GPS, Glonass, Galileo, BeiDou Receiver Testing Using a GNSS Signal Simulator

Application Note

Products:

| R&S®SMBV100A

Testing global navigation satellite system (GNSS) receivers can be done easily, reliably and cost-efficiently by using the R&S®SMBV100A vector signal generator. This GNSS simulator can generate GPS, Glonass, Galileo and BeiDou signals for up to 24 satellites in realtime.

This application note explains how to perform automated receiver tests using the R&S®SMBV100A. The presented tests include TTFF, sensitivity and location accuracy measurements, moving receiver and interference tests, and many more. Basic remote control examples are provided for the individual tests to ease programming.
This application note also includes a short guide for parsing NMEA data.

ROHDE&SCHWARZ

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1 Note

The abbreviation "SMBV" is used in this application note for the Rohde & Schwarz product R&S®SMBV100A.

As the GNSS simulation capabilities of the SMBV are being enhanced successively, some features presented in this application note may have been improved or added since the last release of this document. Therefore, please note the release date of this application note, because it is updated from time to time.

2 Introduction

Global navigation satellite system (GNSS) technology has become an integral part of our daily life. The range of applications spans consumer, industrial, automotive and military sectors. The importance of GNSS continues to increase, as there is potential for even more. The trend is clear, and new satellite systems are being deployed around the world. In the consumer market, receivers are becoming more and more widespread, since they are vitally used in cars and mobile terminals for navigation and positioning.
These receivers can be tested easily, reliably and cost-efficiently by using a GNSS simulator such as the SMBV from Rohde & Schwarz. GPS, Glonass, Galileo, and BeiDou signals for up to 24 satellites can be generated in realtime with a single standalone instrument that can even support other digital standards such as LTE and WLAN. This sets new standards in the field of satellite simulation for R&D and production.

The purpose of this application note is to explain how to perform automated receiver tests using the SMBV. Although the SMBV can simulate different satellite systems in parallel (hybrid constellation) in a straightforward way, we will focus on non-hybrid scenarios to keep the examples simple. Generally, the given examples are kept generic to a certain extent to serve as a basis for user-specific versions.

This application note starts by pointing out the advantages of GNSS simulation and briefly presenting the SMBV and its key features (section 3). The test setup is described in detail in section 4. Section 5 contains various fundamental receiver tests including time to first fix, sensitivity and location accuracy measurements as well as moving receiver and interference tests, each described in a separate subsection. A basic remote control example is given in each of these sections to show how to configure the SMBV for a particular test. In section 6, we present some instrument features that are worth considering when operating the SMBV in an automated test setup. A short guide for parsing recorded receiver data (in NMEA format) is given in section 7. The application note closes with a short summary.

3 GNSS Signal Simulation

3.1 Advantages of Simulation over Real GNSS Satellite Signals

One approach to testing a GNSS receiver is to use real satellite signals. The receiver is equipped with an antenna and receives genuine signals from a navigation system. This approach allows testing of the receiver under real-world conditions including a multitude of effects, but it has also severe disadvantages. The test conditions vary strongly and are unknown to a certain degree. This makes it impossible to repeat a test under the exact same conditions. In addition, the receiver always has to cope with the full range of real-world effects including restricted satellite visibility, multipath propagation and interference, to only name a few. Testing under less complex, well-defined conditions may not be straightforward. In fact, testing with genuine satellite signals can become quite cumbersome, since it may be necessary to test the receiver at different times and diverse locations around the world. This not only costs a lot of time and money. Some tests may even be impractical. For example, tests in parking decks and street canyons may be rather easy to carry out, but extensive testing at high altitudes or high velocities (as occur e.g. in aircraft) may be practically impossible.

A GNSS signal simulator can overcome these problems. This instrument generates a test signal that models the satellite signals and real-world effects as seen by the receiver in the field. A simulator offers the following benefits:
- The generated signals are exactly known. The receiver characteristics can thus be tested under controlled conditions with absolute certainty
- The test conditions can be exactly reproduced. This makes it possible to repeat a measurement under the exact same conditions over and over again
- Comprehensive testing under various conditions, locations and times can be performed in a laboratory. Even the movement of the receiver along any route can be simulated in the laboratory
- Time and cost savings are enormous. A key receiver characteristic such as time to first fix can be tested for locations such as Munich, New York, Beijing and Sydney within a few hours. This is not possible when using real GNSS signals for testing
- The complexity of the test conditions is scalable from basic testing with one static satellite to realistic multi-GNSS signal simulation with modeling of multipath and atmospheric effects. For example, this makes it possible to perform dedicated tests that include certain effects (while blanking others) to study a certain performance aspect. As a result, the user can gain a more detailed insight into the performance of the receiver
- In contrast to real GNSS signals, the signals generated by a simulator are virtually noiseless and thus offer the best possible signal-to-noise ratio for testing. On some simulators (such as the SMBV) the user can set a well-defined noise contribution

Due to the above reasons, a GNSS signal simulator is the ideal choice for testing the performance and verifying the proper operation of your GNSS receiver in research and development (R&D) and production.

3.2 Rohde & Schwarz GNSS Signal Simulator

The SMBV is a cost-efficient general-purpose vector signal generator with outstanding RF performance capable of generating signals for all main communications and radio standards. Equipped with one or more GNSS options, the SMBV is also a full-fledged GNSS signal simulator for GPS, Glonass, Galileo, and BeiDou.

Overview of GNSS options for the SMBV		
Option	**Name**	**Remark**
R&S®SMBV-K44	GPS (6 satellites)	
R&S®SMBV-K65	Assisted GPS	Requires K44
R&S®SMBV-K93	GPS P code	Requires K44
R&S®SMBV-K66	Galileo (6 satellites)	
R&S®SMBV-K67	Assisted Galileo	Requires K66
R&S®SMBV-K94	Glonass (6 satellites)	
R&S®SMBV-K95	Assisted Glonass	Requires K94
R&S®SMBV-K107	BeiDou (6 satellites)	
R&S®SMBV-K111	GBAS	
R&S®SMBV-K91	GNSS Extension to 12 Satellites	Requires K44, K66, K94 or K107
R&S®SMBV-K92	GNSS Enhanced (e.g. moving scenarios, multipath)	Requires K44, K66, K94 or K107
R&S®SMBV-K96	GNSS Extension to 24 Satellites	Requires K44, K66, K94 or K107 and K91
R&S®SMBV-K101	Obscuration and automatic multipath	Requires K44, K66, K94 or K107
R&S®SMBV-K102	Antenna pattern, body masks	Requires K44, K66, K94 or K107
R&S®SMBV-K103	Spinning/attitude	Requires K44, K66, K94 or K107 and K102

The SMBV is a powerful one-box solution for reliable and flexible GNSS receiver testing. It offers the following key features:

- Realtime GNSS signal generation for GPS L1/L2 (C/A and P code), Glonass L1/L2, Galileo E1, and BeiDou L1.
- Simulation of up to 24 satellites
- Unlimited simulation time with automatic, on-the-fly exchange of satellites
- Simulation of static satellite signals with zero or constant Doppler shift
- Simulation of hybrid GPS, Glonass, Galileo, and BeiDou satellite constellations as seen by today's GNSS receivers in the real world
- Stationary receiver simulation with custom or predefined geographic location (various cities around the world)
- Moving receiver simulation along predefined or user trajectory (with the possibility to directly import NMEA and KML data)
- Hardware in the loop (HIL) operation for realtime position and attitude update
- Dynamic and realtime power control for individual or all satellites to simulate obstructed satellite visibility (shadowing). Activation/deactivation of satellites in realtime without interrupting signal generation
- Simulation of multipath propagation (with configurable delay, power, Doppler shift and carrier phase for each satellite signal echo)
- Automatic obscuration and multipath simulation with predefined and user-specific scenarios to emulate real-world conditions
- Modeling of ionospheric and tropospheric effects on the satellite signal propagation
- Antenna pattern and predefined body masks for all common vehicles
- Attitude simulation and spinning
- Import of almanac files for up-to-date and historic satellite orbits
- Import of RINEX files for up-to-date and historic ephemeris data (up to 12 ephemeris sets)
- Support of pre- and user-defined Assisted GPS (A-GPS) test scenarios including generation of assistance data
- Standalone one-box solution – no external software required, no additional PC needed

In addition to GNSS signal generation, the SMBV also supports standard-compliant signal generation for digital communications standards such as GSM/EDGE, 3GPP with HSPA, LTE, WLAN, WiMAX, Bluetooth®, etc., and radio standards such as FM stereo (with RDS), HD Radio™, Sirius and XM Satellite Radio, and DAB. Since today's mobile phones implement a number of the above communications standards in addition to GPS, it is definitely a benefit to have a single, handy instrument that can generate all of the necessary test signals – all in realtime and without the need of external software.

