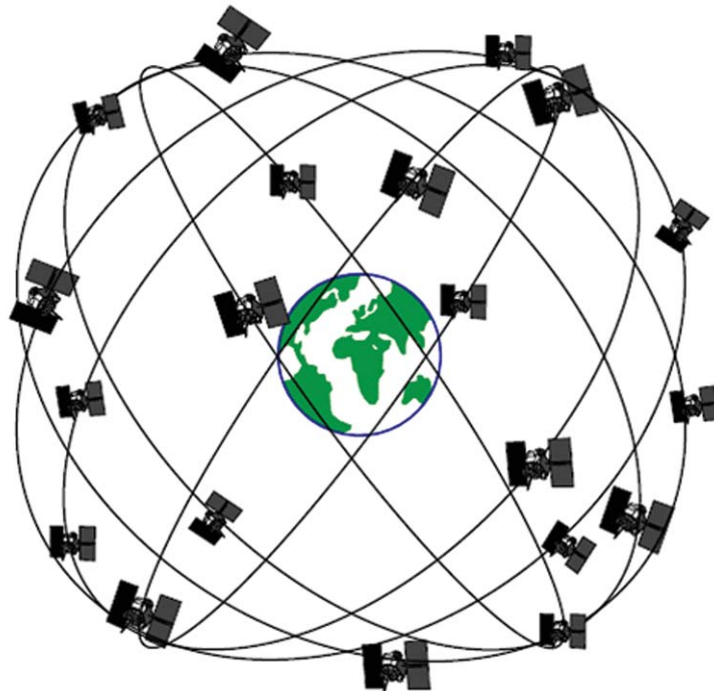
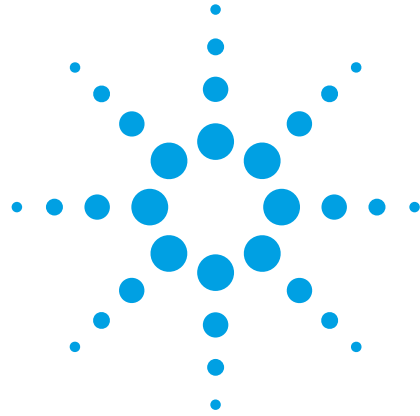


# Typical GPS Receiver Verification Tests Using a GPS Signal Simulator

Application Note



**Agilent Technologies**

# Table of Contents

|   |   |
|---|---|
| Introduction .....                          | 3 |
| Test Equipment.....                         | 4 |
| E4438C-409 GPS simulation capabilities..... | 4 |
| Test setup.....                             | 5 |
| Scenario generator.....                     | 5 |
| Typical Measurement Tests.....              | 6 |
| Time to first fix (TTFF).....               | 6 |
| Warm start time to first fix.....           | 7 |
| Reacquisition time .....                    | 7 |
| Static navigation accuracy.....             | 8 |
| Radio frequency interference .....          | 8 |
| Receiver sensitivity.....                   | 9 |
| Summary.....                                | 9 |
| Bibliography .....                          | 9 |
| Reference Literature.....                   | 9 |

## Introduction

This paper describes a set of typical GPS receiver verification tests using a GPS signal simulator. These tests are used to verify the functionality of embedded GPS receivers in mobile consumer products such as cellular phones and other handheld receivers. Using a metric grade GPS signal simulator in a GPS receiver test environment provides regulated control, easy repeatability, and maximum flexibility. In this environment, the tests listed in this paper create a standard validation procedure for the testing and verification of most GPS receivers. The flexibility of the signal source allows for testing of not only GPS receivers but other wireless formats and standards as well.

Global Positioning System (GPS) receiver technology is now commonplace in our daily lives, having penetrated our electronic world from cell phones, to personal navigation devices (PND), to cameras, to assimilation with RFID tags. The technology is rapidly expanding its reach into new areas, enlarging the ever-expanding role that GPS technology will play in our lives.

