POSITIONING WITH THE GLOBAL POSITIONING SYSTEM

Clyde C. Goad
National Geodetic Survey
National Ocean Survey
National Oceanic and Atmospheric Administration
Rockville, MD 20852
USA

ABSTRACT

This year (1980) the U. S. Department of Defense has scheduled to have in operation six satellites of the Global Positioning System (GPS), which will provide timing and three dimensional position recovery potential to North America during certain segments of a day. By the mid-eighties, continuous timing and three dimensional recovery from 18 GPS satellites are planned. Although the GPS is designed for fast position recovery to the 10-meter level, extended data collection periods could yield subdecimeter relative positioning on a routine basis.

INTRODUCTION

One of the most promising systems for highly accurate position determination in the next decade is the NAVSTAR Global Positioning System (GPS) being developed by the U. S. Department of Defense. This system, which has been described extensively in recent literature (e.g., Parkinson, 1979), will satisfy many present navigation requirements and new demands for geodetic control, in a very cost-effective manner.

P-CODE

The P-code (a 0 degree or 180 degree pseudorandom phase shift sequence) is used to modulate the 1575.42 MHz (L1) and 1227.60 MHz (L2) carrier frequencies emitted by the satellites at a 10.23 MHz rate. A dense spectrum of sidebands is produced because the code does not repeat itself for a week. The spectrum is spread over roughly a 20 MHz bandwidth centered on the carrier frequency.

E. M. Gaposchkin and B. Kołaczek (eds.), Reference Coordinate Systems for Earth Dynamics, 191–194.
Copyright © 1981 by D. Reidel Publishing Company.

https://doi.org/10.1017/S0252921100081252 Published online by Cambridge University Press

In standard GPS navigation receivers, the incoming signals are cross-correlated with similar reference signals generated by the receiver. The time delay between the reference signal and the satellite signal is determined by finding the time delay which maximizes the cross-correlation. The time delay, when multiplied by the speed of light in a vacuum, is called the pseudorange. The difference between the L1 and L2 pseudoranges is used to calculate the ionospheric contribution to the higher frequency (L1) pseudorange. By combining the L1 pseudo-random range information for four or more satellites the receiver position with respect to the GPS reference system and the offset of the receiver clock from GPS system time can be determined.

RECONSTRUCTED CARRIER PHASE METHOD

The difference between the incoming satellite signal and the properly time-delayed receiver reference signal is essentially a sine wave beat frequency. After removing the data message, a low-frequency signal generated in the receiver is phase-locked to the beat frequency to improve the signal-to-noise ratio. This signal is called the reconstructed carrier, even though it is at a much lower frequency than the original carrier. Whenever the distance from the satellite to the receiver changes by one wavelength of the carrier frequency, the phase changes by one cycle in the reconstructed carrier. The phase also depends on differences in initial phase and frequency between the receiver and satellite clocks.

The mathematical description of the reconstructed carrier phase technique is given in Bossler, et al. (1980). It is seen that the phase difference between two stations from a satellite will give the range difference with an ambiguity equal to some multiple of the carrier wavelength along with any clock mismatch between the two ground stations. Again differencing this phase difference at the two ground stations with the same measurement but to another satellite (a second difference) will eliminate the mismatch from the receivers' clocks. The ambiguity will still remain, however. The method of resolving these ambiguities is to solve for measurement biases along with the vector components from one station to the other. The biases will be poorly determined if only a few minutes of observations are available, but the uncertainty decreases as the observation time increases. However, because of the need to correct for the ionosphere, the effective ambiguity length for this method is 10.7 cm, instead of the 19.0 cm wavelength for the L1 frequency.

It appears likely that the main accuracy limitation in using the reconstructed carrier phase method will come from uncertainty in the tropospheric propagation corrections. The portion resulting from the dry part of the atmosphere can be well modelled from

https://doi.org/10.1017/S0252921100081252 Published online by Cambridge University Press

surface measurements of the pressure. However, the portion of the correction due to water vapor distribution is more difficult. If the most accurate values for relative positions are desired, it will probably be necessary to incorporate water vapor radiometers at each receiver site for base lines greater than roughly 3 km in length.

A simulated test situation for the P-code used in Bossler, et al. (1980) was repeated using the double difference phase technique. The solution state consisted of the differences in absolute receiver coordinates and measurement biases representing the ambiguities. The data rate was assumed to be only one phase measurement per receiver pair per satellite every 10 minutes to avoid overly optimistic results from oversampling. Measurement noise was assumed to be random and to have an amplitude of 2 cm to reflect the 1 cm level of residual error in the tropospheric refraction correction for each of the four measurements used in forming the double difference.

The results indicate that resolution of the ambiguities is possible, even allowing for the shorter effective ambiguity length mentioned earlier. A detailed description and results may be found in Bossler, et al. (1980).

It is then legitimate to carry out a new simulation in which biases are not solved for as long as the ambiguities can be clearly resolved. The results of such a simulation are as follows:

sigma (dx) = 0.6 cm

sigma (dy) = 0.5 cm

sigma (dz) = 1.3 cm

These results indicate that the ultimate resolution potential using 2 hours of tracking data may be at the 1 or 2 cm level. This is much better than the 10 cm level originally desired.

CONCLUSIONS

It is felt that using the reconstructed carrier phase method will be useful in exploiting the potential of the NAVSTAR Global Positioning System. Obviously there is a great deal of additional research needed to achieve this goal. Studies to date indicate that a highly portable receiver with an antenna similar in size to those used with modern Doppler receivers can be developed. Depending on funding, prototype receivers may be available by 1982. If prototype receivers perform according to expectations, operational copies could be available in the 1984-1985 time frame.

https://doi.org/10.1017/S0252921100081252 Published online by Cambridge University Press

REFERENCES

Bossler, J. D., C. C. Goad, and P. L. Bender, 1980, Using the Global Positioning System (GPS) for geodetic positioning, accepted for publication in Bulletin Geodesique.

Parkinson, B. W., 1979, Global positioning system (NAVSTAR), Bulletin Geodesique, 53, 89-108.

https://doi.org/10.1017/S0252921100081252 Published online by Cambridge University Press