A New Tracking Approach for Multipath Mitigation Based on Antenna Array

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I INTRODUCTION

In Global Navigation Satellites Systems (GNSS), multipaths (MP) are still one of the major error sources. The additional signal replica due to reflection will introduce a bias in conventional Delay Lock Loops (DLL) which will finally cause a strong positioning error. Several techniques, based on Maximum Likelihood estimation (ML), have been developed for multipaths mitigation/estimation such as the Narrow correlator spacing [1] or the Multipath Estimating Delay-Lock-Loop (MEDLL) [2] algorithm. These techniques try to discriminate the MP from the Line Of Sight Signal (LOSS) on the time and frequency domains and thus, short delay multipaths (<0.1Chips) can not be completely mitigated.

Antenna array perform a spatial sampling of the wave front what makes possible the discrimination of the sources on the space domain (azimuth and elevation). As the time-delay domain and space domain can be assumed independent, we can expect to mitigate/estimate very short delay MP by using an antenna array. However, we don't want to increase too much the size, the complexity and the cost of the receivers and thus, we focus our study on small arrays with a small number of antennas: typically a square 2x2 array. Consequently, conventional beamforming (space Fast Fourier Transform) is not directive enough to assure the mitigation of the multipaths, and then this first class of solutions was rejected. In order to improve the resolution, adaptive beamformers have also been tested. However, the LOSS and the MP signal are strongly correlated and thus, classical adaptive algorithms [3] are not able to discriminate the sources.

These preliminary studies have shown that the mitigation/estimation of multipaths based on the space domain will exhibit limited performances in presence of close sources. Then, in order to propose robust algorithms, we decided to investigate a space-time-frequency estimation of the sources. Space Alternating Generalized Expectation maximisation (SAGE) algorithm [4], which is a low-complexity generalization of the Expectation Maximisation (EM) algorithm, has been considered. The basic concept of the SAGE algorithm is the hidden data space [4]. Instead of estimating the parameters of all impinging waves in parallel in one iteration step as done by the EM algorithm, the SAGE algorithm estimates the parameters of each signal sequentially. Moreover, SAGE algorithm breaks down the multi-dimensional optimization problem into several smaller problems. In [5], it can be seen that SAGE algorithm is efficient for any multipaths configurations (small relative delays, close DOAs) and space-time-frequency approach is clearly outperforming classical time-frequency approaches. Notwithstanding, SAGE algorithm is a post processing algorithm. Thus, it's necessary to memorise in the receiver the incoming signal in order to apply SAGE estimation. For example, if we want to process 10ms of signal with a 10MHz sampling rate, we need to store a matrix of m*105 with m the number of antennas. In such condition, we can understand than SAGE algorithm is hardly implemented in real time. The challenge is then to find a new type of algorithms that reach the efficiency of the SAGE algorithms, but with a reduced complexity in order to enable real time processing. Furthermore, the implementation should be compatible with conventional GNSS tracking loops (DLL and PLL). To cope with these two constraints, we propose to apply the SAGE algorithm on the post-correlated signal. Indeed, the correlation step can be seen as a compression step and thus, the size of the studied signal is strongly reduced. In such a way, SAGE algorithm is able to provide estimates of the relative delay and Doppler of the received signals with respect to the local replicas. Thus, a post correlation implementation of SAGE can be seen as a discriminator for both the DLL and the PLL.

II NEW TRACKING APPROACH

The performances of the post-correlated version of SAGE (named the SAGE / STAP multi-correlators) have been already presented in [6]. In this paper, we present how the SAGE / STAP multi-correlators algorithm can be used with conventional tracking loops. The improvement of the signal time-delay estimation, and thus of the final user positioning accuracy will also be addressed. Fig. 1 to Fig. 3 illustrate the performance of the SAGE / STAP multi-correlators algorithm. Fig. 1 shows a sky plot of the simulated scenario based on the well known DLR model [7] where 4 satellites are tracked. Fig. 2 presents the tracking results of the PRN 22 and Fig. 3 illustrates the final user positioning error for 3 different approaches: conventional tracking loop (DLL/PLL), conventional tracking loop enhanced with a conventional beamformer and last, tracking loop driven by the SAGE / STAP multi-correlators algorithm. The conventional DLL is based on the Early minus Late discriminator with a Chips Spacing of 0.1Chips, and the PLL is based on the arctangent discriminator.

