GPS - A POINTING AID FOR THEODOLITES, LASER TRACKERS AND THREAT EMITTERS

Robert Van Wechel
Interstate Electronics Corporation
1001 E. Ball Rd., P. 0. Box 3117
Anaheim, CA 92803

ABSTRACT

The GPS equipment developed in the tri-service GPS range applications program is now available for use. One promising application on test and training ranges is for pointing control of theodolites, laser trackers, and threat emitters. Theodolites and laser trackers are capable of extremely high accuracy in range applications, but suffer from a very narrow acquisition range, thus requiring external acquisition aiding. Unmanned threat emitters are also used that require external pointing information.

In this application of GPS, a GPS receiver or translator is used on the test or training vehicle, and the position of the vehicle is downlinked to the tracking site. A pointing angle is then computed at the tracking site and is used to point or steer the theodolite, laser tracker, or threat emitter. Because of the high accuracy, of differential GPS, this method is very precise. Also, with a direct high-rate datalink, time delays for the pointing information can be very low, again providing very accurate pointing for high-dynamic vehicles.

This method promises to be a highly cost-effective approach for steering these devices because it eliminates the requirement for continuous manning of the sites.

INTRODUCTION

The coming availability of the Global Positioning System (GPS) equipment on test and training ranges provides a very effective method for precise unmanned acquisition and steering of cinetheodolites, laser trackers, and simple threat emitters. Although the GPS is not yet fully deployed, current plans indicate full deployment by 1993, which will provide a 24-hour worldwide source of precision-position information.

The Office of the Undersecretary of Defense for Research and Engineering provides the instrumentation for the Major Range and Test Facility Base (MRTFB)[1]. In 1981 this office investigated the use of an orbiting radio multilateration system, the Navstar GPS, to meet the time and space-position information (TSPI) requirements of the MRTFB.

A tri-service GPS range applications steering committee contracted with The Analytic Science Company (TASC) to summarize these requirements. The study sampled 22 ranges, including Training Ranges and Operational Test and Evaluation (OT&E) ranges, as well as Developmental Test and Evaluation (DT&E) ranges. The final steering committee report in January 1983 concluded that GPS could satisfy about 95 percent of TSPI range requirements and would be cost effective. (Note that the other 5 percent are satisfied mostly by theodolite and laser trackers.)

The Range Applications Joint Program Office (RAJPO) was established at the United States Air Force Armament Division at Eglin Air Force Base in 1983. Mr. Tom Hancock was appointed program manager of the Tri-Service GPS-RAP. A Transition Advisory Group was established to create the specifications for the GPS range hardware and system. A contract to perform the full-scale engineering development of the GPS-RAP system was awarded to Interstate Electronics in 1985.

As a result of this development, a family of GPS equipment (figure 1) for range applications has been developed. This family of equipment includes low- and high-dynamic GPS receivers [1,2], GPS pods for application in high-dynamic aircraft, a high-capacity datalink [3], small missileborne GPS translators, a ground-based GPS translator processing system [4,5], and a ground-based GPS reference receiver system.

For highly precise range tracking, video and film cinetheodolites and laser trackers are unsurpassed in accuracy. Accuracies of less than a meter (down to 1/3 meter) have been achieved in range applications. These devices require external control for acquisition, however, because of their extremely narrow field of view. This has been done manually or by external radar control in past applications.

Threat emitters used in air combat training [6,7,8] have similar pointing requirements. Threat emitters are used to simulate enemy threat radar systems. The use of full emulation of these threats proves expensive. Previous attempts to control less expensive simple emitters through multilateration techniques have not been fully satisfactory because of accuracy and time delay limitations.

With the increased use of the Global Positioning System (GPS) on test ranges as a source of medium precision tracking information, the use of GPS to provide cost-effective pointing control becomes attractive.

