Qualification of high dynamics GPS receiver for space borne application

Hemachandran.S, Harikumar G, L.G MahendraMurali, M Baskaran
Abdul Shukkoor, Dr. Mohanlal PP
ISRO Inertial Systems Unit, Indian Space Research Organisation,
Vattiyoorkavu, Thiruvananthapuram
s_hemachandran@vssc.gov.in

Abstract:
Space-borne receivers are designed for specific scientific application or high accuracy aided navigation. The design of a high dynamics GPS receiver involves taking care of many complex receiver tracking problems and application of novel computation methods to give instantaneous position and velocity at every one second interval. The time synchronization of GPS receiver and rest of the onboard computer is another design capability essential for aided navigation. GPS receiver testing methodologies for space borne application is unique. Apart from looking for standard deviation of position, velocity and other receiver capabilities, the GPS receiver is subjected to various environmental tests. High dynamic performance capability of the receiver is qualified using a GPS simulator setup. The paper describes the unique design features and capabilities of a space-borne GPS receiver and various test procedures adapted for its qualification.

Key words: GPS receiver, space qualification, GPS simulator, test procedure.

I. INTRODUCTION

GPS receiver technology has grown many fold on commercial, industrial, scientific and space segments. Commercial receivers are used only for position determination and related services. Receivers developed for launch vehicle or spacecraft would experience a large doppler shift that makes the design and validation a challenging process. The technology has advanced very much, processing capability and RF design have become compact, and hence the GPS receiver is now being used as secondary navigation system in many launch vehicle and satellite systems. New generation launch vehicles and long duration missions need some type of external aiding for all kinds of inertial navigation systems due to their inherent limitation. The GPS receiver has become a de-facto option for aided navigation combined with other navigation sensors.

Space-borne GPS receiver capability is given in section II. Section III is on design guidelines and section IV & V is on static and dynamic tests of the receiver. Typical test results are also described in these sections. Section VI gives the environmental tests on the receiver and conclusions of the paper are presented on section VII.

II. GPS RECEIVER CAPABILITY

The GPS receiver needs specific capabilities for space borne application. The characteristics of a typical receiver are the following: 8 channel receiver with Mil-1553 and RS232C data output, 1PPS timing port, and 20V to 40V operating range. It can withstand a velocity of 10500m/s, acceleration 15g and jerk 20g/sec. It generates messages at one second rate. The message structure is defined in such a way that most of the performances are verifiable under different test conditions. The output data comprise of position, velocity in ECEF, latitude, longitude and altitude, receiver health and mode of the position fix 2D/3D. The receiver channel status indicates which satellite is acquired, tracked and its carrier to noise ratio (C/N), range and range rate of the satellite under track. The ephemeris of the satellite under tracking is given periodically. The receiver clock bias and the arrival of external time sync command is also provided for qualification purpose. The data is in custom binary form.

III. DESIGN GUIDELINES

Most of the components are selected from the preferred part list and others are screened before using them. The PCB design is followed as per ISRO guidelines. The vibration sensitive components are mounted with special care. The PCB mounting and chassis design are done to withstand the environmental test condition.

IV. STATIC TEST OF GPS RECEIVER

Apart from hardware qualification norms, the performance of the receiver is established by the following series of tests.

1. Test configuration

The GPS receiver is fed with an active antenna at roof top and the data is acquired using a checkout system unit. The checkout system realized on LapTop PC with PCMCIA based Mil-1553 controller for handling Mil-1553 data and serial port for handling the serial data. The data format is in custom binary format. The 1PPS (pulse per second) timing signal is given to counter. The software is realized on LabWindows platform. The PC acts as Bus Controller (BC) and commands the GPS receiver at 500msec interval and the data is logged for post processing. The real time display shows the receiver channel, position, velocity and GPS time. The Fig 1 shows the typical diagram.

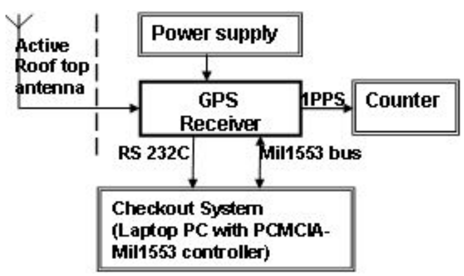

Fig 1: typical test set up

2. Time to First fix(TTFF)

The time to first fix of the receiver is the time taken by the receiver to get its 3D position fix from the cold start (from the power on). The assumption is that the receiver is not having the satellite almanac or ephemeris information at the cold start. Real time display of the checkout system gives the time to first fix from the command button provided at GUI interface. The test can be repeated and the average time taken for time fix may be observed.

