A GPS RECEIVER/TRANSMITTER UNIT FOR TRACKING LAUNCH VEHICLES

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ABSTRACT

Launch Vehicle tracking is indispensable due to the fact that wayward vehicles must be destroyed lest they cause loss of life and/or damage to property. Launch Vehicle tracking data is also useful in assessing vehicle performance and mission success.

Cincinnati Electronics (CE) has developed a Global Positioning Satellite (GPS) Receiver/Transmitter Unit (RTU), specifically for use with launch vehicles. The CE GPS RTU was flown as an experiment on the Missile Technology Demonstration (MTD) flight at White Sands Missile Range (WSMR). This paper provides an overview of CE's GPS RTU and provides the results of CE's GPS RTU MTD-3 flight performance.

KEYWORDS

GPS, Launch Vehicle, MTD, S-Band, Tracking

INTRODUCTION

Presently 12 C-Band tracking radars support the U.S. Eastern and Western ranges. Due to a variety of factors, including aging equipment, labor intensive operations, maintenance costs, and reliability concerns, the U.S. Air Force is exploring new tracking system architectures for the Eastern and Western Ranges. A GPS based system appears to be an excellent candidate architecture to replace the existing C-Band radar tracking system.

The GPS system consists of 24 satellites that transmit precise position location, speed, and time information to GPS receivers. Launch Vehicles equipped with GPS receivers would allow the vehicles to transmit their position location and speed back to the range. Potential benefits of this approach include lower launch costs and increased reliability after making the initial investment in conversion costs.

HARDWARE CONFIGURATION

A system block diagram of CE's GPS RTU as flown on MTD-3 is provided in Figure 1. CE's GPS RTU is composed of two primary sections: a GPS receiver and an S-Band Transmitter. The CE GPS RTU will track a satellite as long as the C/N_0 is greater than 30 dB-Hz. Below this threshold, the probability of cross correlation becomes unacceptable and the SV signal will not be used. The CE GPS RTU was located inside the interstage section of the MTD-3 rocket booster. The L1-Band antenna configuration included two patch antennas located 180° apart on the motor adapter. The motor adapter diameter was approximately 52.5 inches. The antenna outputs were cabled to two LNAs with 7 dB gain and then coupled together prior to being input to the CE GPS RTU. LNAs were used to overcome cable and coupler losses. CE's GPS RTU was the only experiment to use two patch antennas.