But even as GPS technology becomes more common, GPS receiver manufactures, OEM integrators, and contract manufacturers struggle for standard tests to verify receiver performance. Verification is required both to validate GPS receiver functionality and to objectively evaluate competing GPS IC performance. Verification procedures require a controlled environment that facilitates precise repeatability. Using actual GPS satellite signals and receiving them through an antenna, in most cases, does not provide this type of environment. A realtime GPS signal simulation, generated by an RF signal source, offers an excellent starting point for creating such an environment.

As GPS receivers are incorporated into mobile consumer products such as cellular phones, it also becomes important to have a flexible test environment. The source should be flexible enough to generate not only GPS signals, but also other wireless standards.

The tests described in this paper will help in the evaluation of GPS receiver performance and will provide a validation technique for GPS products in a controlled environment.

## Test Equipment

The GPS signals used for these tests were created by an Agilent Technologies E4438C ESG vector signal generator with the Option 409 GPS Personality (See Figure 1). The E4438C is a high performance, general purpose RF signal generator capable of providing many of today's wireless signal formats.

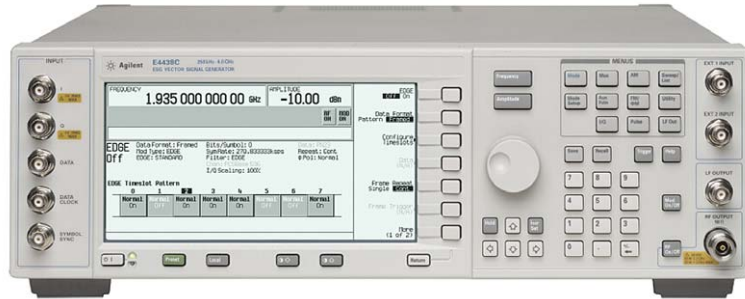


Figure 1. E4438C ESG vector signal generator

The GPS personality (E4438C Option 409) can provide up to 8 real-world GPS satellite signals. The satellite signals are configured based upon pre-configured scenario files. These signals, including Doppler shifts, are synchronized with the actual satellite orbits so that they are consistent with the navigation message contained in the satellite signals. (See section below on scenario generation).

The GPS receiver used in the test set-ups was the U-blox AEK-4T evaluation kit with U-center software. All U-center screen captures are used in this paper with written permission from U-blox.

### ***E4438C-409 GPS simulation capabilities***

The user interface of the E4438C-409 GPS personality is shown below in Figure 2. The GPS signal simulator allows the following capabilities:

- Multi-satellite GPS configuration (maximum 8 satellites)
- Signal simulates real world scenarios (multiple scenarios available)
- Real satellite data (synchronized satellites with Doppler shifts and navigation messages)
- Adjustable number of visible satellites between 1 and 8
- Automation of waveform playback through SCPI commands
- 10baseT LAN, GPIB, and RS-232 connectivity

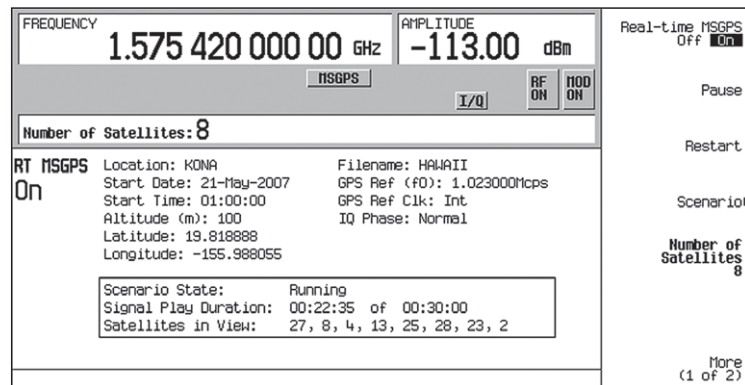


Figure 2. E4438C-409 GPS personality user interface

## Test setup

The test setup is shown in Figure 3. The realtime GPS signal is created by the E4438C and the RF output is sent to the GPS receiver. The GPS receiver is connected to the PC through a USB cable and to the evaluation software.

