation equipment into orbit. The reliability of launcher tracking systems is of paramount importance for achieving the mission of launch operators and to safely inject objects in-orbit. In this perspective, developing innovative tracking systems, to be cooperating with radar and GNSS, is crucial to produce even more reliable data, guaranteeing safety and effective launch operations. The TDOA (Time Difference of Arrival) is an interesting method to localize flying objects as aircraft or satellites and it gave extremely positive contribution to the STRAINS experiment operated by the S5lab group at Sapienza in 2021, while being tested on a stratospheric balloon. The method is based on an architecture of ground-based sensors that can receive signals from an emitting target and track its position. While the stratospheric test has been giving positive results and important lessons learned, an attempt to simulate the TDOA multi-lateration technique for launcher tracking has been made at Sapienza S5lab to examine the performances and the feasibility of this method. Using the Linear Least Squares (LLS) method, it has been produced an algorithm that simulates tracking with 6 stations placed near the launch base. The implementation of a simulation algorithm based on least squares estimation led to results which were then improved by an order of magnitude adding a Taylor expansion. A parametric analysis, conducted by analyzing which input parameter affects the error, gave a clear overview of the critical points and a preliminary feasibility study put the basis for a future in-depth analysis for the improvement of launcher systems TDOA. Choosing an accurate synchronization technology, that guarantees an expected error in a scale of nanoseconds, helps to reach better results as well as a good fitting configuration of the stations. This can be guaranteed by implementing innovative technologies, such as Software-Defined Radios and Disciplined Oscillators, in the hardware. This paper shows a preliminary performance analysis of this new promising tracking method for launchers. After an explanation of the TDOA technique, the model development of TDOA positioning (using LLS) is described, afterwards a parametric analysis is made, underlining the main input parameters that affect the estimation error and finally, in the last section, considering an actual launch base possible applications are presented.