

# **UTILIZING GPS FOR ULTRA-HIGH DYNAMIC VEHICLE TRACKING IN SPACE**

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## **ABSTRACT**

GPS will provide a very attractive means to track kinetic energy weapons in space for the Strategic Defense Initiative programs for system test and evaluation. However, the small size and very high dynamics of these vehicles complicate the use of GPS. This paper considers these issues and suggests a solution.

## **INTRODUCTION**

As more information becomes available on the Strategic Defense Initiative program, we get some indications of the vehicles and weapons involved. The very high dynamics of some of the proposed kinetic kill vehicles will require the incorporation of unique tracking techniques for Time Space Position Information (TSPI) determination during test and evaluation. For example, some of the kinetic kill vehicles being considered will travel at velocities in the 10's of kilometers per second and experience acceleration of 100 g's and jerk of up to 100 g's per second.

At the tracking distances required, GPS will be mandatory for TSPI. Unfortunately, existing GPS receivers are incapable of coping with these dynamics. Not only are they incapable of rapid target acquisition, but they also cannot maintain lock during conditions of extremely high dynamics. Two recent developments in GPS receiver design offer potential solutions for these two seriously limiting problems.

## **FAST ACQUISITION**

The fast acquisition and reacquisition problem was first experienced in GPS tracking of the TRIDENT II missile, for which positive track had to be achieved within five seconds after the missile came into view. To solve this problem, a unique 1023-stage signal correlator was developed by Interstate Electronics. Extensive system testing has proven the design. A search algorithm for all 1023 C/A-code arrival states and  $\pm 1200$  m/s ( $\pm 5$ kHz) carrier Doppler executes in 300 milliseconds (per channel).

## HIGH DYNAMICS ISSUE

The extremely high dynamic tracking problem is currently solved by coupling a multichannel GPS receiver with an inertial reference unit (IRU), the technique that is being used on the tri-service Range Applications Program. However, even this solution will not handle the extremely high dynamics required by the contemplated kinetic kill vehicles. To solve the problem, the NASA Jet Propulsion Laboratory (JPL) has developed a Fast Fourier Transform (FFT) carrier tracker. The satellite carrier Doppler is normally tracked with a third order Costas phase locked loop. However, the received GPS satellite signal-to-noise ratio is too low to operate a phase locked loop with sufficiently wide bandwidth to handle these very high dynamics.

Figure 1 is a functional block diagram of the FFT concept. By performing an FFT process on a sequence of correlator delays, each separated by 1/2 code chip, a “window” is generated in carrier Doppler by the FFT and in time delay by the sequenced correlator delays.