The following default assumptions are made for each of the test measurements unless otherwise noted.

- No ionospheric or tropospheric range delay
- Zero clock and ephemeris error
- No multipath fading
- Time is given in UTC time
- Minimum visible satellites = 8
- Static (non moving) GPS receiver
- Specific scenario is selected from the E4438C-409 application

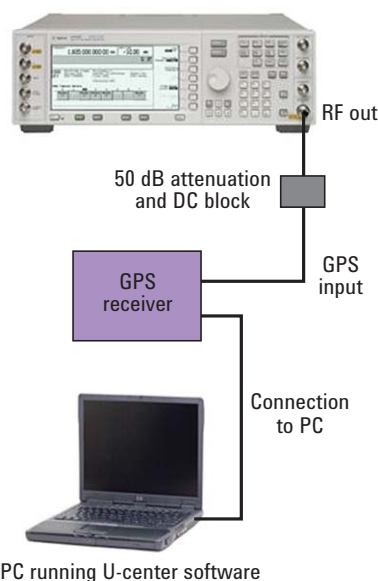


Figure 3. Test configuration

## Scenario generator

Each of the scenarios for the E4438C-409 application is generated by the NAVSYS Corporation GPS Signal Simulation Toolbox. A script was created to generate specific satellite information based upon a given location (longitude, latitude, and altitude), specific time and period, and corresponding Yuma almanac file. The satellite information includes satellite navigation data as well as power levels and Doppler shifts for each visible satellite during that time period.

Verification of the accuracy of the scenario files was performed by NAVSYS Corporation. Actual measurements of carrier frequency and pseudo range were collected with the NAVSYS High Gain Advanced GPS Receiver (HAGR) over a period of 12 hours. A scenario file was generated using the Signal Simulation Toolbox over the same period for comparison. A comparison between simulated values and actual received signals is shown in Figure 4. The solid blue line is actual data from the HAGR. The red dashed line represents simulated data from the scenario generator. The comparisons were made for all visible satellites during the 12 hour period. Excellent accuracy between simulated and captured GPS signals was observed on all visible satellites.

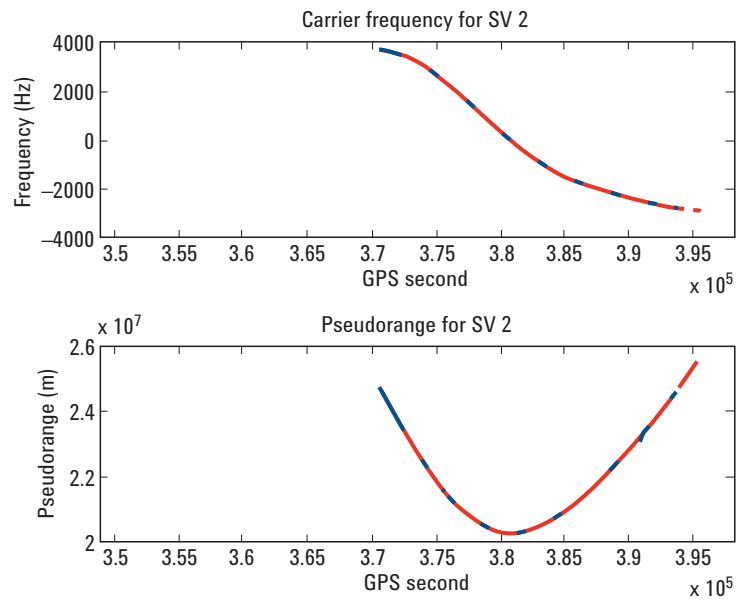


Figure 4. Scenario verification

## Typical Measurement Tests

### *Time to first fix (TTFF)*

**Test objective: Measure the time required by the GPS receiver to achieve a GPS navigation fix from a cold start.**

A cold start is defined as a receiver that is turned on without current ephemeris data. Typically a cold start can be achieved by a receiver that has been turned off for at least 2 hours. The TTFF is defined as the time interval between startup of the GPS receiver (power up) to the first valid navigation 3D data point derived from the simulation.

