

RAIM and How to Test Using the GPSG-1000

The GPSG-1000 Portable Satellite Simulator is uniquely placed in both capabilities and price to provide outstanding value to aircraft maintenance and avionics installation facilities. This document discusses Receiver Autonomous Integrity Monitoring (RAIM) fundamentals and possible testing solutions using the GPSG-1000.

RAIM Overview

GPS position solutions are dependent upon the integrity of the broadcasted SV signal. An SV may develop a fault or the broadcast may be affected by atmospheric interference. In any case, GPS signals do not include any internal information about the integrity of its signals. It is possible for a GPS broadcast to have incorrect information that may cause navigation position to be in error. RAIM was developed because the integrity of the GPS position is of special importance in safety critical GPS applications such as aviation navigation.

Receiver Autonomous Integrity Monitoring (RAIM) is a GPS receiver algorithm that determines the integrity of the GNSS position solution. RAIM detects faults in a GPS SV signal by comparing redundant GPS pseudorange measurements. A pseudorange that differs significantly from the expected value may indicate a fault of the associated SV broadcast.

In order for a GPS receiver to perform RAIM a minimum of five SVs with satisfactory geometry must be visible. Traditional RAIM uses Fault Detection (FD) only; newer GPS receivers incorporate Fault Detection and Exclusion (FDE).

FDE requires a minimum of six visible SVs to not only detect a fault, but to exclude it from the position solution. Detection and exclusion of position faults allows the GNSS navigation to continue without interruption.

A RAIM enabled GPS receiver will report RAIM availability if the sufficient number of SVs are visible and do not exhibit position faults. If a sufficient number of SVs are not available the GPS receiver will report RAIM unavailable.



Testing RAIM

In the following simulation we are going to discuss some ways that RAIM and FDE may be tested with the GPSG-1000.

RAIM with FDE

To begin, we will start a simple static simulation. We have turned SBAS off so that only GPS SVs will be used in the position solution. From the side menu, select Waypoint. On the Waypoint List we selected Kansas City International Airport, then select Use. See Figure 1.

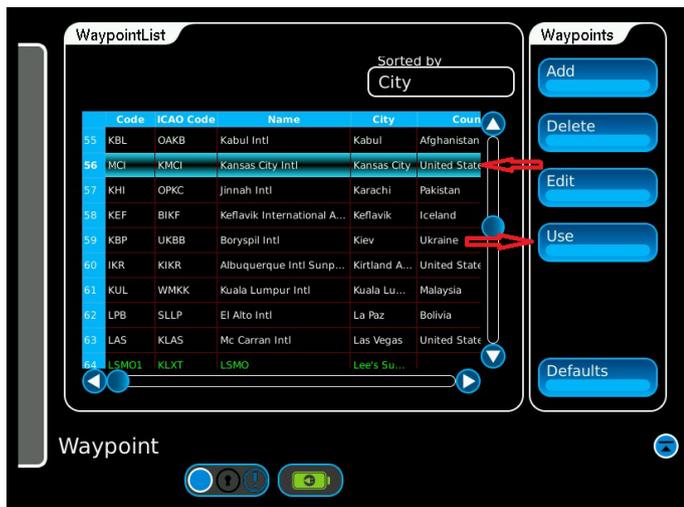


Figure 1. Waypoint List

The Simulation screen will pop up with the coordinates for MCI. Select Run. See Figure 2.