The SMBV can be equipped with an additive white Gaussian noise (AWGN) generator for superimposing noise on the RF output signal in a controlled and deterministic way. It is also possible to superimpose a CW jamming signal.

All instrument settings can be set remotely using SCPI commands. It is thus possible to use the SMBV for automated tests executed in production and also during R&D. Remote control is possible via Ethernet LAN (TCP/IP), GPIB (IEC/IEEE) and USB.

3.2.1 You Need More Than 24 Satellites?

A single SMBV can simulate up to 24 satellites. If an application requires more than that, a second SMBV can be used in parallel. For example, one SMBV can be used to simulate 12 GPS and 12 Glonass satellites and a second SMBV can be added to simulate 12 Galileo satellites.
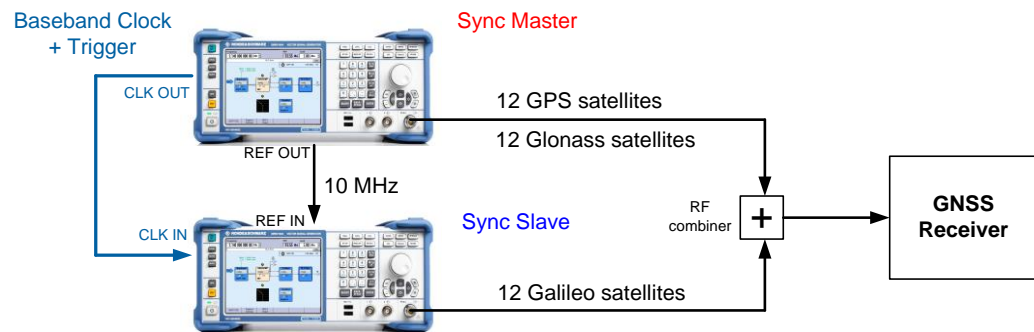
One SMBV acts as master instrument and supplies all necessary synchronization signals to the slave instrument via just two connection cables. The instrument setup is simple, easy to configure and provides highly synchronized signals. It is explained in more detail in reference [2].

With two SMBVs, up to 48 simulation channels are available. This is also beneficial for simulating multipath propagation, where each satellite echo requires an extra simulation channel (see section 5.9).

4 Test Setup

There are basically two methods for transmitting the GNSS test signal generated by the SMBV to the receiver under test:

- Radiation (over the air) using a transmit antenna at the SMBV

- Direct physical connection using an RF cable between the SMBV and the receiver

4.1 Radiation

This method may be used if it is impossible to physically connect to the receiver under test. If the receiver lacks connections for external access, the only way to supply it with a GNSS test signal is to transmit the signal over the air. For this method, an antenna needs to be connected to the RF output of the SMBV that radiates the generated test signal to the receiver antenna. The two antennas should be placed near to each other. However, the distance between them should be large enough so that the receiver antenna is in the far-field region of the transmit antenna. The transmit antenna can be a *passive* GPS/Glonass antenna generating a right-hand circular polarized signal. Such antennas are usually available as patch or helical antennas for 50 Ω systems, often also with suitable connectors.

The radiation method has some disadvantages, however. Interference in particular is a severe problem:

- The radiated test signal and the real GNSS satellite signal may interfere. On the one hand, the test signal may disturb the real GNSS signal and cause errors in nearby operating receivers. On the other hand, the real GNSS signal may disturb the test signal, which leads to uncontrolled conditions and errors at the receiver under test. In addition, interference from other sources may also contribute. For example, nearby objects may reflect the GNSS signal and cause multipath conditions
- In order to prevent interference, a suitable RF shielded chamber is needed for testing. The chamber should provide sufficient shielding at the used carrier frequency, the chamber's internal surface should provide sufficient absorption (to minimize internal reflections), and the size of the chamber should be large enough so that the receiver antenna can be placed in the far-field region of the transmit antenna

- The calibration of the power level at the receiver antenna is difficult. Reliable sensitivity tests are therefore difficult to perform
- The receiver cannot be tested standalone, i.e. without receive antenna. The test results will contain receiver as well as antenna characteristics

Open radiation of the test signal is not a very controlled and robust method. For this reason, we focus on a direct physical connection with an RF cable. This method ensures that the signal is transferred from the SMBV to the receiver without interference.

4.2 Direct Connection

This method uses neither a transmit nor a receive antenna. The GNSS test signal is transferred to the receiver under test using a direct 50 Ω coaxial transmission line. As a consequence, the antenna of the receiver needs to be disconnected or bypassed. Receivers with built-in antennas that cannot be removed sometimes offer a separate connector for connecting to a GNSS simulator. The following figure shows the basic test setup:
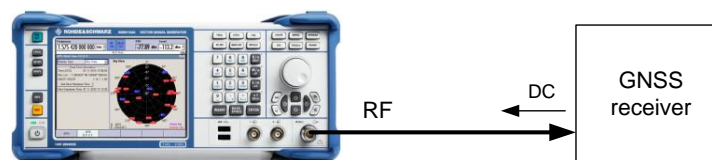
Reverse power protection:
Receivers work with either passive or active antennas. Passive antennas do not require a DC bias voltage, whereas active antennas need to be supplied with a suitable DC voltage to power their integrated low-noise amplifier (LNA). Usually, the supply voltage is fed from the receiver to the antenna via the coaxial RF transmission line. The required DC voltage is typically in the order of 3 V to 6 V. When the receiver is connected to the SMBV as shown in the figure above, this DC voltage is fed into the SMBV's RF output. The SMBV offers a reverse power protection up to 50 V DC voltage. Voltages up to 10 V pose no problem for the SMBV. The receiver can be connected to the SMBV *without* requiring any protective components such as a DC block. This is a clear benefit, since it keeps the setup simple. Voltages between 10 V and 50 V do not damage the SMBV, but they will activate the overvoltage protection and thus cause the SMBV to stop RF signal output.
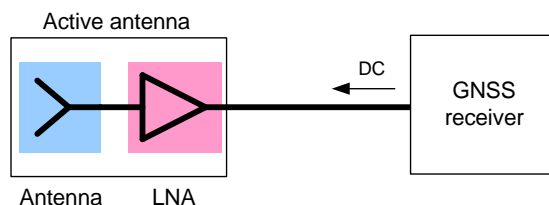
Cables:

To connect the receiver to the SMBV, use suitable, good-quality cables exhibiting low loss at GNSS frequencies. Any loss occurring along the transmission line can be compensated by setting a correspondingly higher level in the SMBV. The RF level can be set with a resolution of 0.01 dB over the entire dynamic range of the SMBV. To achieve a high level accuracy at the receiver under test, the cable loss should be known precisely either from the cable's specifications or a calibration measurement.

