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GPS Attitude Determination

**Quarterly Progress Report 1, FY'96-97
September-November 1996**

to the Naval Research Laboratory

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Abstract

This report summarizes the progress for the first quarter of FY'96-97 by the Colorado Center for Astrodynamics Research (CCAR) on the application of GPS based attitude determination techniques to near-Earth spacecraft. Two areas are addressed - application of an open architecture receiver for spaceborne attitude determination and coarse spacecraft attitude determination based on GPS signal-to-noise ratios (SNR). We have started work with the GEC Plessey GPSBuilder 2 receiver and identified modifications required to use the receiver for attitude determination functions. In particular we made arrangements for the addition of a second RF section to be added to the receiver and determined that the receiver tracking loop must be modified from a frequency lock loop to a phase lock loop (PLL) design. In the area of coarse attitude determination based on SNR, we have made improvements to a fuzzy estimation algorithm which provide attitude estimates at the 7 deg RMS level for flight data sets from CRISTA SPAS and GANE. We have also begun work on a maximum likelihood estimation technique using these same observables. Two research papers [1,2] funded under this grant were presented at the ION GPS-96 meeting in Kansas City. One of them [2] received an award for best paper in the session. Charles Behre, a doctoral student supported under this grant successfully completed his comprehensive exam on October 28, 1996.

1. Open Architecture Receiver

The goals for the first quarter of FY'96-97 were to gain familiarity with the GEC Plessey GPSBuilder 2 receiver and identify modifications required to use the receiver for attitude determination functions. These objectives have both been met.

The GPS Builder-2 is an open architecture receiver based on two ASIC's developed by GEC Plessey. All receiver source code is available to the user and actually runs on the host computer rather than as firmware in an onboard microprocessor. This permits the user to make changes to the tracking and navigation solution algorithms as desired. The GPS Builder-2 is nominally configured with a single front end or RF section, but has provisions for addition of a second set of RF components. This would be required for attitude determination functions. GEC Plessey has agreed to perform this upgrade on our receiver free of charge.

Prior to shipping the receiver to GEC for the upgrade, we conducted a series of performance tests to quantify the pseudorange and carrier phase measurement quality. At this point we found out that the existing receiver tracking loops are not suitable for attitude determination. The existing code implements carrier tracking via a frequency lock loop. This type of loop has advantages in high dynamic situations; however, it produces random walk errors in the carrier phase observables. This makes the phase observations useless for attitude determination. GEC has provided us with some receiver code to implement phase lock loop (PLL) tracking and we have started to incorporate this into the main receiver code. This should produce better quality phase measurements.

During the next quarter we plan to complete work on the receiver tracking loops and to assess the measurement quality. Once that is completed we will return the receiver for the upgrade. At the end of the next quarter we will submit a technical memorandum describing the operation and performance of this receiver and its applicability for navigation and attitude determination in space.

2. Coarse Attitude Determination Algorithms

Our objectives for the first quarter of FY96-97 were to continue work on the fuzzy estimation algorithm which uses GPS SNR data to determine coarse vehicle attitude. During this time we have processed additional data sets from CRISTA SPAS and GANE, and made algorithm improvements which reduced typical RMS attitude errors from 10 deg to under 7 deg. In addition, doctoral student Charles Behre passed his Ph.D. comprehensive exam on October 28, 1996 [3].

Improvements were made to the specification of the fuzzy membership functions and to the procedure for determining a final attitude estimate based on the individual observations. These led to consistent results at the 7 deg level for actual flight data sets. We have decided to concentrate our efforts on the CRISTA SPAS and GANE data and leave RADCAL for the time being. RADCAL has exceptionally low SNR values and is not considered to be very reliable.

In November, we started looking at maximum likelihood estimation techniques for attitude determination based on the SNR data. The method is based on an approach described by Shuster for optimal single axis attitude determination [4]. With this technique one can derive a covariance for the attitude errors as well as an estimate of the attitude itself. This is a definite advantage over the fuzzy algorithm which does not give any indication of the accuracy of the solution. Initial results with the maximum likelihood approach look promising and we plan to investigate this further in the second quarter.

References

- [1] Comp, C.J. and P. Axelrad, "An Adaptive SNR-Based Carrier Phase Multipath Mitigation Technique," ION GPS-96, Kansas City, 683-697, September 1996.
- [2] Ward, L.M. and P. Axelrad, "A Combined Filter for GPS-Based Attitude and Baseline Estimation," ION GPS-96, Kansas City, 1047-1061, September 1996.
- [3] Behre, C.P., *GPS Based Attitude Algorithms for Low Cost Satellite Missions*, Ph.D. Prospectus, University of Colorado, October, 1996, 34 pages.
- [4] Shuster, M.D., "Spacecraft Attitude Determination and Control," Chapter 5 in *Fundamentals of Space Systems*, V.L. Pisacane and R.C. Moore, Eds., Oxford University Press, 1994.

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