IAF-93-A.1.5

ESTIMATION OF THE MOTION OF TETHERED SATELLITE SYSTEMS

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The purpose of this paper is to present the results of an investigation into the problems involved in estimating the motion of tethered satellite systems using observational data from ground-based tracking stations.

Many aspects of the dynamics of tethered satellites have been studied. As examples, dynamic models of tethered satellite systems have been developed, and deployment and retrieval control laws have been synthesized and ground-tested. A space-based orbital test of tether dynamics and control during a NASA Spa Shuttle mission was partially successful. Also, the Canadian Space Agency has conducted a sub-orbital tethered body experiment. Furthermore, the third author, along with the first author, has developed and applied methods for predicting the lifetimes of freee tethers and of systems of a tether connected to a subsatellite. All of these studies have provided knowledge on the prediction of the behavior of tethered stellite systems which are known a priori to be such. On the other hand, there has been very little work done on the estimation of the motion of tethered satellite systems or on using observations of several satellites, some of which are tethered to each other, in order to identify the tethered sets of two or more.

In this paper, we will use a point-mass, extensible tether model and a spherical satellite model of a tethered satellite system, an oblate earth model and a COSPAR atmosphere model as our "real world" system. We will then consider the estimation of the motion of that system using several dynamic models, for example, massless and massive tether models as well as the real world model with noise added. The performance of both a batch estimator and a sequential-type estimator will be evaluated.

IAF-93-A.1.6

LONG-TERM CIRCULAR ORBIT PROPAGATION ERRORS CAUSED BY EARTH'S ANOMALOUS GRAVITY AND DRAG PARAMETER UNCERTAINTY

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Orbit propagations of low-altitude artificial satellites are in general affected by various types of force model errors. More noticeable among them are the errors caused by the incorrect truncation of Earth's gravity field and by the uncertainty in the atmospheric drag model parameters. Considering these two types of errors, this work aims at developing a stochastic procedure to evaluate the order of magnitude of the accumulated global error in long-term circular orbit propagations. In both the Earth's anomalous gravity and drag parameter uncertainty cases, the statistical estimates of errors in orbital elements are obtained in terms of their covariances. After testing the theory in both the cases separately with some simple examples, it is combined to apply to a satellite with the orbital and structural configuration similar to that of the first Brazilian satellite, launched on 9th February 1993. The error estimates obtained in all the cases have been compared with the true errors generated by a numerical procedure and analyzed in detail so as to make some conclusive remarks over the theory developed here. The results obtained in all the cases are reasonably good and conservative and the theory developed in short-term propagations is found valid for long-term propagations too.

IAF-93-A.1.7

INVESTIGATION OF SOLAR RADIATION EFFECTS ON GPS PRECISE ORBIT DETERMINATION

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Abstract

The Canadian Active Control System (ACS) data processing center in Ottawa has been generating ephemerides with sub-meter precision for all operational Global Positioning System (GPS) satellites on a daily basis since August 1992 to facilitate geodetic positioning and to determine the earth rotation parameters. The present study investigates solar radiation pressure models developed for GPS satellites, namely the ROCK42 model by Rockwell International with and without inclusion of thermal reradiation effects and the S20 and T20 models by the Aerospace Corporation. Comparison of these models show scale differences of about 3-6%. Using hypothetical trajectories and accounting for the scale differences, solar radiation pressure effects are shown to agree at the decimeter level. Orbit prediction tests based on processing of carrier phase data from a global network of GPS stations do not favour any of the solar radiation models since the orbit determination process used does not have sufficient sensitivity

IAF-93-A.1.8

On the Design of Observers for Attitude Estimation of Geosynchronous Satellites

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New spacecraft technology missions require a high pointing accuracy of the control frame roll, pitch and yaw offsets. The three-axis attitude sensing can be achieved combining the output measurements of Earth and Sun sensor heads; however, this strategy cannot be adopted in any orbital position: the yaw offset optical measurement is not available in eclipse and cannot be accomplished with adequate accuracy in high collinearity condition between Earth, spacecraft and Sun. The implementation of a dynamic observer is therefore necessary to produce a proper estimate of the yaw angle.

Highly evolved satellites carry active payloads, like moving appendages for communication experiments; these data relays are equipped with own control loops to track low-orbit targets, producing a large exchange of angular momentum with the platform, whilst imposing severe attitude pointing and stability constraints.

A state observer driven by the Earth sensor outputs can provide a good yaw estimation even in the presence of reaction torques originated from the payloads and perturbing the spacecraft attitude.

The present work illustrates a study carried out in Alenia Spazio on the design of an accurate observer in order to determine the yaw angle; classic techniques such as full-state and reduced order Luenberger observers are investigated, as well as the Kalman approach. In all cases, the reduction of the effect due to the noise generated by the Earth sensor constitutes a driving concept in the design, conditioning the pole assignment. The performance of the estimator is tested with typical disturbance profiles originated by moving payloads.

When a neat torque impulse is applied by an external disturbance, like it could be the case of a firing jet, the performance of the yaw observer (driven only by the Earth sensor information) always appears degraded; in this case, a "fast" correction algorithm is suggested, based on a least-squares procedure, to update the state vector estimate furnished by the observer.