The GPS simulation is first started on the E4438C before the GPS receiver is turned on. At least 20 valid sample TTFF's should be collected. The mean, minimum, and maximum values for these samples are analyzed and the standard deviation should be computed.

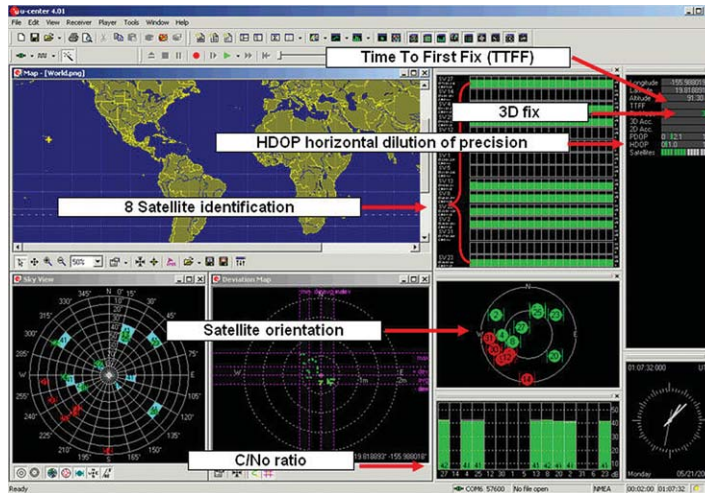


Figure 5. U-center software

### ***Warm start time to first fix***

**Test objective: Measure the time required by the GPS receiver to achieve a GPS navigation fix from a warm start.**

This is a similar test to the previous cold start TTFF. The receiver in this case contains current ephemeris data for all satellites in the simulation. Typically, this can be achieved by a receiver that had previously been on and then was turned off for a short period of time.

The GPS simulation is first started on the E4438C. The GPS receiver is turned on and allowed to achieve a location fix. This assures current ephemeris data in the GPS receiver. The GPS receiver is then turned off for a short period of time and then on again. The time interval from this turn-on to a valid 3D location fix is the TTFF. At least 50 valid sample TTFF's should be collected. The mean, minimum, and maximum values for these samples are analyzed and the standard deviation should be computed.

### ***Reacquisition time***

**Test objective: Establish the time required to reacquire a navigation fix following a short blockage of all GPS signals during normal operation.**

The method of blockage can be achieved in a number of ways. The two most common ways would be to attenuate the signal by inserting an attenuation of at least 60dB in the feed line or simply to disconnect the feed line from the simulator to the receiver. Measurement data is similar to the TTFF measurements.

The GPS simulation is first started on the E4438C. The GPS receiver is turned on and allowed to achieve a location fix. The GPS signal (RF cable) is then disconnected from the input of the GPS receiver to simulate a short blockage of the signal. The signal is then reconnected. The reacquisition time is the interval between the reconnection of the GPS signal and first valid navigation data point derived from the simulation. At least 50 valid reacquisition samples should be collected. The mean, minimum, and maximum values for these samples are analyzed and the standard deviation should be computed.

