DIFFERENTIAL GPS APPLICATION FOR SEA-SKIMMING AERIAL TARGETS

Martin J. Spadaro
Vector Microwave Research Corporation
Missile Systems Group

ABSTRACT

Low cost, commercial off-the-shelf Global Positioning System (GPS) receivers can be used to provide real-time track of ground launched subsonic, sea-skimming missile targets when integrated with existing telemetry equipment and commercial radio modems. GPS reference stations can be deployed that are capable of generating, broadcasting and monitoring Differential GPS corrections that effectively eliminate the deliberate position errors imposed by the Department of Defense. Commercial GPS receivers are effective and provide contiguous position data even during the boost phase of flight when G forces exceed the receiver manufacturer's published specifications.

KEYWORDS

DGPS, Positioning, Telemetry, Missile Target

INTRODUCTION

Beginning in May of 1992 the United States Navy took possession of 180 anti-ship cruise missiles (ASCM), several launchers and over 100 tons of spare parts from the former East Germany for the cost of transportation. The missiles, called SSN-2D and built in the former USSR, were to be modified to satisfy range safety requirements, fueled, and launched under the auspices of the Surrogate Target Program (STP) as targets for AEGIS weapons system testing. The launch site was to be the west end of San Nicolas Island, CA, 60 nautical miles south of the NAVAL AIR WARFARE CENTER-WEAPONS DIVISION (NAWCWPNS) at Point Mugu, CA. Traditional methods of missile track required a FPS-16 radar in conjunction with a radar beacon on board the missile. Because of shadow zone and accuracy problems with the FPS-16 radar on San Nicolas Island, a new method of track was desired. A GPS receiver was incorporated into the missile for this purpose.

As a result of a compressed launch schedule, the instrumentation added to the missile was selected from existing components to minimize lead times. A commercial off the shelf (COTS) GPS receiver and a pair of radio modems for uplink of differential corrections were procured. An AN/DKT-59V telemetry set for GPS position downlink was acquired as GFE.

GPS RECEIVER PERFORMANCE

The Rockwell Navcore V GPS receiver was selected for tracking the missile. This receiver had 5 parallel satellite tracking channels and could keep track of up to 9 satellites using the 5th. The receiver required only 4 satellites to generate a position solution. The receiver accepted differential correction messages broadcast from a GPS reference station established behind the beach launch site and 600 feet higher in elevation.

In order to ensure that the GPS receiver had sufficient time to acquire and track all visible satellites prior to missile first motion, external power was supplied through an added pull-away umbilical. An external GPS antenna was added to the outside of the missile's metallic launching container to provide the best possible pre-launch coverage to the missile GPS receiver. A solid state 1 X 2 RF switch was designed to provide the hand-off required between an internal (missile mounted) GPS antenna and an external (launch container mounted) GPS antenna. The solid state RF switch was commanded from the launch system by the action of umbilical disconnect just prior to liftoff. After having acquired and tracked visible satellites while in the launching container, the GPS receiver switched to the internal antenna just prior to exiting the container and continued to track satellites with favorable relative positions. Figure 1 illustrates the internal and external GPS antenna mounting configuration.

After several launches it was evident that the 10-12 G launch acceleration was too much for the GPS receiver's satellite tracking loops when the satellites were closely aligned with the missile's flight path. Since the GPS receiver was capable of maintaining current satellite status of 9 satellites, it normally recovered within seconds by switching to the satellites with favorable relative positions and contiguous position solutions resulted. For all flights the GPS receiver delivered accurate position solutions (2-5 m RMS estimated) during the cruise phase of flight. The maximum rated acceleration of the GPS receiver was 4 G's.