External attenuator:

For levels down to –120 dBm, the specified absolute level uncertainty of the SMBV is <0.5 dB at GNSS frequencies. For levels down to –145 dBm, the level uncertainty increases. To maintain the high level accuracy of the SMBV also for RF output levels below –120 dBm, we recommend using an external attenuator with a fixed attenuation, e.g. 30 dB. Use a high-quality resistive coaxial attenuator with a high attenuation accuracy. The specified power dissipation rating of the attenuator, often 2 W, is also of importance, especially when the receiver outputs a DC supply voltage for an antenna. The attenuator must be capable of dissipating the unwanted RF power and the DC voltage. The dissipated RF power is negligible at these low RF levels, but the dissipated DC power is not. For example, in a 50 Ω system, 6 V corresponds to a power of 0.72 W. A 30 dB attenuator would have to dissipate 0.72 W DC power coming from the receiver. If the power dissipation rating is not sufficient, the attenuator will be destroyed (if not extra protected). If the receiver outputs a DC supply voltage, an attenuator with a frequency range down to DC should be used. Attenuators not fulfilling the criteria for power dissipation and frequency range can be protected by a DC block between the receiver and attenuator.
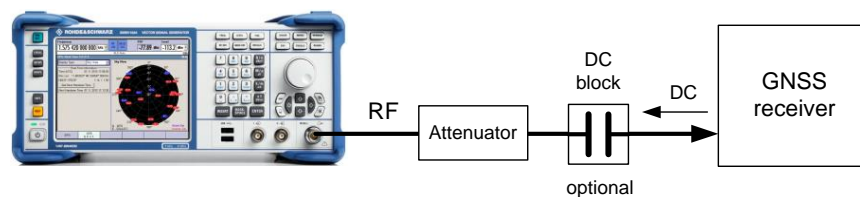
The use of external attenuators is recommended for levels below –120 dBm for the following reasons:

- The level uncertainty increases for lower levels
- The maximum attenuation of the internal step attenuator is –120 dBm. Lower levels are achieved by reducing the internal amplification. The signal level goes down, but the noise floor remains at a constant level. Applying an external attenuator instead will lower the signal level *and* the noise floor to the same degree, thus maintaining the dynamic range
- The minimum of the level setting range is –145 dBm. Attenuators are the only way to reach even lower levels (e.g. for sensitivity tests)

Antenna LNA:

An active antenna amplifies the received signal by means of a built-in LNA with a typical gain of 20 dB to 30 dB. By disconnecting the antenna to establish a direct connection to the SMBV, this LNA is removed with the antenna. This has two important consequences:

- The gain of this LNA is missing
- The noise figure of the system is no longer dominated by this LNA

The missing gain can be easily compensated by the SMBV without any restriction on the dynamic range of the simulator. Just increase the RF output level of the SMBV as needed to provide the receiver with the proper input level.

Generally, the antenna LNA, i.e. the first amplifier in a chain of cascaded amplifiers, dominates the noise figure of the entire system. The noise figure of the antenna LNA is typically 1.5 dB to 1.8 dB. By removing this LNA, the second amplifier in a chain now dominates the noise figure of the system. Often, this amplifier has a worse noise figure than the antenna LNA. This fact can have an impact on receiver sensitivity tests, e.g. when satellite C/N ratios are read from the receiver and validated. The dependency of the reported C/N ratios on the noise figure of the system should be taken into account when defining the test limits. To re-establish the noise figure of the original system, an external LNA with the same noise figure (and similar gain) as the removed LNA can be used in the setup as a replacement for the antenna's built-in LNA.
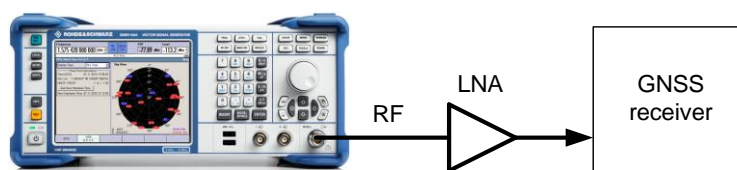
4.3 Complete Setup

So far we have only considered the connection between the SMBV and the receiver. The complete setup, however, also involves an analysis part and a remote control part as shown in the following figure:
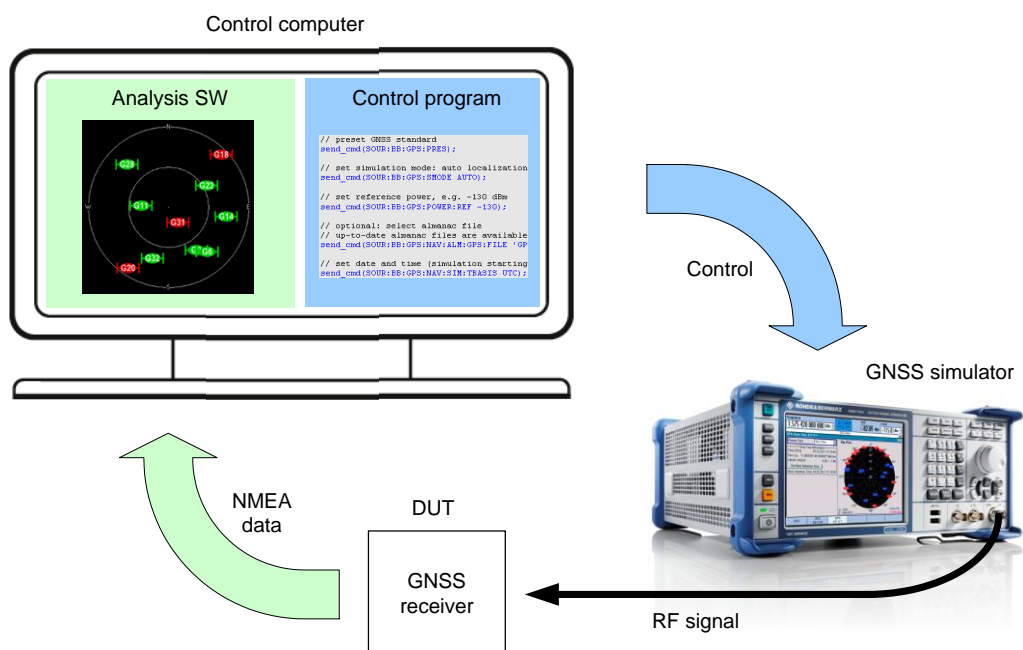
SMBV remote control part:
The SMBV can be controlled either manually via the instrument GUI or remotely. Remote control requires a control computer connected to the SMBV via LAN, GPIB or USB (see reference [6] for details). For example, it is possible to remote-control the SMBV in two ways:

- Via a remote desktop connection over LAN. In this case, the settings are made manually via the remote instrument GUI. (VNC software is installed on the SMBV, so the control PC just requires a browser to connect)
- Via an automated test program. In this case, the settings are made programmatically using SCPI commands

Analysis part:
The receiver under test usually reports its results in the standardized NMEA data format. This data can be read in and processed by third-party software that makes it possible to analyze, visualize and log the data. Many vendors provide special evaluation software of this kind for their receivers. The software usually also allows the user to control the receiver, e.g. to initialize a cold start. (Generally, the control of the receiver is device-specific and thus beyond the scope of this application note.)

4.4 Sometimes Receivers Know Too Much…

As time constantly passes, the date and time information transmitted by real satellite signals only advances and never reverses. Some receivers rely on this physical law to validate their results: A receiver that has acquired a certain date and time "knows" that it is not possible to go back in time, although simulated satellite signals may indicate something else. Such a receiver will refuse to accept the time stamp in the past and interpret it as an erroneous result. Similarly, a receiver that has acquired a location fix "knows" from the almanac which satellites are visible at that location. Although simulated satellite signals may show that the receiver has moved around half the world in just a few minutes, the receiver will still search for the known satellites, which are, however, not visible at the new, distant location. The receiver will thus fail to acquire a position fix. Normally, the validation mechanisms help to reduce navigation errors, but can be disadvantageous when working with a GNSS simulator.

From the simulator's side, it is no problem to simulate a point in time, e.g. Sept. 23, 2011, 4:00 p.m., again and again. Also stepping back in time and simulating a time point years ago, e.g. in 2002, is no problem at all. The same applies for the location; the simulator can emulate the satellite signals as received in e.g. Munich and a minute later as received in e.g. Beijing. From the receiver's side, however, this may cause problems, for example if internal protocol checks validate the obtained time data. These problems can be overcome by making the receiver forget the current date and time, where it is located at the moment and where the satellites are orbiting. This is done by cold-starting receiver, which erases information about the current time and position as well as almanac data.

One distinguishes between cold, warm and hot starts of a receiver. The following table gives an overview:

Cold, warm and hot start conditions	
Type	**Available information**
Cold start	Time, position, almanac and ephemeris are unknown to the receiver.
Warm start	Time, position within 100 km and almanac are known to the receiver. Ephemeris is unknown.
Hot start	Time, position within 100 km, almanac and ephemeris are known to the receiver.

To fully exploit the benefits of a simulator, it must be possible for the user to cold-start the receiver under test – either via the receiver control software or via an externally accessible button on the device. Developers should therefore design a way to initialize a cold start.

To avoid problems related to stored time and almanac information, it is strongly recommended to erase the receiver's memory by a cold start before starting the measurement with the SMBV.