3. Static Position, velocity and update rate.

Test configuration is as in fig 1 and the data is acquired continuously for 30 minutes. The mean and standard deviation of position & velocity in ECEF, latitude and longitude are found out. The GUI is provided to tabulate the test results over the specified period. The expected deviation in x, y & z position and velocity must be less than the 3 sigma specification. Typical checkout display is shown in Fig 2.

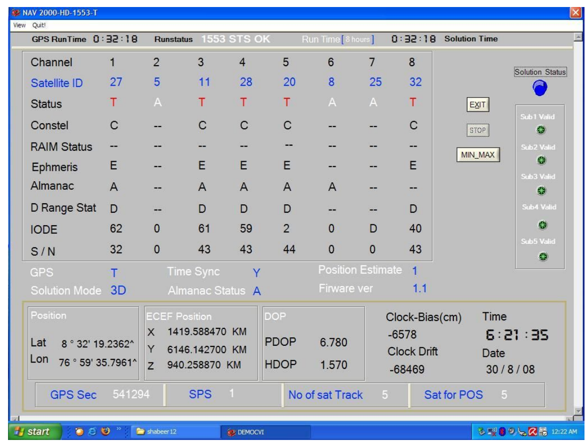

Fig 2: Checkout display GUI

4. Reacquisition time

The reacquisition time is determined to assess the capability of the receiver in the event of an RF signal outage. GPS RF signal strength varies depending on the trajectory and maneuver of vehicle, where the number of satellites visible may reduce below the position fix criteria. The reacquisition time is the time measured from the point of RF disruption to reacquisition provided the receiver was in a stable 3D position fix for at least 5 minutes prior to the outage. The RF disruption can be made by inserting a RF attenuator on signal path and observing the time for the position fix (3D) after making the attenuation zero. The typical reacquisition time is much less than TTFF.

5. IPPS clock stability

The Fig 1 is test setup and the 1PPS output of the GPS receiver is observed after the 3D position fix. The clock stability is measured using a 10nsec stability counter. The expected clock stability is less 100 nsec.

V. DYNAMIC TEST OF GPS RECEIVER

The GPS receiver is connected to GPS simulator as in Fig 3. The LNA and the variable attenuator in L1 band are connected as shown in Fig 3. The simulator has the capability to change the signal strength of the satellites individually or collectively. It also provides the motion simulation capability under various scenarios. The scenarios are the different conditions of trajectory one can create to validate the GPS receiver. Typical scenarios are launch vehicle ascend, orbital phase and descend for reentry modules from orbit etc. The simulator also provides a capability to specify a 3D antenna pattern with respect to vehicle body.

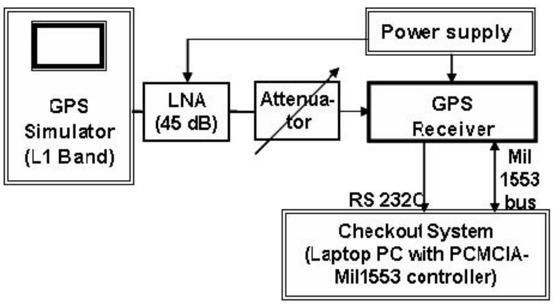

Fig 3 : GPS receiver in GPS simulator test bed

1. GPS receiver sensitivity

In a typical static test profile, GPS simulator generates the GPS satellite signal as experienced by a static receiver depending on the position (latitude, longitude & altitude) of the receiver. The attenuator is kept at 20dB as shown in Fig 3. The antenna pattern is omni-directional. The checkout system is kept in acquisition mode. The receiver power level is varied by adjusting the base power level of the simulator, attenuator value and observing for 5 minutes whether the receiver is able to track satellites.

2. Flight profile test.

The aim is to verify the receiver performance as in the actual flight scenario. The simulated trajectory profile in ECEF frame is generated and fed to the simulator. The UTC time of the profile and the realized 3D antenna pattern is also given to the simulator at start. The test set up is same as in Fig 3. The LNA and attenuator are kept to simulate actual use condition. The Carrier/Noise (C/N) ratio at the receiver is taken as the reference once the receiver tracking capability is established in previous test conditions.

The data is acquired in mil-1553 bus and the necessary parameters like position, velocity, PDOP, number satellite tracked and used for computation of position etc are monitored against the simulator log.

The typical residual error in position and velocity are shown below in Fig 4.