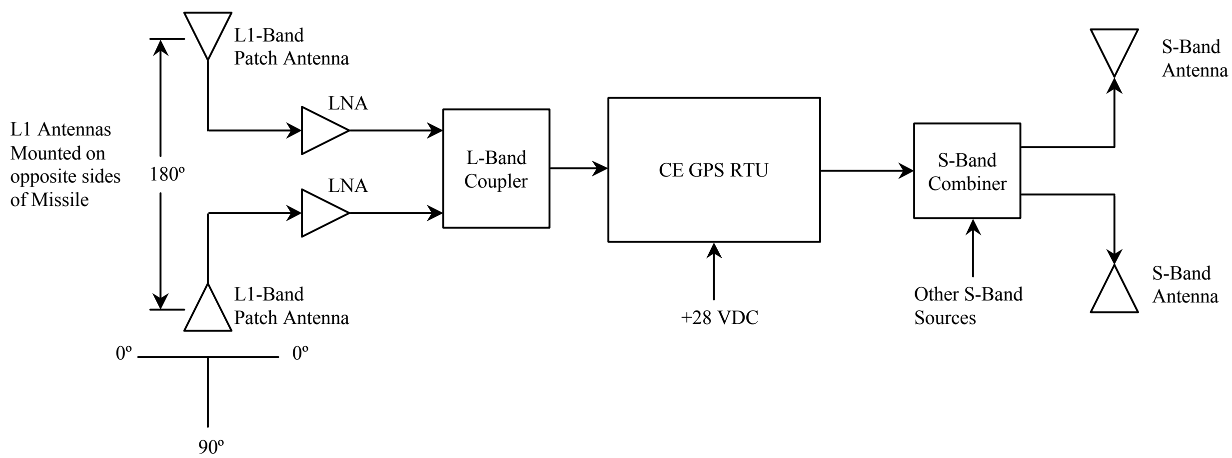

Figure 1 GPS Receiver/Transmitter System Block Diagram

MISSILE TECHNOLOGY DEMONSTRATION

On Thursday, September 24, 1998, the MTD-3 rocket carried out a high-precision launch for the U.S. Air Force and U.S. Army at White Sands Missile Range, New Mexico. The MTD-3 launch was the third in a series of high-precision suborbital technology demonstrations. MTD-3 lifted off at 6:50 a.m. MDT from the White Sands Missile Range. The vehicle reached an apogee of around 180 km and traveled approximately 113 km downrange. The MTD-3 vehicle was comprised of a single-stage Minuteman II SR-19 rocket motor which carried a modified Pershing II Medium Range Ballistic Missile reentry vehicle. Suborbital rockets like MTD-3 are used by various groups on a variety of high-altitude missions including missile testing, demonstrating new space/launch vehicle related technologies, and carrying out scientific research above the earth's atmosphere.

The MTD-3 flight included 65 seconds of powered flight, RV separation at 67 seconds and the booster tumbled for an additional 367 seconds before impact for a total flight time of 434 seconds. The tumble phase of the experiment was intended to represent a launch vehicle becoming unstable. The tumble included a 3.6 rpm rotation and the booster was wobbling in a cone shape.

RESULTS

Telemetry was received from the CE GPS RTU for 430 seconds of flight. During the entire flight, the CE GPS RTU remained in navigation mode and transmitted continuous position, velocity and satellite information to the ground station. Flight statistics as measured by the CE GPS RTU are given as follows:

- Maximum velocity achieved during boost phase was 1692 m/s, at 64.4 seconds.
- Maximum velocity achieved during tumble phase was 1694 m/s, at 422.0 seconds.
- Maximum altitude achieved was 189010 meters, at 241.6 seconds.

Throughout the boost phase of the launch, there were eight satellites in view and the CE GPS RTU maintained lock on all eight from launch through RV separation. Table 1 shows the average received C/N_0 of the eight satellites tracked during the boost phase. As can be seen in Table 1, the average C/N_0 through out the boost phase has a minimum of 15 dB of margin over the requisite 30 dB-Hz.

Table 1 MTD-3 Boost Phase Satellite Carrier-to-Noise Summary (0 to 70 Sec.)

SV Number	**5**	**6**	**10**	**13**	**17**	**24**	**26**	**30**
Average C/N_0 (dB-Hz)	52.41	48.70	46.44	47.54	45.97	48.61	50.62	50.44
1 sigma C/N_0 (dB-Hz)	0.73	2.10	3.77	2.44	2.51	1.81	0.64	2.19
Minimum C/N_0 (dB-Hz)	51	44	39	38	37	45	49	45

The boost phase of the flight was complete at RV separation (67 seconds) and the booster section containing the CE GPS RTU began to tumble as it fell back to earth. During the tumble phase, the CE GPS RTU maintained lock on 7 to 8 satellites until impact. In fact, eight satellites were tracked for 421 seconds out of 430 seconds of the total experiment data. As shown in table 2, the average C/N_0 received during the tumble phase was not affected by the booster unstable dynamics. Table 3 shows the overall flight C/N_0.

Table 2 MTD-3 Tumble Phase Satellite Carrier-to-Noise Summary (70 to 430 Sec.)

SV Number	**5**	**6**	**10**	**13**	**17**	**24**	**26**	**30**
Average C/N_0 (dB-Hz)	49.27	49.48	50.09	47.83	48.06	49.45	47.10	51.03
1 sigma C/N_0 (dB-Hz)	2.39	2.83	2.22	3.14	2.23	2.46	3.08	2.23
Minimum C/N_0 (dB-Hz)	42	37	45	38	40	42	35	38

Table 3 MTD-3 Overall Launch Satellite Carrier-to-Noise Summary (0 to 430 Sec.)