If it is not possible to cold-start the receiver, the following workarounds can be used:
- Force a cold start by removing the battery or power supply of the receiver. Wait for capacitors to discharge.
- Use up-to-date almanac data and always advance the simulated time point from test to test so that the receiver never experiences a time point in the past. (Be careful when simulating a time point in the far future, because the receiver will not accept the real-world GNSS signals until this time point is also reached in real life.)

5 GNSS Receiver Testing

The following sections explain how the SMBV can be used to perform some basic receiver tests. To determine the receiver's general performance, some fundamental parameters are usually measured. The methods and examples presented in this application note should only be regarded as basic guidelines. There are many alternative methods to characterize the receiver's performance. Some tests may be more relevant than others, depending on the intended application of the receiver. This application note covers the most common receiver tests but does not provide a complete set of tests. The following tests are described in the following sections:

- Time to first fix measurement
- Reacquisition time measurement
- Sensitivity measurement
- Location accuracy measurement
- Testing dynamics of a moving receiver
- Long-term stability measurements
- Influence of interference
- Influence of multipath reception
- Influence of atmospheric modeling
- Leap second insertion
- 1PPS signal

The following table gives an overview and a short explanation of some of the fundamental parameters and technical terms used in this application note.

Definition of technical terms	
Technical term	**Definition**
Time to first fix (TTFF)	The time the receiver needs to acquire a first position fix from the received satellite signals. One distinguishes between cold, warm and hot start TTFF.
Reacquisition time	The time the receiver needs to reacquire a position fix after the total loss and reappearance of the satellite signals (e.g. tunneling).
Acquisition sensitivity	The minimum satellite power level at which the receiver can acquire GNSS signals and consequently acquire a position fix.
Tracking sensitivity	The minimum satellite power level at which the receiver can keep tracking the code and carrier phase and consequently maintain a position fix. The tracking sensitivity is generally significantly lower than the acquisition sensitivity.
Location accuracy	The spatial accuracy to which the receiver can determine its position in relation to the true position. One distinguishes between absolute, repeatable and dynamic location accuracy. Absolute: The accuracy of a position fix with respect to a fixed, known position. Repeatable: The variation between position fixes obtained for the same location. Dynamic: The accuracy of a position fix achieved with a moving receiver.
Multipath	Real satellite signals that get reflected off buildings and other urban objects reach the receiver via multiple propagation paths that can be different for each satellite. The receiver thus receives not only the direct line of sight signal but also signal replicas reaching the receiver with individual delay, attenuation, and Doppler shift.
One pulse per second (1PPS)	A pulsed TTL signal with a frequency of 1 Hz generated by the receiver. It is synchronized to the GPS time and can thus serve as a precise timing signal.

The SMBV can be remote-controlled via automated test programs using SCPI commands. In the following sections, we provide some remote control examples that are written in a simplified pseudo code syntax:

- The fictive function "send_cmd" sends an SCPI command to the SMBV
- Fictive functions such as "get_result" query a result from the receiver
- Fictive functions such as "calculate_result" call an action (e.g. computation, analysis)
- A comment line is indicated by "//"

To make the code examples easier to read, the following color coding is used:

- Blue indicates SMBV-related commands
- Green indicates general and receiver-related commands

The GNSS-related SCPI commands start with "SOUR:BB:<GNSS>", where <GNSS> is either "GPS" for GPS, "GAL" for Galileo, "BEID" for BeiDou or "GLON" for Glonass. In the code examples "GPS" is used. However, "GPS" can be replaced by "GAL", "BEID" or "GLON" if the other GNSS standards are to be used.

Some general settings apply to all code examples and are therefore mentioned at this point:

- The RF frequency is set via the GNSS standards by setting the parameter "RF band".
  Example: SOUR:BB:GPS:RFB L1
  RF frequency settings made using the command "SOUR:FREQ" are overwritten as soon as the GNSS signal is turned on.

- The RF level is set via the GNSS standards by setting the parameter "Ref. Power".
  Example: SOUR:BB:GPS:POW:REF –130
  Note that this parameter does not set the total RF output level directly but rather indirectly, as this parameter sets the reference power for the satellite power levels. The total RF output power depends on additional (configurable) factors such as the number of satellites, their relative levels, etc. This is described in greater detail under "Satellite power" on page 17.
  RF level settings made using the command "SOUR:POW" are overwritten as soon as the GNSS signal is turned on.

- The RF output is activated using the command "OUTP:STAT ON".

- The baseband generator is activated using the command "SOUR:BB:GPS:STAT ON". This command starts baseband signal calculation. Since the calculation process can take some time, this command should be followed by a synchronization command such as "*OPC?". Please see reference [5] for details and limitations on "*OPC?" and for more sophisticated synchronization techniques that also allow multi-tasking.

- To ensure proper timing of the measurements, the SMBV can be explicitly triggered manually or remotely to output the GNSS signal (internal triggering). The trigger mode is set to "Armed Retrigger" using the command SOUR:BB:GPS:TRIG:SEQ ARET
  In this mode, every trigger event causes a restart of the GNSS signal. The trigger event can be issued using the command

```
SOUR:BB:GPS:TRIG:EXEC
```
This command actually starts the GNSS signal. The signal can be stopped by using the command
```
SOUR:BB:GPS:TRIG:ARM:EXEC
```

It is also possible to have the SMBV triggered by an external signal (external triggering).

For general information and tips about SCPI programming, see also application note "Top Ten SCPI Programming Tips for Signal Generators" (reference [5]).

Satellite power

The satellite power is set using the parameter "Ref. Power".

Ref. Power	-130.00	dBm ▾

```
SOUR:BB:GPS:POW:REF -130
```

In addition, a power offset from this reference level can be defined for each satellite individually (in "User" power mode).

Power Mode	User ▾

```
SOUR:BB:GPS:POW:MODE USER
```

Maximum Number Of Satellites				6 ▾

	State	Standard	Signals	SV-ID	Power /dB
Sat 1	On	GPS	C/A	14	-1.30
Sat 2	On	GPS	C/A	23	0.00
Sat 3	On	GPS	C/A	11	-3.80
Sat 4	On	GPS	C/A	3	-2.40
Sat 5	On	GPS	C/A	25	0.00
Sat 6	On	GPS	C/A	18	0.00

```
SOUR:BB:GPS:SAT4:POW -2.4
```

The resulting power level of each satellite is calculated from the reference power and the power offset value. For example, the reference power is set to –130 dBm, and for satellite 4 (SV-ID 3) the power offset is set to –2.4 dB. The resulting signal level of satellite 4 is thus –132.4 dBm. This is also indicated in the realtime SPOT display.
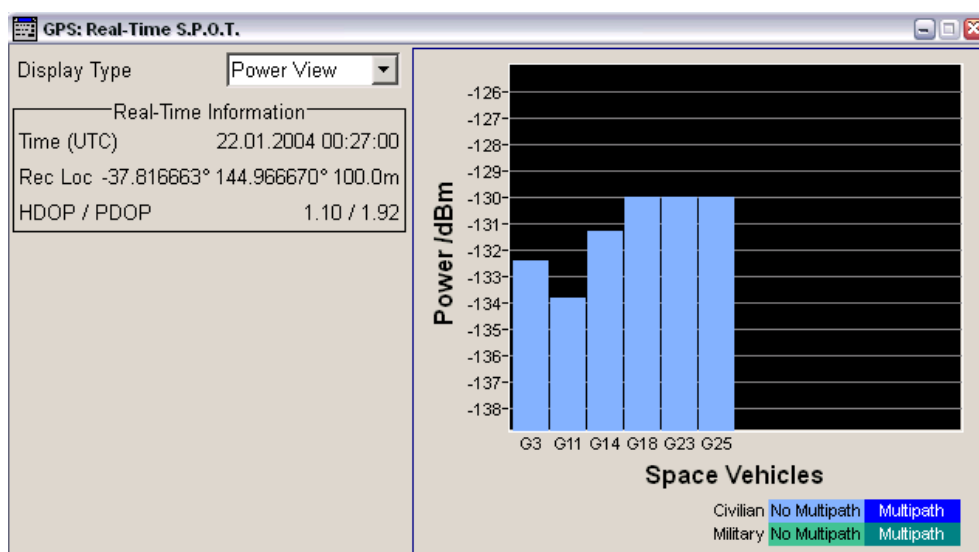
```
SOUR:BB:GPS:RT:GPS:SVID3:TAP1:POW:ABS?
```