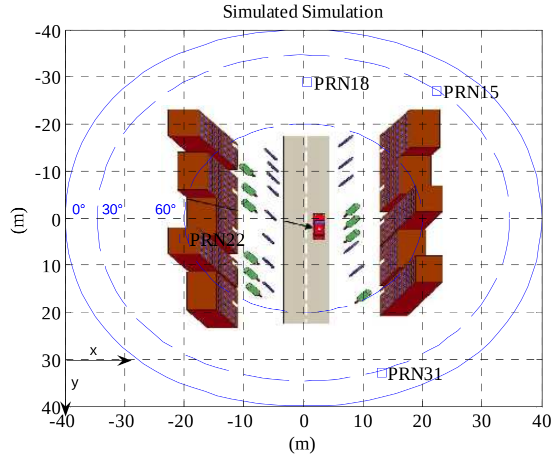

Fig. 1: Skyplot of the simulation.

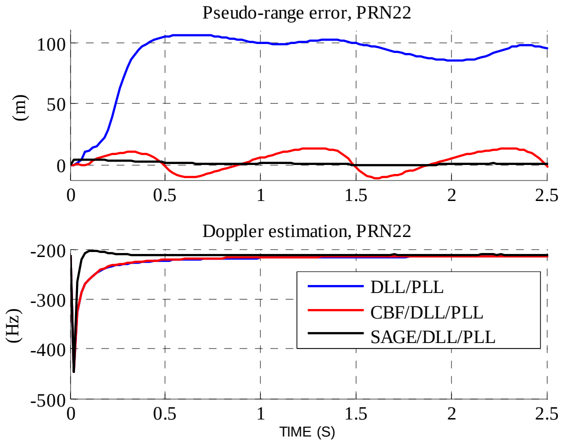

Fig. 2: Pseudo range error and Doppler estimation for the PRN 22.

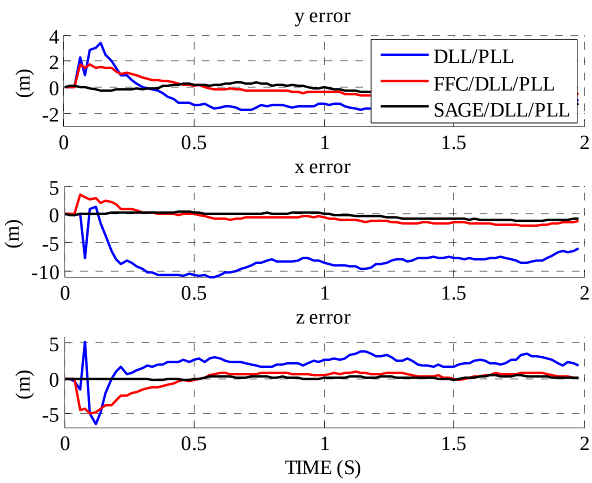

Fig. 3: Positioning error for DLL/PLL, DLL/PLL with beamforming and DLL/PLL driven by SAGE.

In these figures, we can see the influence of the multipaths on the time delay and on the positioning estimation. Although a narrow correlator discriminator was used, the multipaths still add a bias in the time delay estimation and thus, in the receiver positioning estimation. The use of a beamformer slightly reduces the influence of the multipath. The SAGE / STAP multi-correlators approach exhibits the best multipaths rejection performance.

III Conclusion

In this work we have addressed the problem of estimating the propagation time-delay of the LOS signal in a GNSS receiver under severe multipath conditions. The potential of SAGE in a navigation context has already been proven, and a new implementation of SAGE, based on both the correlation properties of the code and the thermal noise, has been proposed in order to reduce the size of the signal and consequently, the memory requirement of the processor. Hence, using the SAGE algorithm in a conventional receiver becomes possible by driving the conventional tracking loops with the SAGE estimation. This paper presents the performances of SAGE in realistic dynamic multipath scenarios generated by the DLR channel model. In these realistic scenarios, the SAGE approach shows a real improvement for the multipath mitigation with respect to conventional multipath mitigation techniques. Thus, this is a promising result before testing the SAGE approach in real world conditions.

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