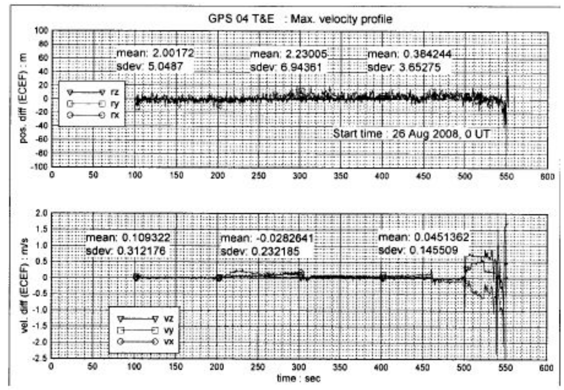

Fig 4: The position and velocity residuals under max-velocity profile.

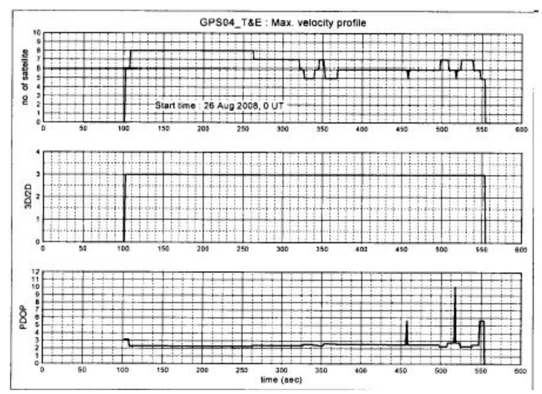

Fig 5: PDOP, 2D/3D status and number of satellite tracked.

The test report is generated under different profile conditions viz. trajectory of the vehicle on which the receiver is used, maximum velocity, acceleration and jerk profile to verify the tracking capability of the receiver.

VI. ENVIRONMENTAL TEST

1. Thermal test.

The test set up is as in fig 1 and the GPS receiver is kept inside a thermal chamber. The GPS is soaked at 8 deg C and 70 deg C for 5 hours and performance is observed for position & velocity for 30 minutes.

2. EMI test.

The package will be subjected to standard electronic package level Conducted Susceptibility, (CS06, CS01, CS02) and Radiated Susceptibility, (RS02, RS03) test, followed by Conducted Emission test (CE01, CE07) and radiated emission test. In the above cases the GPS data is acquired and the performance is observed.

3. Vibration test.

The package is subjected to standard vibration level depending on the flight environment for electronic package. The package is mounted on vibration table and excited with sine, random and shock vibration on all 3 axes of the package. Each vibration test is conducted while GPS receiver data is logged. The variation of position, velocity and PDOP are monitored and performance assessed.

4. Humidity test.

The humidity test is carried out to access the resistance of the components to high humidity condition and variation of temperature cycle associated with humid conditions encountered in tropical areas.

The package is kept on a humidity chamber and the temperature is raised to 45+/- 2 deg C in 2+/- 0.5 hrs with relative humidity not less than 80+/- 5%. The temperature and humidity is monitored for 6 hrs. After the test the package is inspected for corrosion and surface finish. The insulation test is conducted to verify the break down condition.

The receiver will be powered and its normal health will be verified. This test is done only on engineering model of the package.

VII. CONCLUSION

The GPS receiver is realized with industry participation. The performance of the package is evaluated by various tests including realistic and stress trajectories. The GPS receiver is qualified successfully for various space applications.

ACKNOWLEDMENT

Mr. P. S. Veeraraghavan, Director, IISU, is gratefully acknowledged for encouragement and support of the work detailed here. The authors would also like to acknowledge Mr. BC Vidwani. DD LVIS for encouraging us to take up the challenging task.

BIO DATA OF AUTHORS

S.Hemachandran received B.Sc (Engg) degree in Electronics and Communication Engineering from University of Kerala, in 1983 and M.Tech degree in Electrical Engineering from IIT, Kanpur in 1989. Currently working as Dy. Division Head, NSSD-COS, of ISRO Inertial Systems Unit. His research areas are Embedded systems, Real-Time systems, GPS and Signal Processing.

Dr. P.P. Mohanlal received B.E degree in Electronics and Communication Engineering from Madras University, in 1976, M.Tech degree in Applied Electronics and Instrumentation from University of Kerala in 1995 and PhD degree in Computer Science from University of Kerala, in 2005. He is currently heading Navigation Software and Simulation Division in ISRO Inertial Systems Unit. He is a member of the post-graduate board of studies of University of Kerala. His research interests include Aided Inertial systems and intelligent control methods for nonlinear systems (Neural, fuzzy and neuro-fuzzy methods).

Harikumar Ganesan received B.Tech degree in Electrical and Electronics Engineering from National Institute of Technology, Calicut in 2004. He is currently working as scientist/engineer-sc in NSSD-COS, of ISRO Inertial Systems Unit. His research areas are Embedded systems and GPS.