## Static navigation accuracy

**Test objective: Establish the accuracy of the receiver location fix with respect to the simulated location.**

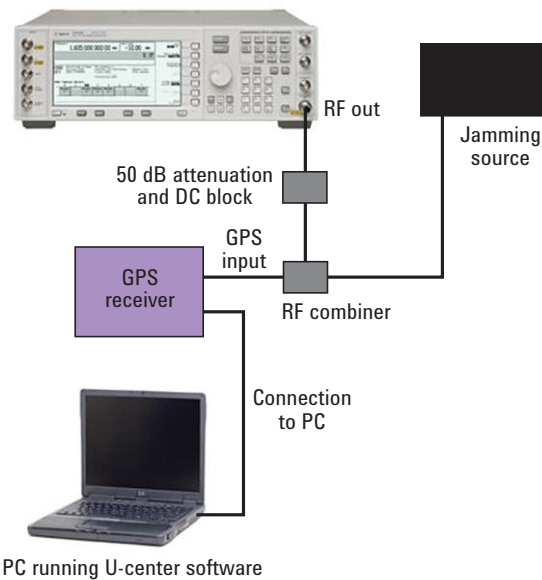
In this test, a static (non moving) scenario is used as the GPS simulated signal.

The GPS simulation is first started on the E4438C. The GPS receiver is turned on and allowed to achieve a location fix. Typical GPS evaluation software provides location fix information. This data, usually longitude, latitude, and altitude information, can be converted to Earth Centered Fixed Cartesian coordinates (ECEF) for evaluation of the simulated versus GPS receiver calculated locations. See Figure 5 for typical location information.

## Radio frequency interference

**Test objective: Establish the ability of the GPS receiver to operate in the presence of interfering (jamming) signals that may be received through its input.**

In this test, the jamming signal power level is increased in 1 dB increments until the first degradation of the GPS receiver is noticed. This is typically a dropped satellite. The jamming signal power level is again slowly increased until the GPS receiver loses its 3D navigation fix. See Figure 6 for test setup.



**Figure 6. RF Interference Test Configuration**

The GPS simulation is first started on the E4438C. The GPS receiver is turned on and allowed to achieve a location fix. The jamming signal is then added to the GPS signal at a level that is discernible to the GPS receiver. The jamming signal is increased in 1 dB steps. Typical data collected for this test are shown below in Table 1.

**Table 1. Data for interference testing**

| 1st satellite loss threshold (dB) | 3D navigation loss threshold (dB) | Jammer center frequency | Jammer bandwidth |
|-----------------------------------|-----------------------------------|-------------------------|------------------|
|-----------------------------------|-----------------------------------|-------------------------|------------------|



## Receiver sensitivity

**Test objective: Verify receiver sensitivity by measuring signal strength (C/No) under various GPS signal power levels.**

To obtain an accurate power level for a GPS satellite signal, the number of visible satellites should be set to 1 on the E4438C-409 application. The power level on the front panel of the E4438C will then accurately reflect the total power in the single satellite signal.

The GPS simulation is first started on the E4438C. The power level on the E4438C is set such that the GPS receiver can identify the single GPS satellite signal. The power level of the GPS satellite signal is then decreased until the GPS receiver loses tracking of the single satellite. This power level and the corresponding GPS receiver C/No ratio should be collected as data.

Another receiver sensitivity test is to measure the power level and C/No ratio level at which 3D location fix is lost. This requires a minimum of 4 satellite GPS simulation. In this test, the GPS simulation is started on the E4438C with all 8 satellites visible. The GPS receiver is turned on and allowed to achieve a location fix. The power level of the E4438C is then decreased until the 3D location fix is lost. Again the power level and the corresponding GPS receiver C/No ratio are collected as data.

*Note: For information on sample sizes, statistical data analysis, and specific test methodology see ION STD-101 "Recommended Test Procedures For GPS Receivers", 27 January 1997.*

## Summary

The ability to reproduce GPS signals easily and accurately with a high performance RF source allows great flexibility in creating a test environment for evaluating GPS receivers. Although the tests mentioned in this paper are not all-encompassing, they can be used as a basis for verification of GPS receivers. The characteristic performance information gathered from these tests will allow verification of GPS receiver performance and comparisons between them. The test equipment used is all standard Consumer off-the-shelf (COTS) equipment and is easily modified to suit changing test requirements.