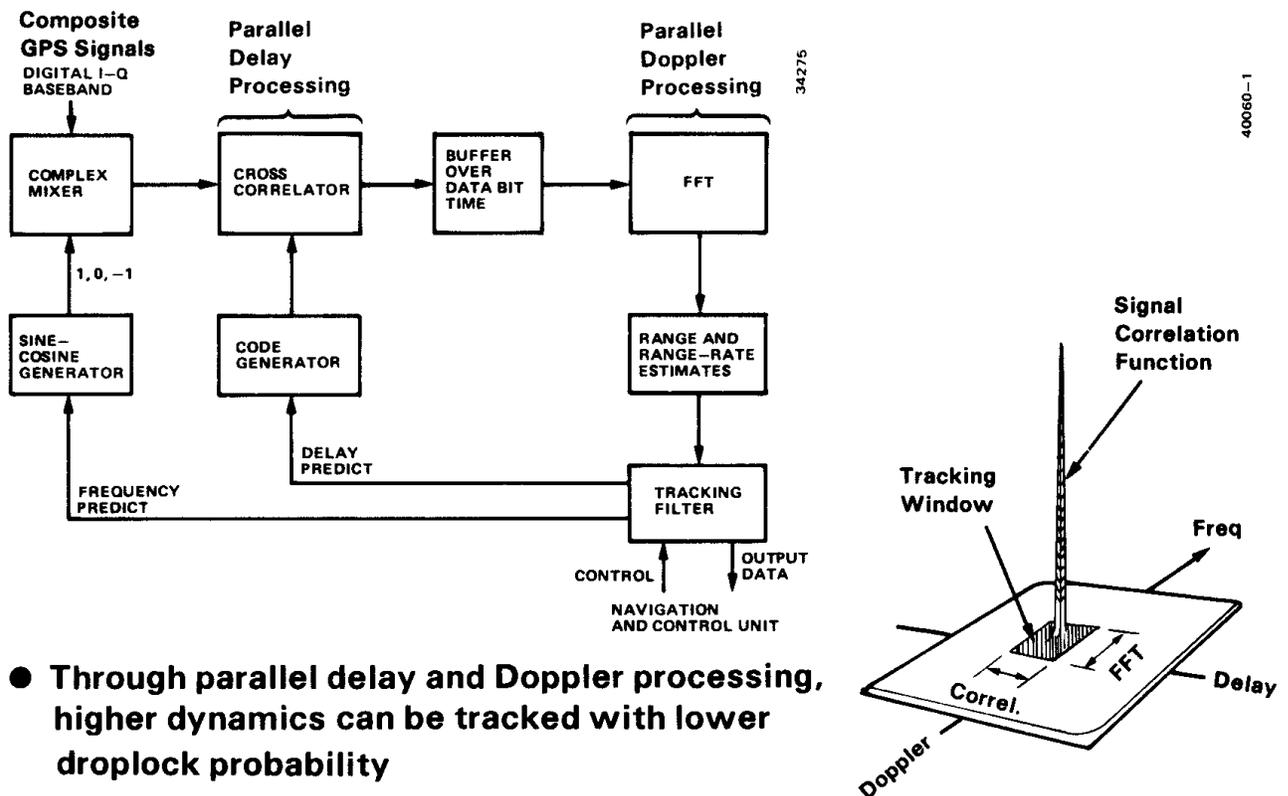


Figure 1. Advanced GPS Signal Processor

Accurate pseudorange and delta-range measurements can be made as long as the signal time-of-arrival and carrier Doppler fall within this “window”. Adjustments are made to the sine/cosine generator (carrier Doppler) and code generator to maintain correct “window” placement for track continuity.

By contrast, conventional code and carrier tracking loops attempt to track the peak of the correlation function. If peak track is lost from signal dynamics, the loops drop lock and the measurements are lost.

## **DATA PROCESSING**

Finally, a high dynamic GPS tracking system without IRU aiding must be capable of updating the GPS state vector (Kalman filter) at a higher than normal rate, typically ten updates per second. An IRU aided system uses coordinate transformations of the inertial measurements to generate high-rate (ten to twenty per second) position/velocity updates. GPS state vector updates are done much more slowly, typically one or two per second, and are only used to maintain the drift calibration of the IRU.

## **TRANSLATED GPS**

Using these techniques, receivers can be designed for fast acquisition and high dynamic tracking. Unfortunately, with the added features they will be relatively large, making them impractical for installation on small highly dynamic vehicles. However, the use of receivers of this type is practical in GPS translator based systems.

In a GPS translator based tracking system, a frequency translator is placed on the test vehicle instead of the GPS receiver. The translator, a relatively small unit, receives L-band signals from the satellites, shifts the spectrum to S-band, and transmits the S-band spectrum to the master station for processing. All signal measurements, including the fast acquisition, FFT tracker, as well as data processing and recording, are accomplished at the master station.

There are a significant number of advantages to GPS translator based tracking systems. The most significant are:

- The advantages of the fast acquisition and high dynamic tracking capability can be achieved while placing a minimum package in the vehicle under test.
- All computational complexity is placed in the ground station. A ten per second GPS state vector update rate is beyond the capability of a microprocessor. A mini-computer is needed which is quite feasible in a ground installation.

- Translated signals can be pre-detect recorded at the ground station eliminating non-reversible real-time signal/data processing errors in the mission replay.

There are further advantages associated with the use of a translator, the most obvious being those associated with the weight, volume, and power consumption of the translator compared to a GPS receiver onboard a small ultra-high dynamic vehicle.

## **CONCLUSION**

For high dynamic vehicle tracking in space, a unique TSPI system is required. Radar systems cannot provide the required accuracy over the extended ranges involved. While GPS tracking can provide the accuracy, conventional GPS cannot handle the extreme target dynamics. Techniques that can be incorporated into GPS receiver design to solve this problem would result in a large complex GPS receiver. Therefore, the logical solution to the problem is to use a GPS translator in the vehicle under test and have all the receiving system complexity reside in the ground monitor station.