GPS errors in the differential mode are typically 2 meters horizontal and 4 meters vertical, which is the level of error which has been shown to exist in the equipment developed for the GPS range applications program [1]. This error level is at the target location (and is smaller than many of the vehicles tracked), thus yielding improved angular accuracy as range increases. It is more than sufficient to provide acquisition control for cinetheodolites and laser trackers, and also to provide steering control for threat emitters. The most significant advantage that GPS offers in this application is in the reduction of manpower required to man the tracking and threat emitter sites. When a large number of sites are required on a range with one or two operators at each site, the savings can be significant.

APPROACH

The approach for GPS steering is shown in figure 2. The aircraft pod or missile contains a GPS receiver and datalink transceiver. The position of the aircraft is downlinked to the threat emitter or cinetheodolite site. For a permanent site, a survey is assumed that precisely locates the site, allowing a computation to be performed at the site to precisely track the aircraft or missile. For portable or mobile application, a GPS receiver is used at the tracking site to provide site position. Truly mobile applications would also require a heading reference. When a calibration can be performed after setup in portable applications, the heading reference is not necessary. In either case, the pointing angle can be computed based upon the aircraft or missile position and the threat or cinetheodolite position. In the case of missile tracking, GPS translators are more commonly used than GPS receivers [4,5]. In this case, the communication link is changed from a digital link to an analog translated GPS signal link and the tracking position of the missile is computed at the ground station. The pointing angles can be computed in the same computer.

TIME DELAY AND ACCURACY CONSIDERATIONS

Previous systems [6,7] have used ground-based multilateration in the central ground-based computer system to compute pointing information for threat emitters. Because of the large time delays present in the computer system and associated communication paths, this has proven to be a troublesome approach, and great difficulty has been experienced in obtaining accurate tracking of high dynamic vehicles.

Figure 3 shows pointing angle errors computed assuming that a 1.1-second time delay (along with an 18.7-meter position error) is present in the control path, and that position, velocity, and acceleration information is transmitted (jerk is assumed unmodeled). In the case of a threat emitter or theodolite with a beamwidth or field of view of 2 degrees, these typical pointing errors can cause problems in maintaining the test vehicle in the field of view when at short range.

Figure 4 shows a projected error level for GPS pointing assuming that the time delay is reduced from 1.1 second down to 0.6 second since no central computer is involved, and test vehicle position can be sent on the datalink at a 5- or 10-Hz rate. Also, the position error of the test vehicle is reduced by using differential GPS. In this way, a high probability of maintaining the test vehicle in the field of view of the theodolite or threat emitter is achieved.

CONCLUSIONS

GPS provides an accurate and cost-effective approach for providing pointing information to cinetheodolites, laser trackers and threat emitters on a GPS-equipped range. The most significant savings are achieved if GPS can be used to eliminate manpower required to man these tracking sites.

REFERENCES

1. Kaatz, G,, T. Kido, C. Richmond and R. Snow, "Test Results for the High Dynamics Instrumentation Set (HDIS)," presented to the Institute of Navigation Satellite Division Technical Meeting, *Proceedings of ION GPS-89*, 27-29 September 1989, pp. 87-102.

2. Ould, P. C. and R. Van Wechel, "The Modular Digital Approach to GPS Receiver Design," *IEEE PLANS 86*, Position Location and Navigation Symposium, Nov 5-7, 1986.

3. Birnbaum, M., R. F. Quick Jr., K. S. Gilhousen and J. Blanda, "Range Applications Joint Program Office GPS Range Datalink," presented to the Institute of Navigation Satellite Division Technical Meeting, *Proceedings of ION GPS-89*, 27-29 September 1989, pp. 103-108.

4. Hoefener, C. and J. Stegmaier, "GPS Provides Precision Tracking for ERIS Might Tests," *International Test and Evaluation Association National Conference*, Colorado Springs, 5-7 October 1988.

5. Wells, L., "Application of Translated GPS to the ERIS Program," presented to the Institute of Navigation Satellite Division Technical Meeting, *Proceedings of ION GPS-89*, 27-29 September 1989.