## Bibliography

*ION STD 101: Recommended Test Procedures for GPS Receivers, Revision C*, Institute of Navigation, 1997 (ISBN: 0936406046)

## Reference Literature

*Agilent E4438C ESG Vector Signal Generator Configuration Guide*, Literature number 5988-4085EN

*Agilent GPS Personality for the E4438C ESG Vector Signal Generator Option 409, Product Overview*, Literature number 5988-6256EN

For more information, please visit

[www.agilent.com/find/409](http://www.agilent.com/find/409)

[www.agilent.com/find/e4438c](http://www.agilent.com/find/e4438c)



### Agilent Email Updates

[www.agilent.com/find/emailupdates](http://www.agilent.com/find/emailupdates)  
Get the latest information on the products and applications you select.



### Agilent Direct

[www.agilent.com/find/agilentdirect](http://www.agilent.com/find/agilentdirect)  
Quickly choose and use your test equipment solutions with confidence.



[www.agilent.com/find/open](http://www.agilent.com/find/open)  
Agilent Open simplifies the process of connecting and programming test systems to help engineers design, validate and manufacture electronic products. Agilent offers open connectivity for a broad range of system-ready instruments, open industry software, PC-standard I/O and global support, which are combined to more easily integrate test system development.

## Remove all doubt

Our repair and calibration services will get your equipment back to you, performing like new, when promised. You will get full value out of your Agilent equipment throughout its lifetime. Your equipment will be serviced by Agilent-trained technicians using the latest factory calibration procedures, automated repair diagnostics and genuine parts. You will always have the utmost confidence in your measurements.

Agilent offers a wide range of additional expert test and measurement services for your equipment, including initial start-up assistance, onsite education and training, as well as design, system integration, and project management.

For more information on repair and calibration services, go to:

[www.agilent.com/find/removealldoubt](http://www.agilent.com/find/removealldoubt)

## www.agilent.com

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

[www.agilent.com/find/contactus](http://www.agilent.com/find/contactus)

### Americas

|               |                |
|---------------|----------------|
| Canada        | (877) 894-4414 |
| Latin America | 305 269 7500   |
| United States | (800) 829-4444 |

### Asia Pacific

|           |                |
|-----------|----------------|
| Australia | 1 800 629 485  |
| China     | 800 810 0189   |
| Hong Kong | 800 938 693    |
| India     | 1 800 112 929  |
| Japan     | 0120 (421) 345 |
| Korea     | 080 769 0800   |
| Malaysia  | 1 800 888 848  |
| Singapore | 1 800 375 8100 |
| Taiwan    | 0800 047 866   |
| Thailand  | 1 800 226 008  |

### Europe & Middle East

|                |                     |
|----------------|---------------------|
| Austria        | 0820 87 44 11       |
| Belgium        | 32 (0) 2 404 93 40  |
| Denmark        | 45 70 13 15 15      |
| Finland        | 358 (0) 10 855 2100 |
| France         | 0825 010 700*       |
|                | *0.125 €/minute     |
| Germany        | 01805 24 6333**     |
|                | **0.14 €/minute     |
| Ireland        | 1890 924 204        |
| Israel         | 972-3-9288-504/544  |
| Italy          | 39 02 92 60 8484    |
| Netherlands    | 31 (0) 20 547 2111  |
| Spain          | 34 (91) 631 3300    |
| Sweden         | 0200-88 22 55       |
| Switzerland    | 0800 80 53 53       |
| United Kingdom | 44 (0) 118 9276201  |

Other European Countries:

[www.agilent.com/find/contactus](http://www.agilent.com/find/contactus)

Revised: March 27, 2008

Product specifications and descriptions in this document subject to change without notice.

© Agilent Technologies, Inc. 2008  
Printed in USA, May 21, 2008  
5989-8572EN



Agilent Technologies