In "Auto" power mode, the power offsets from the reference level are set automatically for each satellite according to its position in the orbit relative to the receiver.


```
SOUR:BB:GPS:POW:MODE AUTO
```

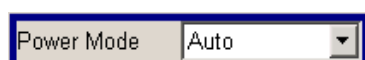|	State	Standard	Signals	SV-ID	Power /dB
Sat 1	On	GPS	C/A	14	0.00
Sat 2	On	GPS	C/A	23	-0.11
Sat 3	On	GPS	C/A	11	-1.28
Sat 4	On	GPS	C/A	3	-1.14
Sat 5	On	GPS	C/A	25	-1.42
Sat 6	On	GPS	C/A	18	-1.70

Maximum Number Of Satellites: 6

The displayed power offsets in the satellite configuration table correspond to the values at the start of the simulation. Note that these displayed values are not updated, although the power offsets change automatically during the simulation.
The momentary satellite power level is shown in the realtime SPOT display and can be queried for each satellite with the command
"`SOUR:BB:GPS:RT:GPS:SVID<ch>:TAP1:POW:ABS?`", where `<ch>` is to be replaced by the respective SV-ID of the satellite.

The total signal level is the sum of all individual satellite signal levels. The momentary total RF output level of the SMBV is displayed in realtime by the parameter "Total Power"[1] and can be queried using the command "`SOUR:BB:GPS:POW:TOTAL?`". The value shown in the level display of the GUI corresponds to the total RF level at the starting time of the simulation. It can be queried using the command "`SOUR:POW?`".

For a full description with power calculation examples, please see reference [1], "Power Configuration" section.

---

[1] This parameter is an internally measured value.

As a general rule, it is strongly recommended to do any power leveling via the level-related settings in the GNSS standard and not via the conventional RF level setting. Power levels set using the conventional method ("`SOUR:POW`" command) are overwritten as soon as the GNSS signal generation (re)starts.

5.2 Time To First Fix

The purpose of this measurement is to test how quickly the receiver can obtain a first position fix. The TTFF is an important performance parameter, since it strongly impacts the usability of the receiver.

For this test, the SMBV simulates a realistic satellite constellation for a fixed location. The "Auto Localization" simulation mode is used, since in this mode the SMBV sets the satellite configuration automatically. The user can select a location from a number of predefined cities around the world or enter a user-defined location. The number of simulated satellites can also be selected, ranging from 4 to 24. The SMBV then automatically simulates the satellites that offer the best constellation for the selected location. The SMBV comes with several almanac files to choose from, but the user can also use up-to-date almanac files available for download on the Internet. For TTFF tests, the reference level is usually set to a level well above the acquisition sensitivity level of the receiver.

Configuration of the SMBV for TTFF testing:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: auto localization
send_cmd(SOUR:BB:GPS:SMODE AUTO);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// optional: select almanac file
// up-to-date almanac files are available on the Internet.
send_cmd(SOUR:BB:GPS:NAV:ALM:GPS:FILE 'GPS_SEM585.txt');

// set date and time (simulation starting point)
send_cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);     // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

// select a location: select a city
send cmd(SOUR:BB:GPS:LOC:SEL "Munich");

// alternatively:
// select a location: select a user location
// send_cmd(SOUR:BB:GPS:LOC:SEL "User Defined");
// send_cmd(SOUR:BB:GPS:LOC:COOR:DEC 90, 180, 5.5);

// set number of satellites: e.g. 6
send_cmd(SOUR:BB:GPS:SAT:COUNT 6);
```

Usually a TTFF measurement is repeated several times with significantly different simulated satellite constellations to test the receiver under a broad range of conditions. The measured TTFFs are finally averaged. To modify the scenario, change one of the following:

- the simulated time (advance by several hours)
- or the number of simulated satellites
- or the simulated location

```
Loop
{
// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);    // trigger

// reset receiver: cold start
do_cold_start();

// measure TTFF
TTFF = get_TTFF();

// turn off GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT OFF);

// modify scenario: advance time by several hours
time_struct = advance_time(time_struct, hours);
      // hours is e.g. 6
      // structure includes current year, month, day, hour,
      minute, second
send cmd(SOUR:BB:GPS:NAV:SIM:DATE %f, %f, %f; time struct.year,
time struct.month, time struct.day);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME %f, %f, %f; time_struct.hour,
time_struct.min, time_struct.sec);
}
```

It is possible to advance or rewind the simulated time. The simulated time point can be changed in large steps (several hours) but also increments of minutes, as may be required for warm and hot start TTFF testing.

TTFF measurements can be quite time-consuming, especially cold start TTFF tests, because it takes some time for the receiver to gather enough information from the navigation message of the satellite signals. Therefore, TTFF tests are not very practical for production, but are extremely important during research and verification stages.

5.3 Reacquisition Time

The purpose of this measurement is to test how quickly the receiver can reacquire the satellite signals after it has lost all signals for a short period of time. The reacquisition time is a performance parameter especially important for in-vehicle GNSS receivers. For example, after leaving a tunnel where all satellite signals were blocked, the receiver should be able to quickly get a valid position fix and restore navigation services.

For this test, the SMBV simulates a realistic satellite constellation for a fixed location, using the "User Localization" simulation mode. This mode gives the user full control over the simulated satellites. The user can specify the number of satellites and their individual power levels, and can also select which satellites should be simulated (via the SV-ID). Alternatively, the SMBV can determine the satellites that form an optimal constellation for the selected simulation time. For testing the reacquisition time, the simulated satellites are deactivated to simulate their loss. After some time, they are reactivated to simulate restored satellite visibility. Note that the satellites can be (de)activated in realtime without interrupting the running scenario. The user can select a location from a number of predefined cities around the world or enter a user-defined location (see section 5.2). The reference level is usually set to a level well above the acquisition sensitivity level of the receiver.

Configuration of the SMBV for reacquisition time testing:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: user localization
send_cmd(SOUR:BB:GPS:SMODE USER);

// select a location: select a city
send_cmd(SOUR:BB:GPS:LOC:SEL "Munich");

// set number of satellites: e.g. 6
send_cmd(SOUR:BB:GPS:SAT:COUNT 6);

// set reference power, e.g. -130 dBm
send cmd(SOUR:BB:GPS:POWER:REF -130);

// set power mode for satellite configuration: auto
send_cmd(SOUR:BB:GPS:POW:MODE AUTO);

// set optimal satellite constellation
send_cmd(SOUR:BB:GPS:GOC);      // activates all 6 satellites

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger

// let the receiver acquire a 3D position fix
wait4fix();

// turn off all satellites
```

```
send_cmd(SOUR:BB:GPS:SAT1:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT2:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT3:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT4:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT5:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT6:STAT OFF);

// wait until the receiver loses lock
wait4nofix();

// turn on the satellites again
send_cmd(SOUR:BB:GPS:SAT1:STAT ON);
send_cmd(SOUR:BB:GPS:SAT2:STAT ON);
send_cmd(SOUR:BB:GPS:SAT3:STAT ON);
send_cmd(SOUR:BB:GPS:SAT4:STAT ON);
send_cmd(SOUR:BB:GPS:SAT5:STAT ON);
send_cmd(SOUR:BB:GPS:SAT6:STAT ON);

// synchronize
send_cmd(*OPC?);

// measure reacquisition time, i.e. TTFF after signal
interruption
reacq_time = get_TTFF();
```

To simulate temporarily interrupted or restricted satellite visibility, the user can
- turn off individual satellites
- reduce the power of each satellites individually
without interrupting the running scenario.

```
// turn off a subset of the satellites
send_cmd(SOUR:BB:GPS:SAT2:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT4:STAT OFF);
send_cmd(SOUR:BB:GPS:SAT6:STAT OFF);

// set power mode for satellite configuration: user
send_cmd(SOUR:BB:GPS:POW:MODE USER);

// set reduced power for the remaining satellites (in relation
to the reference power)
send_cmd(SOUR:BB:GPS:SAT1:POW -3);
send_cmd(SOUR:BB:GPS:SAT3:POW -10);
send_cmd(SOUR:BB:GPS:SAT5:POW -20);
```

As an alternative to the above approach, the user can make use of the R&S®SMBV-K101 "Obscuration and automatic multipath" option of the SMBV. This option makes it possible to simulate obstacles such as tunnels, bridges, and parking decks causing temporary full obscuration of all satellite signals. Different obscuration scenarios can be configured flexibly and conveniently. A detailed description of this feature can be found in reference [7]. Please see this dedicated application note for further details.