SV Number	**5**	**6**	**10**	**13**	**17**	**24**	**26**	**30**
Average C/N_0 (dB-Hz)	49.92	49.31	49.33	47.77	47.61	49.27	47.85	50.91
1 sigma C/N_0 (dB-Hz)	2.50	2.71	3.01	3.01	2.44	2.36	3.11	2.23
Minimum C/N_0 (dB-Hz)	42	37	39	38	37	42	35	38

Plots of the position and velocity error are provided in Figures 2 through 7.

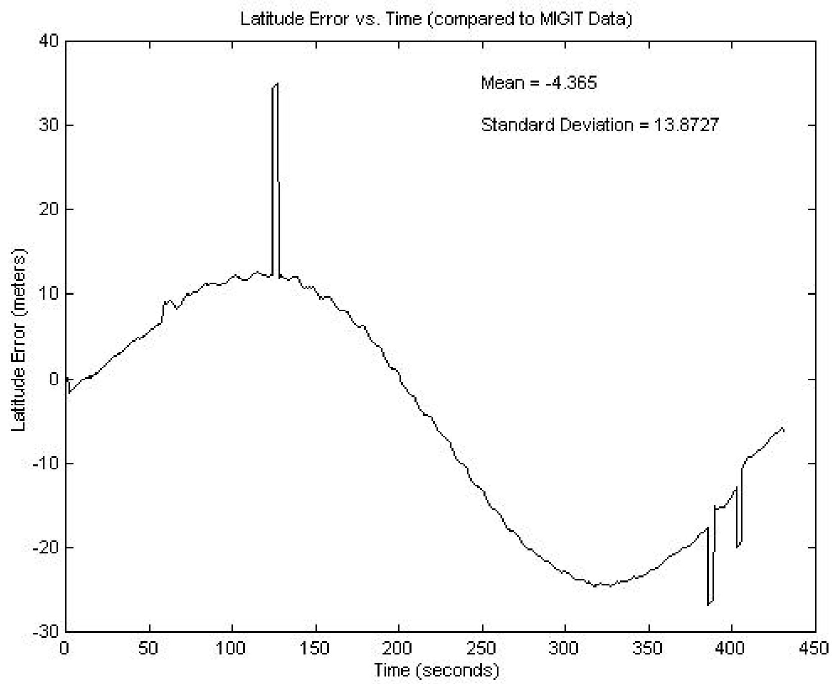

Figure 2 Latitude Error vs. Time