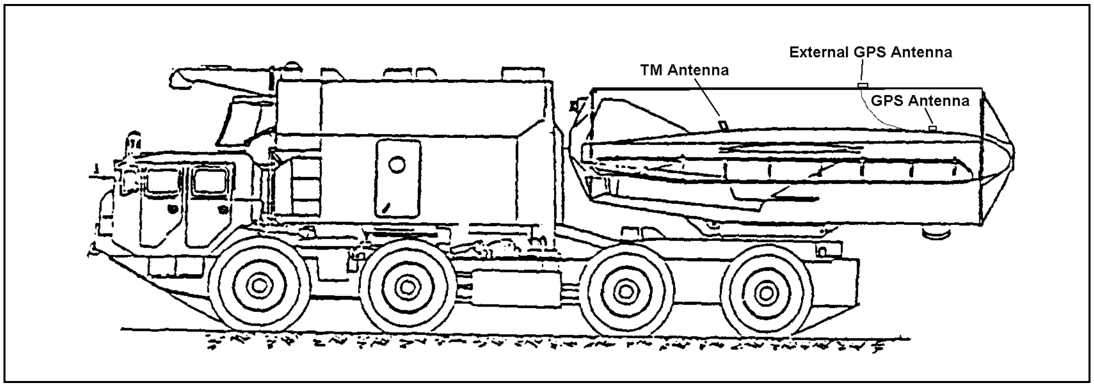

Figure 1. Pre-launch GPS antenna mounting configuration

DIFFERENTIAL GPS REFERENCE STATION

A survey marker was used to establish the precise position of a GPS reference receiver antenna necessary to generate differential GPS corrections. This method of differential GPS requires that a reference GPS receiver calculate range errors (corrections) to all visible satellites by subtracting the observed pseudorange from the known pseudorange. The corrections to the pseudorange to each visible satellite were transmitted to the missile during all phases of flight and improved the missile GPS receiver's position reporting accuracy. A telemetry receiver and FM discriminator were used to confirm that the missile GPS receiver was acknowledging the correction messages sent once each second from the reference station. A Personal Computer was used to initialize and monitor the GPS reference receiver, track and log the missile GPS reported positions and route the pseudorange corrections to the transmitting radio modem. Figure 2 shows equipment block diagrams for the Differential reference station and the missile target. The radio modem installed in the missile was set for receive only operation.

GPS RECEIVER DATA AND TELEMETRY

The AN/DKT-59V Telemetry set is an FM/FM set with 10 subcarrier oscillators (SCO) summed to frequency modulate the transmitter carrier. This particular FM/FM set was designed to accept a 0 to 5 Volt signal at each SCO input. Since the GPS engine came with a TTL compatible data output, the telemetry interface in the missile was very simple and proved to be equally effective. An IRIG Channel H SCO (165 kHz center frequency, 15% PBW) installed in the DKT-59 was connected to the 9600 bit per second TTL GPS receiver data output directly. Since the SCO was DC coupled, the NRZ-L TTL data was compatible. At the telemetry receiving site the FM was adjusted to interface with the Personal Computer's serial data port directly. Seven SSN-2-D missile targets were successfully tracked using commercial off the shelf GPS receivers, radio modems and available telemetry components.

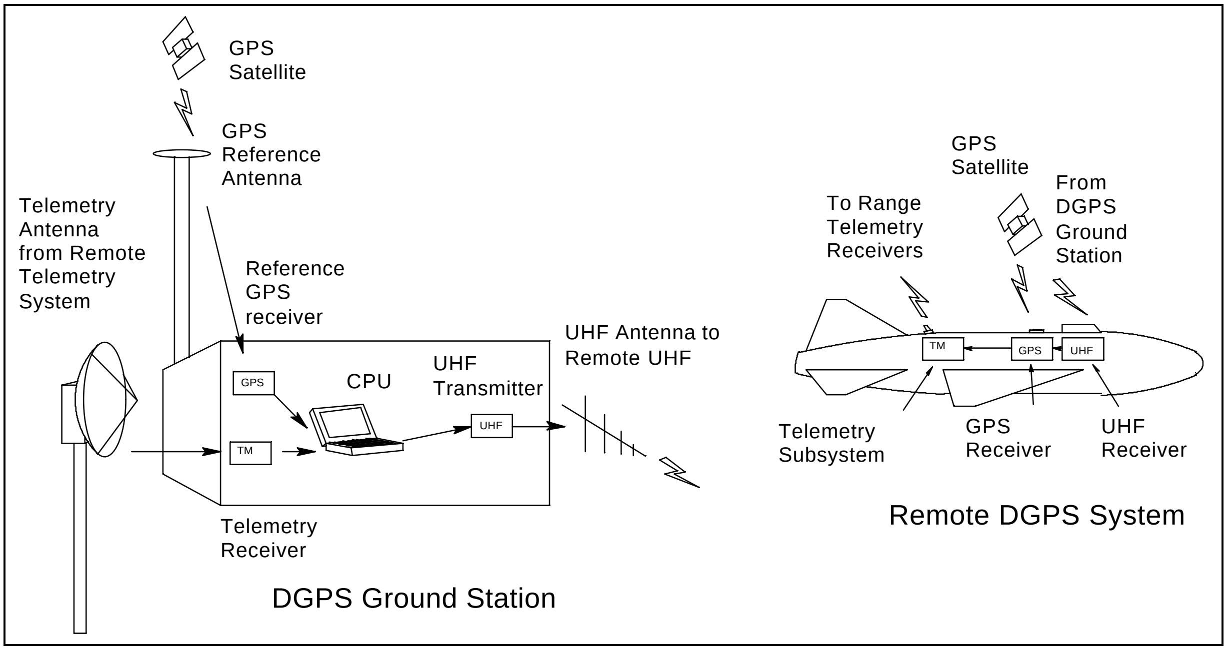

Figure 2. DGPS equipment block diagrams

RESULTS

The Rockwell Navcore V DGPS receiver stayed locked through the launch phase. The telemetry recorded the position with very few missed points. Of note was the performance of the reported altitude from the DGPS receiver. Figure 3 shows a good correlation between the missile target altimeter and the altitude reported by the DGPS system. Only the two sources of altitude were compared because the missile altimeter had the only measurable signal with comparable resolution to the GPS signal.