5.4 Sensitivity

The purpose of this measurement is to find out the minimum satellite signal power at which the receiver is still able to either acquire or track the satellite signals and consequently establish or maintain a valid position fix. The acquisition and tracking sensitivity are two of the most important performance parameters of a GNSS receiver. Although the satellite signal power receivable on the earth's surface (with clear view) is at least about –130 dBm as defined by the specification, this level can drop significantly inside buildings or under tree foliage, for example. However, receivers with low sensitivity levels (e.g. –160 dBm) can still be operated in areas where the satellite signals are low in power due to attenuation. The receiver's sensitivity is thoroughly tested in R&D and is often the only parameter tested in production.

5.4.1 Sensitivity Testing in Production

Sensitivity tests in production are often carried out using a very simple scenario with only one static satellite. With just one satellite, it is not possible to obtain a position fix. Therefore, only the C/N ratio reported by the receiver for the simulated satellite is evaluated. At a known power level, which can in fact be greater than the actual sensitivity level, the receiver must report a certain C/N ratio (test limit). This method saves testing time. Testing with a full position fix, in contrast, takes quite long and is thus rarely performed in production of commercial receivers.[2]

To accurately measure the sensitivity level, the applied power at the receiver's input must be precisely known. The SMBV simulates a single static satellite, since this simple scenario makes it possible to precisely determine the applied power. When setting the reference power at the SMBV, the user needs to take the following into account:
- Cable loss
- External attenuator(s) (optional)
- Missing (active) antenna (optional)

To compensate cable loss, applied external attenuation and missing antenna gain, simply set the reference power to a correspondingly higher level:
SMBV reference power = wanted test level + cable loss + external attenuation + antenna gain

The SMBV generates the static satellite signal at a known power level either in realtime or via its internal ARB generator from a precalculated waveform. This waveform file can be generated with the R&S®WinIQSIM2 software and stored on the SMBV's local hard drive.

For time-critical production tests, a single test run can be sufficient. The receiver is set to a special test mode in which it merely measures the satellite C/N ratio. The SMBV is set to a fixed low power level, and the satellite C/N ratio reported by the receiver is validated.

---

[2] Testing with position fix (from C/A code) is, however, performed in production of military receivers that evaluate the P code. Since the P code is one week long, a time reference is needed first.

Configuration of the SMBV for sensitivity testing in production:

Realtime:
```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: static (default)
send_cmd(SOUR:BB:GPS:SMODE STATIC);

// set number of satellites: 1 (default)
send_cmd(SOUR:BB:GPS:SAT:COUNT 1);

// data source: PRBS (default) for GPS and Galileo
// for Glonass use data source "real navigation data" and set
date and time (proper frequency number is then automatically
set)
send_cmd(SOUR:BB:GPS:NAV:DATA PN9);
// send_cmd(SOUR:BB:GPS:NAV:DATA RND);

// set reference power
test_level = wanted_test_level + level_compensation   // dBm
send_cmd(SOUR:BB:GPS:POWER:REF %d; test_level);
// Choose the test level such that a golden device (reference
receiver) would report a C/N ratio of 38 dB-Hz to 40 dB-Hz.

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger
```

ARB:
```
// preset ARB
send_cmd(SOUR:BB:ARB:PRES);

// load waveform
send_cmd(SOUR:BB:ARB:WAV:SEL "/hdd/WinIQSIM2_GPS_waveform.wv");
send_cmd(*OPC?);      // synchronize

// turn on ARB signal
send_cmd(SOUR:BB:ARB:STAT ON);
send_cmd(*OPC?);      // synchronize

// set RF power
test_level = wanted_test_level + level_compensation   // dBm
send_cmd(SOUR:POW %d; test_level);
// Choose the test level such that a golden device (reference
receiver) would report a C/N ratio of 38 dB-Hz to 40 dB-Hz.

// set RF frequency: L1 + Doppler shift (+ frequency number for
Glonass) as configured in WinIQSIM2 during waveform generation
send_cmd(SOUR:FREQ %d; 1.575422 GHz);
```

```
// The correct frequency to be set is stored in the waveform
file. Please check the "Comment" tag in the waveform header. You
can either use a normal text editor or the ARB Toolbox Plus [3]
to open and display the header information. For example:
```

| Comment | 'Carrier Frequency should be set to 1575422000 Hz in order for GNSS to function correctly' |

```
It is also possible to query this comment by using the command
SOUR:BB:ARB:WAV:TAG? 'COMMENT'
and programmatically extract the frequency value, e.g. by using
a parser routine that checks for numeric characters.
```

```
// reset receiver: cold start
do_cold_start();

// let the receiver acquire the signal
wait4signal();

// get C/N reading from receiver
C/N_ratio = get_C/N_ratio();

// validate the reported C/N value by comparing it with a
specified test limit
pass_fail_state = validate_meas_C/N(C/N_ratio);
```

In production, the sensitivity of the receiver is mostly tested under cold start conditions.

5.4.2 Sensitivity Testing in R&D

Sensitivity tests in R&D can be carried out using:
- static satellites or
- dynamic satellites (moving along their specific orbits as in real life)

In either case, the RF output level of the SMBV should remain constant during the measurement period as explained in the following sections.

By simulating more than one satellite, inter-system interference (e.g. between GPS and Glonass satellites) can be tested.

5.4.2.1 Static Satellites

A satellite scenario with a single static satellite is the simplest scenario and makes it easy to precisely determine the applied input power. This scenario is therefore used in production tests as well as in R&D. Please see also the previous section for details. A satellite scenario with more than one static satellite is also possible. The use of static satellites ensures a reliable and constant satellite signal level for sensitivity testing.

Since receivers can have sensitivity levels as low as –160 dBm, extremely low signal levels have to be generated with high level accuracy. To reach such low levels and for best level accuracy, we recommend using external attenuators (see section 4.2 for details). When setting the RF level of the SMBV, the user needs to take into account the applied external attenuation as well as cable losses and possibly missing gain from an active antenna. Note that for the GNSS standards, the RF level is set (indirectly) using the parameter "Ref. Power". The satellite power levels are calculated from this reference power. For example, the reference power is set to –130 dBm and for each satellite the power offset is set to 0 dB.

	State	Standard	Signals	SV-ID	Power /dB
Sat 1	On	GPS	C/A	1	0.00
Sat 2	On	GPS	C/A	2	0.00
Sat 3	On	GPS	C/A	3	0.00
Sat 4	On	GPS	C/A	4	0.00

Ref. Power -130.00 dBm

Maximum Number Of Satellites 4

In this example, each satellite signal will have a level of –130 dBm, and four satellites together will have a level of four times –130 dBm, which equals –124 dBm [4].

Ref. Power   -130.00 dBm
Total Power   -124.09 dBm

The actual RF output level of the SMBV is displayed by the parameter "Total Power"[3]. By adjusting the reference power, external losses can be compensated with a resolution of 0.01 dB.

Note that all components of the test setup contribute to the overall level uncertainty at the receiver's input. Also attenuators and cables have uncertainties that the user should be aware of. Therefore, choose high-quality equipment for connecting the SMBV to the receiver. In order not to destroy the good level accuracy of the SMBV, the uncertainty of the specified attenuation/loss should be as small as possible.

For sensitivity tests, the "Static" simulation mode is used in the SMBV. The user can set the number of the simulated satellites, their identification number (SV-ID) and their individual power levels (i.e. their power offsets from the reference power). By simulating more than one satellite, inter-system interference (e.g. between GPS and Glonass satellite signals) can be tested.

When testing sensitivity with static satellites, the C/N ratio reported by the receiver for every simulated satellite is evaluated. At high signal levels, the receiver can easily acquire the satellite signals, and the reported C/N ratios are stable values. When the tester begins to decrease the satellite signal level, the C/N ratios also decrease but remain stable values. Sensitivity is tested by decreasing the satellite signal level in steps until the reported C/N readings finally become unstable. At this point, the sensitivity level of the receiver is reached.
- For testing the acquisition sensitivity, a cold start is performed each time the satellite signal level is decreased one step.