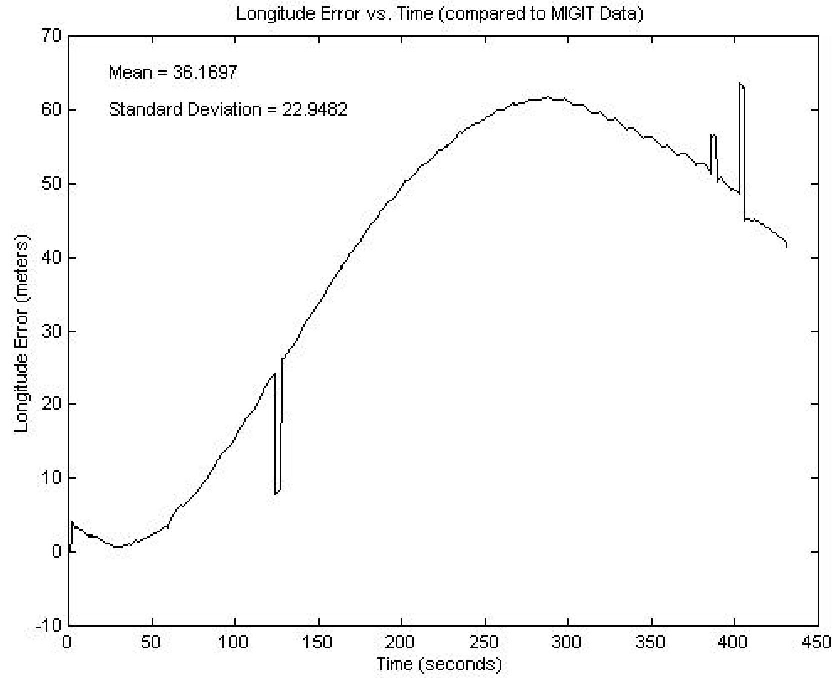

Figure 3 Longitude Error vs. Time

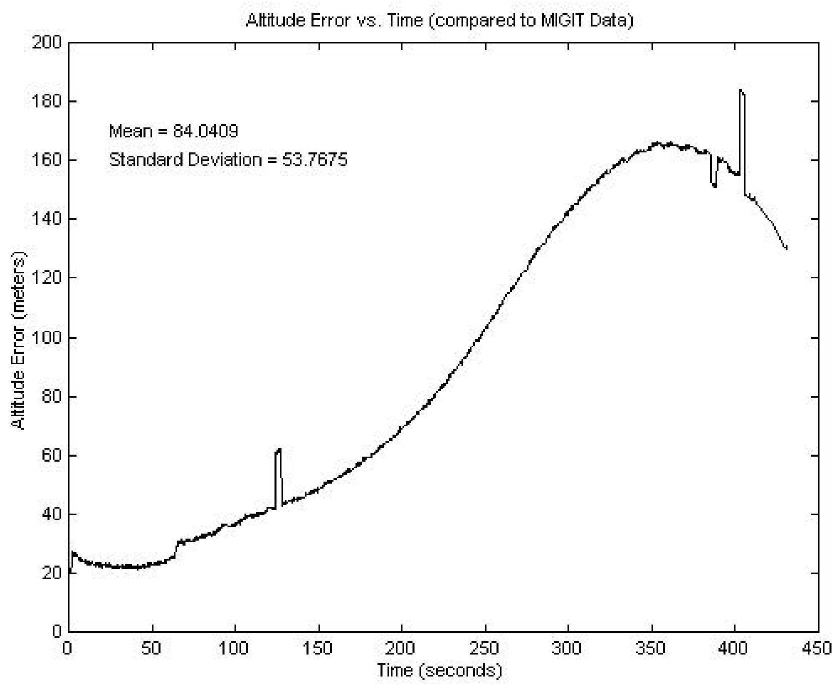

Figure 4 Altitude Error vs. Time

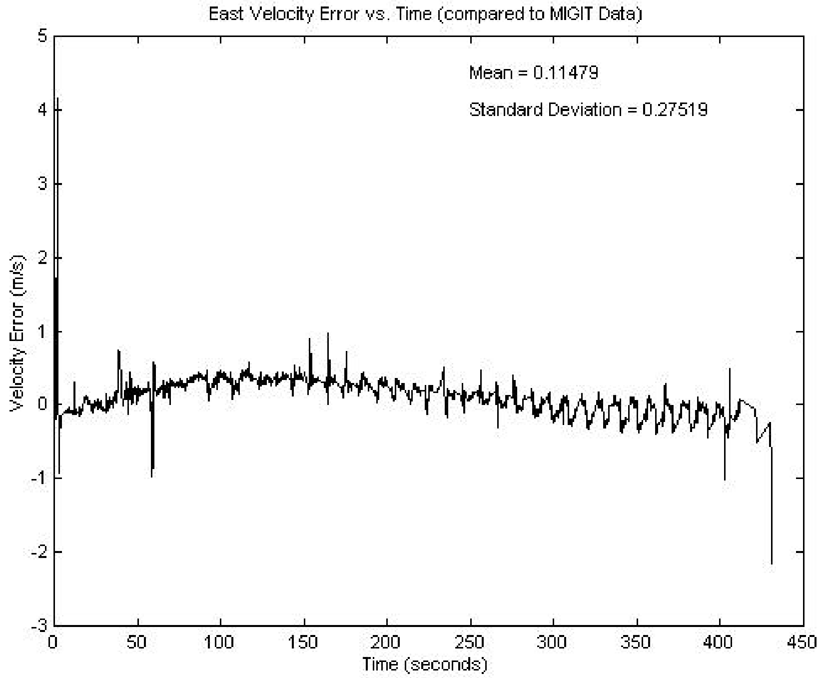

Figure 5 East Velocity Error vs. Time

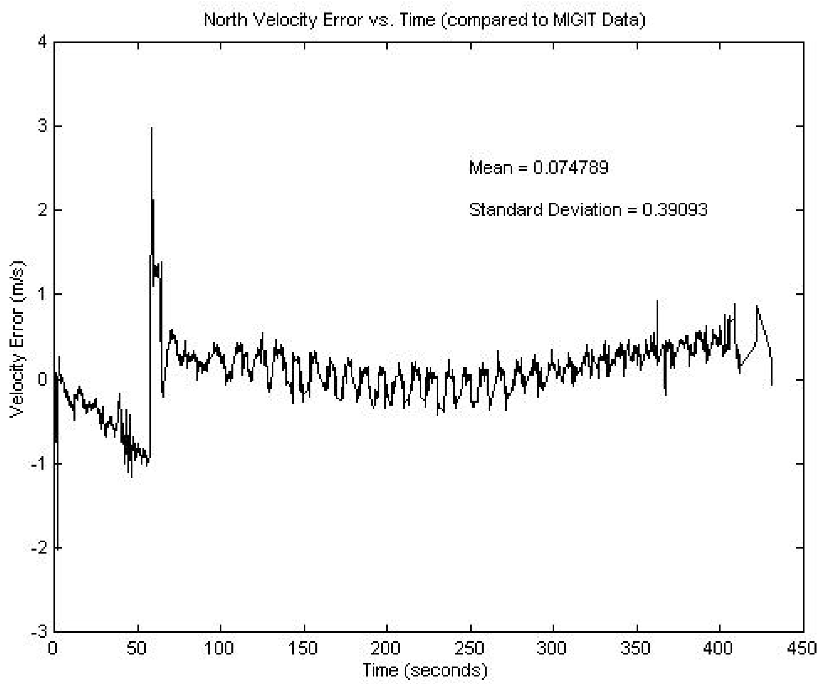

Figure 6 North Velocity Error vs. Time

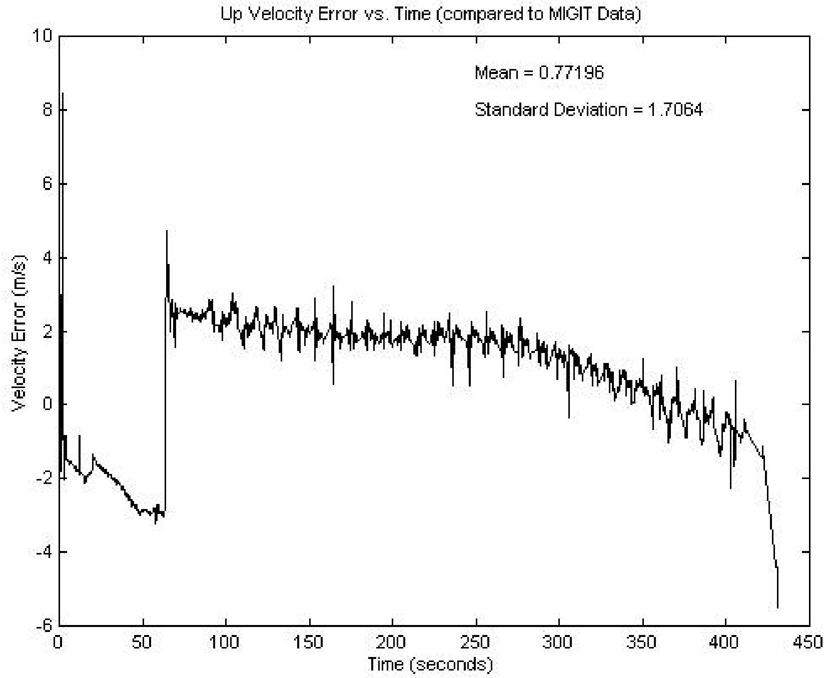

Figure 7 Vertical Velocity Error vs. Time

CONCLUSION

Analysis of the number of satellites tracked and carrier-to-noise (C/N_0) levels received indicate the two L1-Band patch antenna implementation provides outstanding Space Vehicle (SV) coverage with more than adequate signal level to maintain tracking through out the launch.

REFERENCES

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