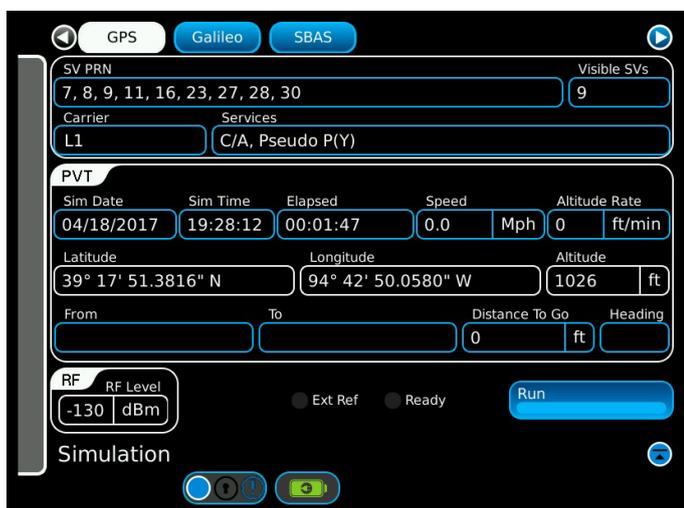


Figure 2. Simulation Screen

We are using a Ublox EVK-6 GPS evaluation kit with the U-Center dashboard to monitor the GPSG-1000 outputs. The EVK-6 is a RAIM enabled GPS receiver. It does not

have an INTEG monitor flag, but the NMEA message GBS (satellite fault detection) may be monitored for failure messages. If the user has the ability to monitor NMEA data on his aircrafts' GPS receiver, the same message may be monitored as well.

To simulate a space vehicle (SV) broadcasting erroneous data, select SV PRN from the side menu. The SV PRN screen will appear. See Figure 3.



Figure 3. SV PRN Screen

Touch the line for any AV and the SV PRN EDIT screen appears. Select Step Error and enter a step error of 500 ft and select Apply. A step error of greater than 100 ft should produce an error. See Figure 4.

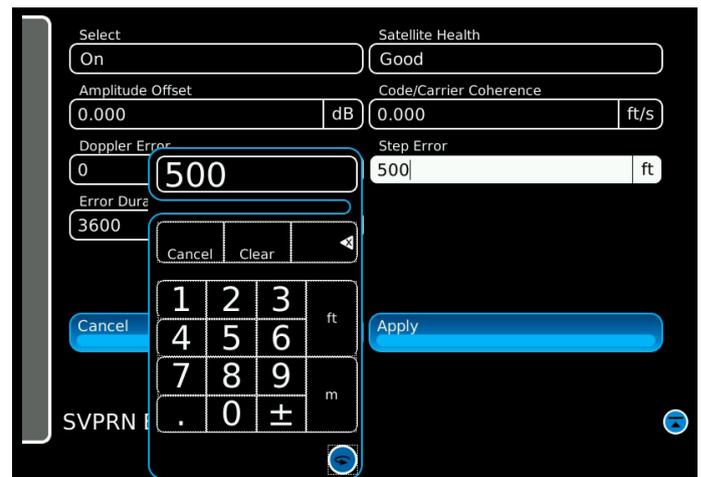


Figure 4. SV PRN Edit Screen

The U-Center Dashboard NMEA GBS message screen now displays Failed SV for the SV chosen. See Figure 5.

NMEA - GxGBS (Satellite fault Detection) - GPGBS (Satellite fault Detection) 0 s

Parameter	Value	Unit	Description
UTC	210732.00	hhmmss.sss	Universal time coordinated
Error Latitude	2.3	m	Expected Error in Latitude (North) Direction
Error Longitude	2.2	m	Expected Error in Longitude (East) Direction
Error Altitude	3.2	m	Expected Error in Altitude
Failed SV	11		ID number of most probably failed SV
Missed Det		%	Probability of missed detection
Bias Estimation	151.7	m	Estimate Bias on most likely failed Satellite
Bias StdDev	14.5		Standard Deviation of Bias Estimation
GNSS System ID			1=GPS 2=GLONASS 3=Galileo 4=BeiDou
GNSS Signal ID			0=All 1=L1C/A 2=L1P(Y) 3=L1M 4=L2P(Y) 5=L2CM 6=L

Figure 5. NMEA GBS Word Data

If we look at the U-Center Statistics report and the visual SV signal display we will see that the chosen SV is being excluded from the position solution. This proves the GPS receiver can detect a fault in the SV broadcast and correctly removes it from the position solution calculation. See Figures 6 and 7.