---

[3] This parameter is an internally measured value.

- For testing the tracking sensitivity, a single cold start is performed at the beginning of the measurement. Once the receiver has acquired the satellites, the signal level is decreased without performing further cold starts.

Configuration of the SMBV for acquisition sensitivity testing in R&D:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: static (default)
send_cmd(SOUR:BB:GPS:SMODE STATIC);

// data source: PRBS (default) for GPS and Galileo
// for Glonass use data source "real navigation data" and set
date and time (frequency number is then automatically set)
send_cmd(SOUR:BB:GPS:NAV:DATA PN9);
// send_cmd(SOUR:BB:GPS:NAV:DATA RND);

// set number of satellites: 4
send_cmd(SOUR:BB:GPS:SAT:COUNT 4);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// activate all 4 satellites
send_cmd(SOUR:BB:GPS:SAT1:STAT ON);
send_cmd(SOUR:BB:GPS:SAT2:STAT ON);
send_cmd(SOUR:BB:GPS:SAT3:STAT ON);
send_cmd(SOUR:BB:GPS:SAT4:STAT ON);

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);        // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger

Loop
{
// decrease power in steps
step = 1;    // dB
power = power – step;

// set reference power
send_cmd(SOUR:BB:GPS:POWER:REF %d; power);

// reset receiver: cold start
do_cold_start();      // only for acquisition sensitivity testing

// let the receiver acquire the signals
wait4signals();

// get C/N reading for one satellite from receiver
C/N = get_C/N_ratio;

// check if C/N reading is below defined threshold
threshold = 15;    // dB
If (C/N < threshold)
```

```
{break;}    // quit loop
}

// sensitivity level
sens_level = power + step - external_losses;
```

Please note that changing the reference power (`SOUR:BB:GPS:POWER:REF`) will cause the GNSS signal to restart. This is generally no problem when testing the acquisition sensitivity because the receiver is reset also (cold start). However, the reset of the GNSS signal may distract tracking sensitivity testing because the receiver can lose synchronization. In this case, the reference power can be kept constant and instead the RF level is reduced directly, as an exception.

For tracking sensitivity testing only:

```
Loop
{
// decrease power in steps
step = 1;    // dB
power = power – step;

// set RF power to not lose sync
send_cmd(SOUR:POW %d; power);

// get C/N reading for one satellite from receiver
C/N = get_C/N_ratio;

// check if C/N reading is below defined threshold
threshold = 15;    // dB
If (C/N < threshold)
{break;}    // quit loop
}
```

5.4.2.2 Dynamic Satellites (Constellation)

Simulating static satellites is the most common method and recommended for sensitivity testing because the SMBV exhibits best fidelity in that configuration. Simulating four or more dynamic satellites, however, allows the receiver to acquire a real position fix. This may be important if the receiver evaluates the military P code[4] or does not report data before a position fix has been established.

To ensure a reliable and constant satellite signal level for sensitivity testing, the "User Location" simulation mode needs to be used in the SMBV. In this mode, the SMBV simulates a realistic satellite constellation at a known, constant power level. The user can set the number of the simulated satellites, their identification number (SV-ID) and their individual power levels (i.e. their power offsets from the reference power). In "User Location" mode, it is also possible to let the SMBV determine the satellites that form an optimal constellation. Their individual power levels are then also set automatically.

---

[4] A position fix (from C/A code) is needed to get a time reference for testing military receivers, since the P code is one week long.

Acquisition sensitivity is tested by decreasing the satellite signal level in steps until the receiver is no longer able to acquire a valid position fix within a specified time period. At each level step, the receiver is reset to cold start condition. To test the tracking sensitivity, the receiver is reset only at the beginning of the measurement. Once the receiver has acquired a valid position fix, the satellite signal level is decreased one step at time until the receiver is no longer able to maintain the position fix within a specified accuracy.

Configuration of the SMBV for acquisition sensitivity testing with position fix:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: user localization
send_cmd(SOUR:BB:GPS:SMODE USER);

// select a location: select a city
send_cmd(SOUR:BB:GPS:LOC:SEL "Munich");

// set date and time (simulation starting point)
send_cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);      // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

// set number of satellites: 4
send_cmd(SOUR:BB:GPS:SAT:COUNT 4);

// set power mode for satellite configuration: user
send_cmd(SOUR:BB:GPS:POW:MODE USER);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// set optimal satellite constellation;
send_cmd(SOUR:BB:GPS:GOC);      // activates all 4 satellites

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger

Loop
{
// decrease power in steps
step = 1;   // dB
power = power - step;

// set reference power
send_cmd(SOUR:BB:GPS:POWER:REF %d; power);

// reset receiver: cold start
do_cold_start();      // only for acquisition sensitivity testing

// get position fix
fix = get_position_fix(timeout);
```

```
If (fix == 0) // no fix
{break;}      // quit loop
}

// sensitivity level
sens_level = power + step - external_losses;
```

Please note that changing the reference power (SOUR:BB:GPS:POWER:REF) will cause the GNSS signal to restart. This is generally no problem when testing the acquisition sensitivity because the receiver is reset also (cold start). When testing the tracking sensitivity however, the receiver will lose its position fix when the GNSS signal restarts. To avoid this, the reference power can be kept constant and instead the RF level is reduced directly, as an exception.

For tracking sensitivity testing only:

```
Loop
{
// decrease power in steps
step = 1;    // dB
power = power – step;

// set RF power to not lose position fix
send_cmd(SOUR:POW %d; power);

// get position fix
fix = get_position_fix(timeout);

If (fix == 0) // no fix
{break;}      // quit loop
}
```

The sensitivity test is repeated with significantly different satellite constellations, e.g. different dilution of precision (DOP) geometries, to test the receiver under various conditions.

5.5 Location Accuracy

The purpose of this measurement is to test how accurately the receiver can determine its true position. The location accuracy is one of the fundamental performance parameters tested during research and verification stages.

5.5.1 Static Location Accuracy

For this test, the SMBV simulates a realistic satellite constellation for a user-defined location. The best simulation mode is "Auto Localization", because in this mode the SMBV automatically simulates the satellites that offer the best constellation for the set location. If the user wishes to have full control over the simulated satellites, the "User Localization" simulation mode can also be used. The SMBV comes with several almanac files to choose from, but the user can also use up-to-date almanac files available for download on the Internet.

For testing the absolute location accuracy, the SMBV simulates different static positions, e.g. random positions that are located within a certain radius around a reference location. The position reported by the receiver is compared with the simulated position, and a 2D and a 3D position error is calculated. The position errors determined for the different test locations are then averaged. The reference level is usually set to a level well above the acquisition sensitivity level of the receiver. Normally, the location accuracy is specified for a specific power level, e.g. –130 dBm.

Like TTFF tests, the location accuracy test is usually repeated with significantly different satellite constellations to test the receiver under a broad range of conditions.