CONCLUSION

Commercial GPS receivers provide a cost effective alternative means of providing missile track data using existing telemetry equipment. Advances in GPS receiver technology, processing power and hybridization/miniaturization have been steady and will continue. Commercial GPS receivers available today include single frequency 20 G acceleration and 20 Hertz update rates. GPS technology will find application in all areas of weapons test and evaluation in the very near future.

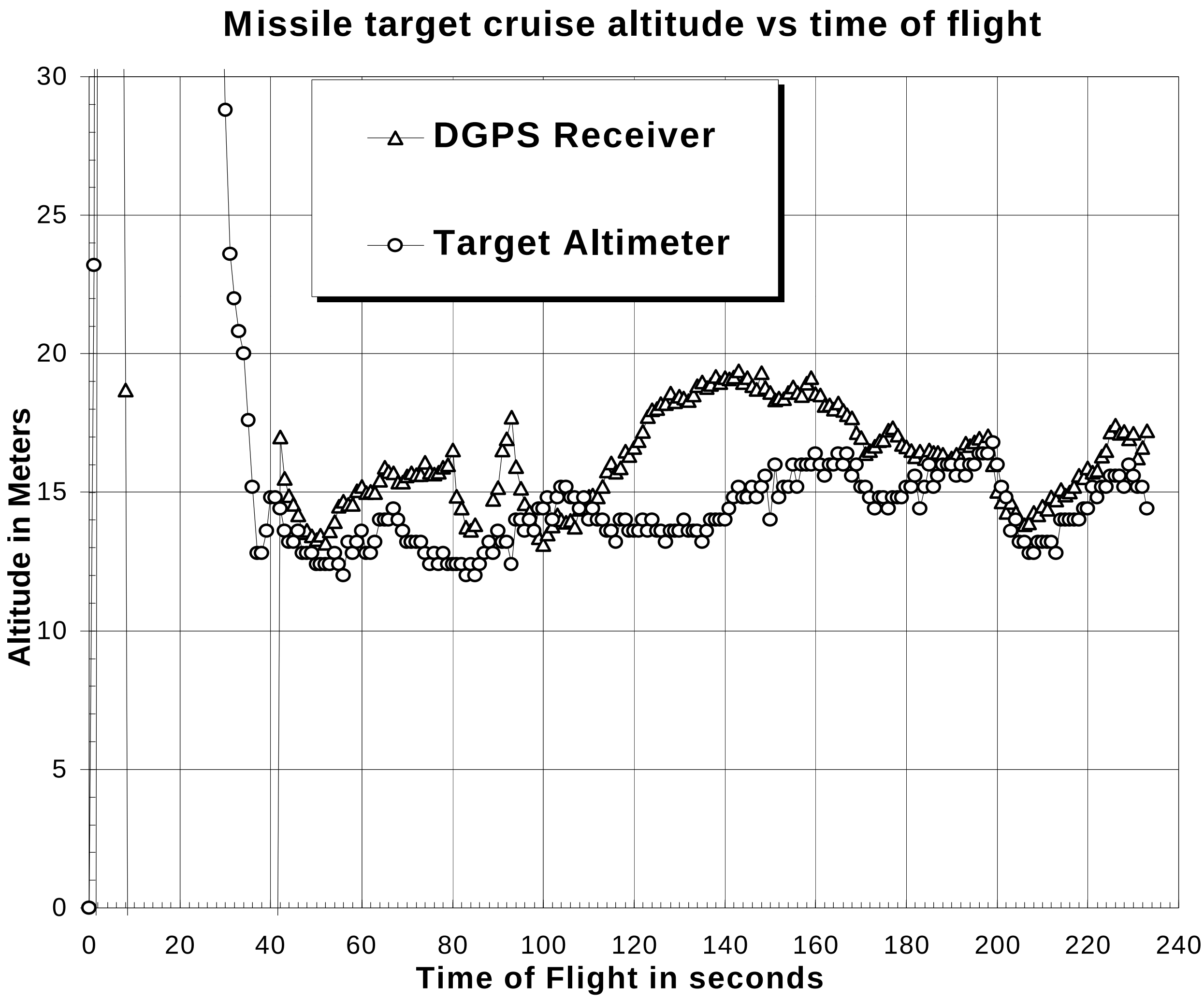

Figure 3. DGPS and altimeter reported altitude