6. Kempf, P. T., "A Now Dimension in Aircrew/EW Training, Red Flag Measurement and Debriefing System," *Journal of Electronic Defense*, Sept. 1986, pp. 51-60.

7. Giadrosich, D. L., "Range Instrumentation for Electronic Combat," *Journal of Electronic Defense*, Sept. 1986, pp. 65-68.

8. Van Wechel, R. and C. Hoefener, "The Role of the Global Positioning System in Advanced Air Combat Training Ranges," *National Aerospace and Electronics Conference*, Dayton, Ohio, 21-25 May 1990.

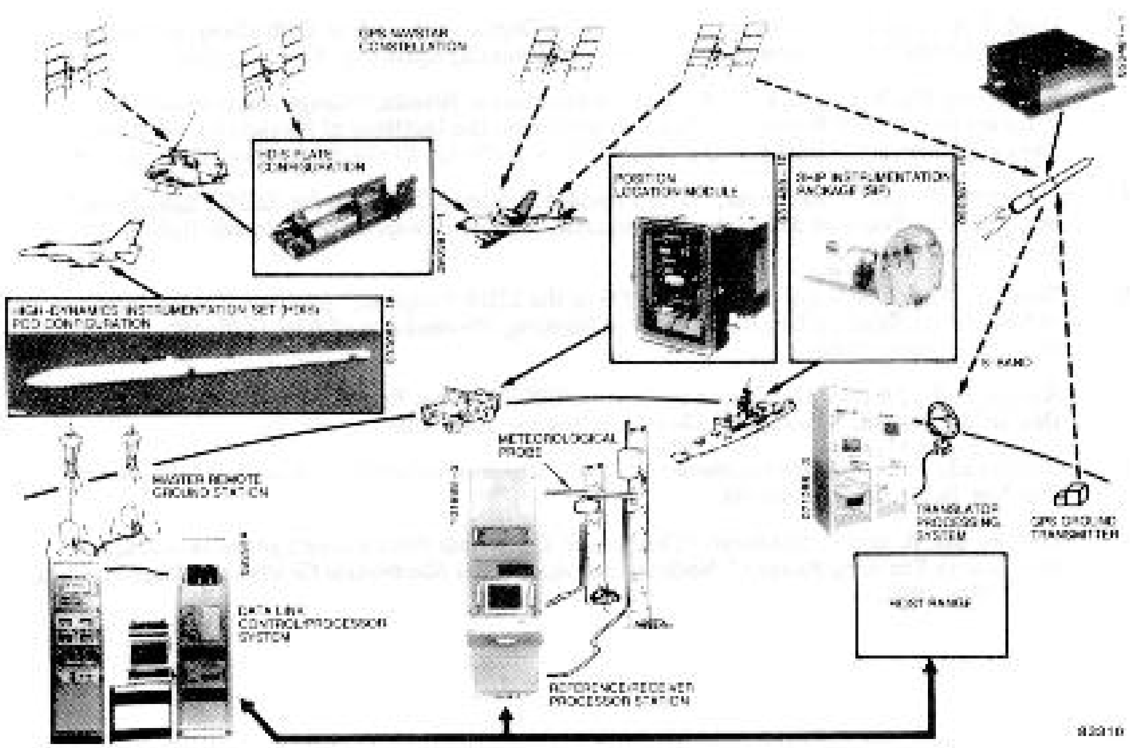

Figure 1. GPS Range Applications Program Equipment