Statistic View

Title	Count	Age	Current	Minimum	Maximum	Average	Deviat
SV G11 Mode ...	192	0	Tracking				
SV G11 Used (...)	192	0	No				
SV G11 E1 (L1C...)	192	0	13.0	13.0	14.0	13.4	
SV G11 A2 (L1...)	192	0	258.0	258.0	259.0	258.7	
SV G11 C/N0 (...)	192	0	37.0	33.0	41.0	39.8	
SV G11 Ch (L1...)	179	1	4				
SV G11 Doppl...	0					0.00	
SV G11 Residu...	191	1	0.00	-164.63	0.47	-58.93	74
SV G11 Range...	0					0.00	
SV G11 Carrier...	0					0.00	
SV G11 Qi (L1...)	191	1	2	0	7	5	
SV G11 Dv Res...	0					0.00	

Figure 6. U-Center Statistics View

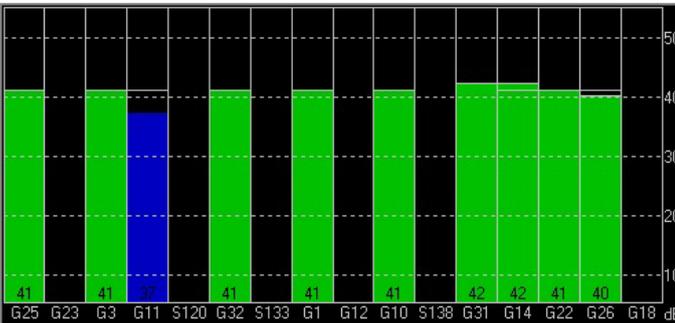


Figure 7. U-Center SV Signal Display

Satellite Health

Select: On

Amplitude Offset: 0.000 dB

Doppler Error: 0 Hz

Error Duration: 3600 s

Go On

Off

Replace

Cancel Apply

SVPRN EDIT: GPS 16

Figure 8. Turning off an SV

We will continue turning off SVs until only 5 are visible to the GPS receiver. Five is the minimum number of SVs visible to support RAIM with FDE. See Figures 9, 10 and 11.

GPS Galileo

Select	SV	Elevation (°)	Azimuth (°)	Health	Doppler	Carrier Incoh.	(1/N)	Amp. Offset	Slip Error (ft)
OFF	1	19.6425	-108.298	GOOD	0	0	0	0	0
ON	3	53.6774	-61.8689	GOOD	0	0	0	0	0
ON	14	49.3222	76.9148	GOOD	0	0	0	0	0
OFF	16	23.2371	173.212	GOOD	0	0	0	0	0
OFF	22	60.8587	-81.6418	GOOD	0	0	0	0	0
ON	23	23.602	-64.5243	GOOD	0	0	0	0	0
ON	25	59.265	42.3328	GOOD	0	0	0	0	0
OFF	26	46.7112	149.452	GOOD	0	0	0	0	0
ON	31	61.735	39.6579	GOOD	0	0	0	0	0
OFF	32	28.0447	94.1791	GOOD	0	0	0	0	0

SV PRN

Reset

Figure 9. SV PRN Screen. Only 5 SVs on

Title	Count	Age	Current	Minimum	Maximum	Average	Deviation	Unit
SVs Used	4437	0	5	0	10	9	2	
Used SVs	4437	0	G3 G14 G23 G25 G31	12	16	16	0	
SVs Tracked	4437	0	G1 G3 G14 G16 G22 G2...	35.00	41.25	40.70	0.42	dBHz
Tracked SVs	4437	0	40.60					
SV C/N0	4437	0						

Figure 10. U-Center Statistics View. Only 5 SVs visible

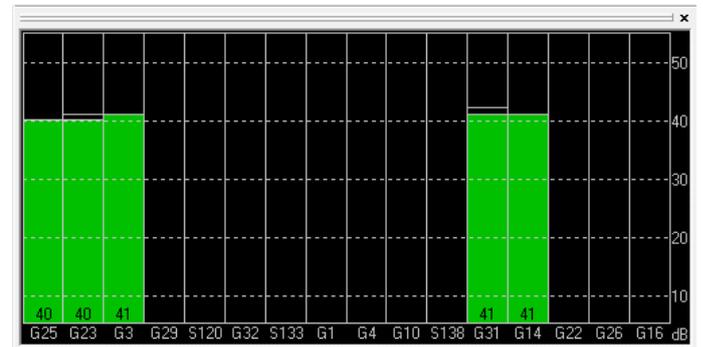


Figure 9. SV PRN Screen. Only 5 SVs on



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