Abstract

In the present research, the main work is focused on designing and simplifying the orbit determination algorithm which will be used for onboard Low Earth Orbit (LEO). The various data processing algorithms, state estimation algorithms and modeling forces were studied in detail, and simplified algorithm is selected to reduce hardware burden and computational cost. This is done by using raw navigation solution provided by GPS Navigation sensor. A fixed step-size Runge-Kutta 4th order numerical integration method is selected for orbit propagation. Both, the least square and Extended Kalman Filter (EKF) orbit estimation algorithms are developed and the results of the same are compared with each other. EKF algorithm converges faster than least square algorithm. EKF algorithm satisfies the criterions of low computation burden which is required for onboard orbit determination. Simple static force models also feasible to reduce the hardware burden and computational cost.

The present thesis is divided into five chapters.

Chapter 1 introduces the topic of research and takes the review of research papers available in the literature. The literature survey is carried out for various orbit determination strategies used till date for GPS based onboard orbit determination. This chapter also spelt out the motivation behind the present research. The detail aims and objectives of the present research were provided here. The organization of the thesis is given in the final section of this chapter.

Chapter 2 deals with the theoretical background required for the selected research work. Several reference systems are being used in the study of the natural as well as artificial satellites. Basic principles of satellite orbital mechanics are explained in detail in this chapter. Perturbing force models and its effect on various satellite orbital elements for long term and short term orbit propagation are also summarized in detail. The numerical propagator algorithms were studied for the present application. These include Euler’s method and Runge Kutta (RK) method. The details of the same are explained in this chapter. Various orbit estimation methods were studied and the same is explained in this chapter. This involves batch least square methods, linear Kalman filter and extended Kalman filter. This chapter also deals with the methods and related mathematics for GPS measurement model and GPS raw measurements processing. GPS pseudorange model were studied and explained in this chapter.

Chapter 3 explains the efforts done on execution of objectives for the development of orbit determination system software for Low Earth Orbit (LEO) satellite using Global Positioning System (GPS) data for on-board use. This
chapter focuses on the selection of the appropriate methods/models suitable for the scope of the present work. This includes the selection of reference coordinate system, system model, perturbing force models, GPS observable, measurement model, method of orbit propagation and method of orbit estimation. Considering the limitation of hardware and computational cost, it is decided to use bit low fidelity models for orbit determination. This decision leads to select zonal secular perturbation $J_2$ and effect of atmospheric drag along with two body satellite equation of motion. With this study it was concluded that it is sufficient to use satellite dynamic model with $J_2$ and effect of atmospheric drag for on-board processing. The algorithm for the orbit propagation is developed using fixed RK 4th order numerical integration method. Sequential state estimation algorithm is used, considering specific requirement for onboard processing. Extended Kalman Filter (EKF) is selected for the present application due to its recursive nature and efficiency to handle nonlinearities. The software for the same has been developed and results were tested. The software for the same is developed in MATLAB.

**Chapter 4** in this chapter the results obtained related to numerical integration for orbit propagation, GPS data processing, least square orbit determination and EKF orbit determination method are discussed. The effect of various zonal perturbations like $J_2$, $J_3$ and $J_4$ and the atmospheric drag were tested. The developed algorithm has been tested for two separate cases. The satellite dynamic model equations are integrated using 4th order Runge-Kutta method. The variations in the orbitl elements due to various perturbations are presented in this chapter. Nonlinear least square is employed to determine the position of a GPS receiver from GPS pseudorange measurements. Least squares differential correction algorithm is used to determine the orbit of a spacecraft from simulation of position and velocity measurements generated along the reference trajectory. The values obtained of the components of state vectors are in close agreement with the initial estimates of these components, with the exception of $y$ component. Due to the non-linear relation of the state vector and the measurements, multiple iterations are required to compute the state estimate. For this EKF is used. It is observed that EKF converges much faster than least square method due to its sequential nature.

**Chapter 5** summaries the work done and states the future scope of the present research work. It involves study of more improved and advanced estimation methods for orbit determination. It will be future explored towards the step of hardware payload development for actual satellite missions.