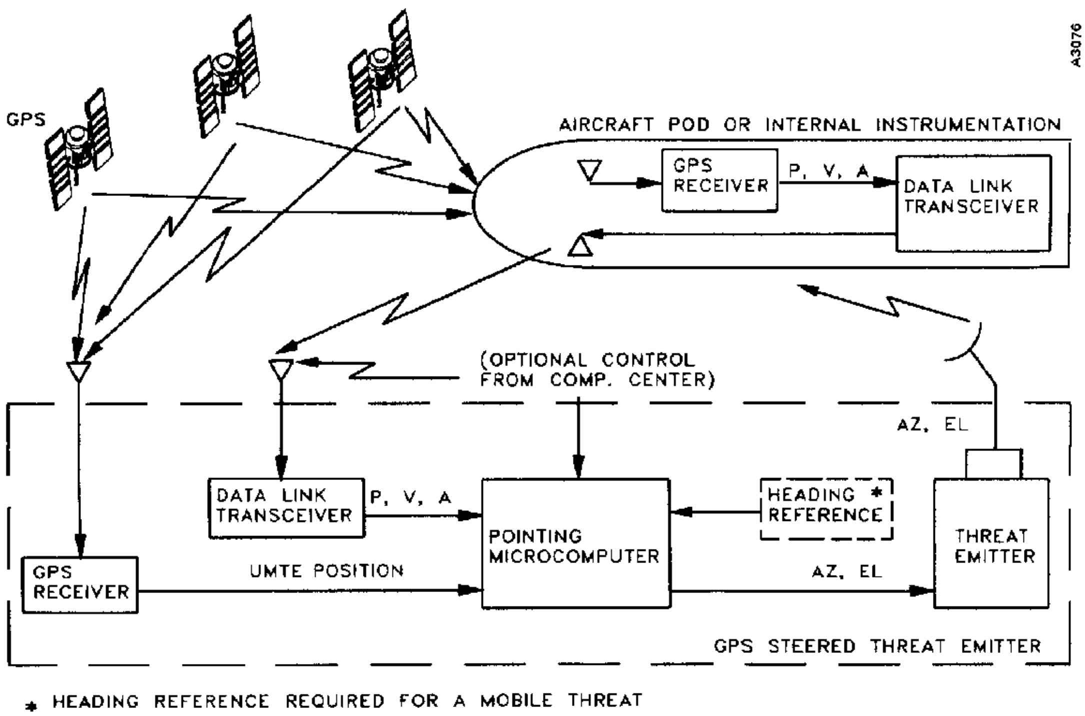

Figure 2. Approach for GPS Steering

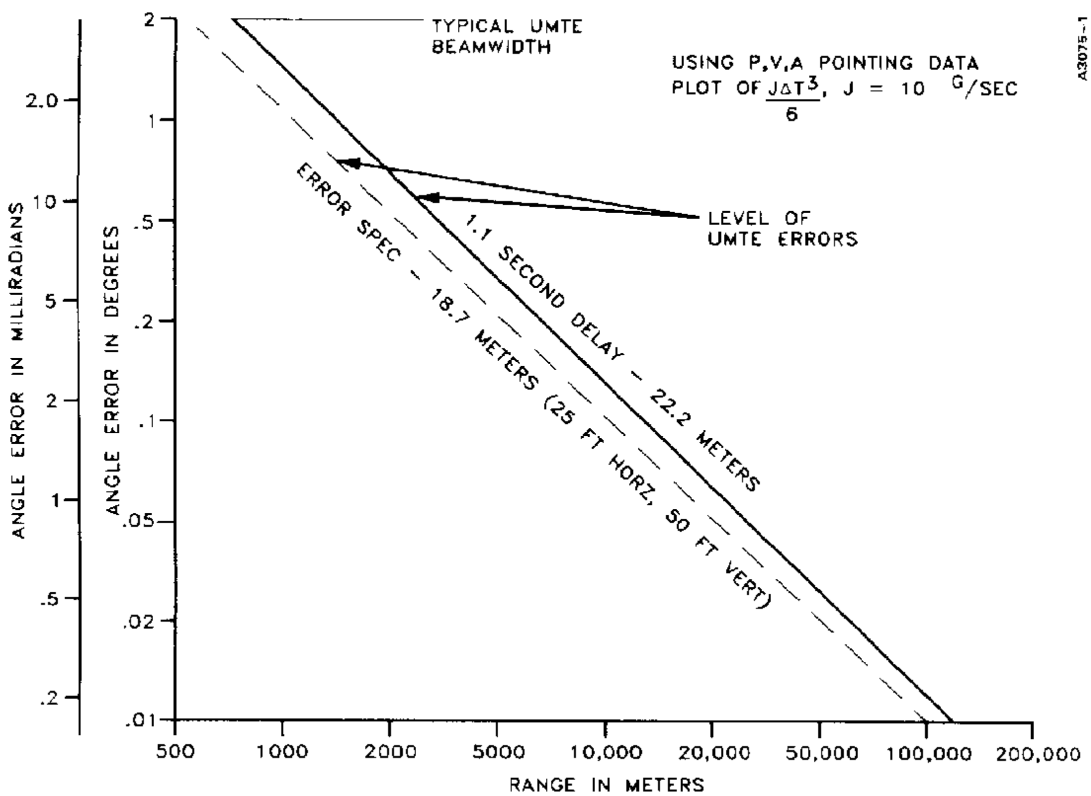

Figure 3. Pointing Error vs. Range for Typical Ground-Based Multilateration System

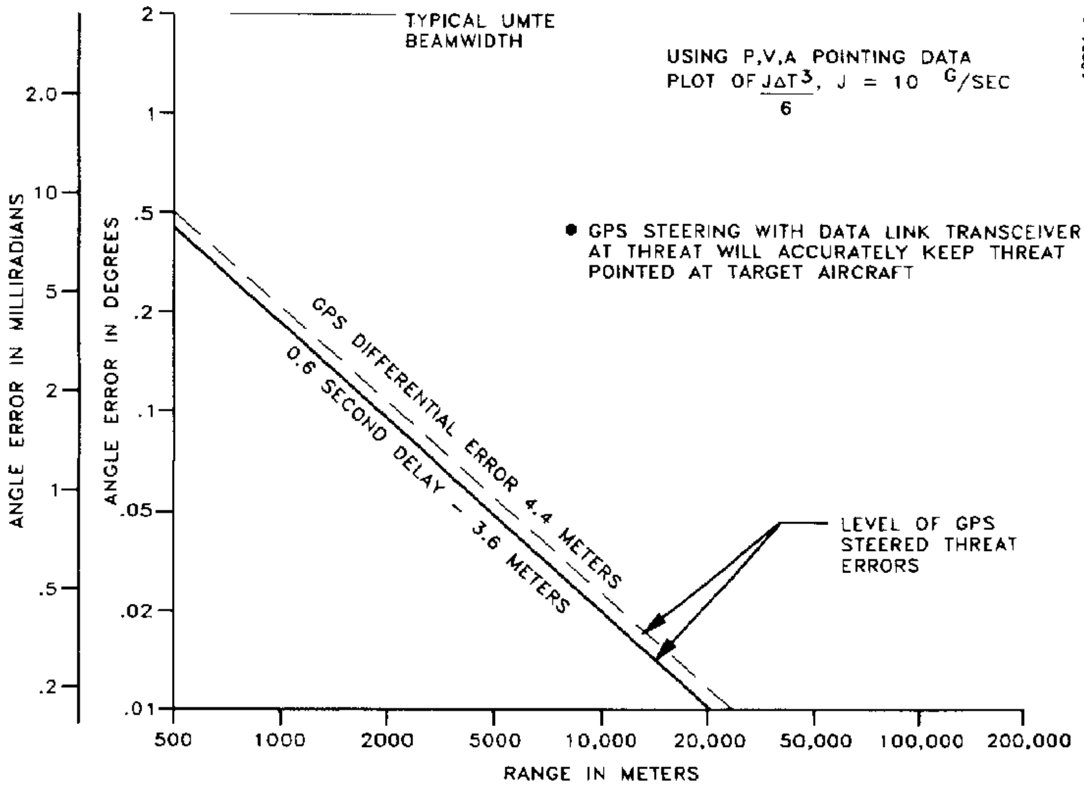

Figure 4. Projected Pointing Error for GPS