Configuration of the SMBV for absolute location accuracy testing:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: auto localization
send_cmd(SOUR:BB:GPS:SMODE AUTO);

// set number of satellites: e.g. 4, 8 or 12
send_cmd(SOUR:BB:GPS:SAT:COUNT 4);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// set date and time (simulation starting point)
send cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);     // set time basis
send cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

Loop
{
// set location: user-defined position, e.g. randomly generated
position within a given radius around a reference location
ref_coord = [0.00; 0.00; 0.00]      //latitude, longitude,
altitude
radius = 3000;    // in meters
sim_coord  = calculate_random_coord(ref_coord, radius);
send_cmd(SOUR:BB:GPS:LOC:SEL "User Defined");
send_cmd(SOUR:BB:GPS:LOC:COOR:DEC %f, %f, %f"; sim_coord.lat,
sim_coord.lon, sim_coord.alt);

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
```

```
send_cmd(*OPC?);       // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger

// let the receiver acquire a 3D position fix
wait4fix();

// get position from receiver
meas_coord = get_position();

// calculate position error
position error = calc position error(sim coord, meas coord);
}
```

5.5.2 Dynamic Location Accuracy

For this test, the SMBV simulates the movement of the receiver along a trajectory. The best simulation mode is "Auto Localization", but "User Localization" can also be used, if the user wishes to have full control over the simulated satellites.

For testing the dynamic location accuracy, the movement of the receiver along a simple trajectory is simulated using a movement trajectory file. The SMBV comes with some trajectory files to choose from, but the user can also use custom trajectory files, e.g. a custom waypoint file.
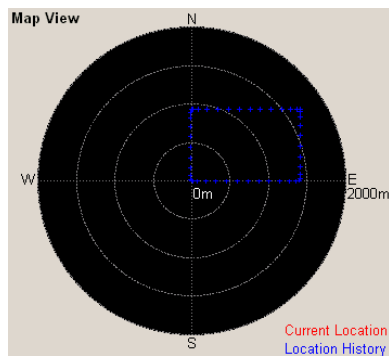
The position reported by the receiver is compared with the simulated position defined in the waypoint file. A 2D and 3D position error is calculated by calculating the distance between the reported values for longitude, latitude and altitude and the defined values in the waypoint file. For testing, the reference level is usually set to a level well above the acquisition sensitivity level of the receiver.

The location accuracy test is usually repeated with significantly different satellite constellations and different receiver trajectories to test the receiver under a broad range of conditions.

For more details on moving receiver simulation and code examples, see section 5.6.

5.6 Moving Receiver

The purpose of this measurement is to test how the receiver performs while it undergoes movement in either or all of the three directions: latitude, longitude and altitude. Usually fundamental performance parameters such as location accuracy and reacquisition time are measured. The test primarily shows how well the receiver can track satellites while moving

- at diverse velocities
- with different accelerations
- along different trajectories with ideal or restricted satellite visibility

Every receiver has a limit on the velocity, acceleration and jerk[5] that it can handle.

For this test, the SMBV simulates the movement of the receiver along a trajectory, i.e. the SMBV not only simulates the satellite motion (as done for a static location) but additionally emulates the receiver motion. As a consequence, the receiver will navigate as if it were indeed physically moving. The simulated trajectory is defined via a movement trajectory file. The SMBV comes with some trajectory files to choose from, but the user can also use any custom trajectory file. A trajectory file can have the following format:

- waypoint file
- script file
- NMEA data file
- KML data file
- XTD data file

Waypoint file:
A waypoint file is a simple text file (.txt) with the following format:

- 1st row: time resolution [ms]
- 2nd row: set of coordinates: longitude [° (decimal format)], latitude [° (decimal format)], altitude [m]
- All following rows: like 2nd row

```
RESOLUTION: 150
144.966666334601,-37.8166633061788,100.000000009313
144.966662392613,-37.8166632247233,100.000000039116
144.966658453002,-37.8166630889914,100.00000008475
...
...
144.966677890476,-37.8166633333331,100.00000003539
144.966673889123,-37.8166633333333,100.000000008382
```

Each line in the waypoint file represents a position point on the trajectory. After the specified time interval, 150 ms in this example (specified resolution), the next position point is simulated.

Script file:
A script file is a text file (.txt) that contains a set of commands:

- REFERENCE: longitude [°], latitude [°], altitude [m] (relative to WGS84 ellipsoid)
- START: east [m], north [m], up [m], velocity [m/s]
- ARC: center east [m], center north [m], angle [°]

---

[5] Jerk is defined as the time derivative of acceleration, which is a sudden abrupt motion.

- LINE: distance east [m], distance north [m], acceleration [m/s^2]
- STAY: time [ms]

The REFERENCE command sets a reference location. The START command sets the start location with respect to the reference location using east, north, up (ENU) coordinates. It also sets the start velocity. The ARC command generates a movement with constant velocity along a 2D circular arc. The arc center coordinates need to be specified relative to the reference location. The sign of the specified angle determines the rotation direction; positive angles correspond to a counterclockwise rotation and negative angles to a clockwise rotation. The LINE command generates a movement along a 2D line. The movement can exhibit a constant acceleration/deceleration. The STAY command causes the movement to stop for the specified time period. Please see reference [1] for a full description of the commands and their syntax.

```
*********************** MOVEMENT FILE ************************
%% This is a comment. The line above is MANDATORY as first line
in the file. If this line is missing, the SMBV will interpret
this script file as a waypoint file, which will lead to an
error.
%%
%% Set reference location
REFERENCE: 144.96667,-7.8166633,100
%% Set start location (set identical to reference location) and
start velocity
START: 0, 0, 0, 6.9444
%% Stay at start location for 1000 ms
STAY: 1000
%% Move north for 400 m with constant velocity
LINE: 0, 400, 0
%% Turn 90 degrees right in a sharp curve
ARC: 0, 380, -90
%% Move east for 1000 m with constant acceleration
LINE: 1000, 0, 0.55
%% Move further east for 100 m with constant deceleration
LINE: 100, 0, -0.25
…
…
```

The command lines in the file are processed sequentially. From command to command, the end position of the previous command is used as start position for the next command so that a continuous trajectory is created. The same applies for the velocity; the velocity at the end position is used as the starting velocity for the next command.

NMEA data file:
An NMEA data file (.nmea) contains a list of sentences. Each sentence is composed of a $ sign, a "talker ID" (two characters), a "message ID" (three characters), a number of data fields (separated by commas) and an optional checksum (separated by * sign):

```
$GPGGA,173032.00,3748.99055,S,14457.98521,E,1,08,0.92,96.7,M,-1.8,M,,*66
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
$GPGSV,3,1,09,05,24,135,47,15,24,060,47,16,23,226,47,18,39,335,47*74
$GPGSV,3,2,09,21,62,240,47,25,22,353,47,26,21,098,47,29,71,079,47*77
```

```
$GPGSV,3,3,09,30,,,43*74
$GPGLL,3748.99055,S,14457.98521,E,173032.00,A,A*7C
$GPGRS,173032.00,1,-1.9,1.0,1.1,2.6,-0.8,-4.7,2.0,-0.4,,,,*4A
$GPGST,173032.00,4.5,,,,0.70,0.85,1.3*74
$GPZDA,173032.00,07,11,2010,00,00*66
$GPGBS,173032.00,0.7,0.9,1.3,,,,*49
$GPRMC,173033.00,A,3748.98668,S,14457.98506,E,13.947,358.25,071110,,,A*41
$GPVTG,358.25,T,,M,13.947,N,25.830,K,A*30
$GPGGA,173033.00,3748.98668,S,14457.98506,E,1,08,0.92,96.7,M,-1.8,M,,*6B
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
…
…
```

The talker ID "GP" stands for GPS and "GL" for Glonass. The message ID "GGA" contains position fix information, i.e. time, position and other fix-related data (see section 7 for more information on the NMEA format). This message is evaluated by the SMBV. The user can load the NMEA data file as it is. The SMBV scans the file for the GGA messages and extracts the information to create the trajectory. As a result, real-word trajectories such as roads, flight paths, ship paths, etc., can be reproduced on the basis of logged NMEA data.

KML data file:
A KML data file (.kml) can be created, edited, and displayed with Google Earth and Google Maps. It has XML syntax and contains geographic data as well as other data (such as images, 3D models, textual descriptions, "camera view" parameters, etc.). The geodetic reference system is the WGS84, i.e. the geographic coordinates are given as longitude, latitude and altitude (if available). Please refer to the Google Earth documentation for the description of the file format.

XTD data file:
A XTD data file (.xtd) contains position coordinates (in different formats such as ENU, Cartesian ECEF, or WGS84) and optionally velocity and/or attitude data. This extensive file format makes it possible to simulate sophisticated motion including velocity and attitude information. Please refer to reference [1] for the description of the file format and some file examples.

The SMBV provides trajectory file examples for every supported file format.

A movement trajectory file can be played back either a single time, continuously cyclic or continuously forth and backwards (round trip).
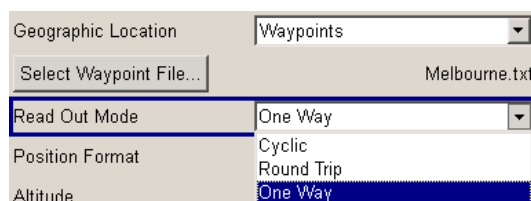
For moving receiver simulation, the best simulation mode is "Auto Localization", because the simulated satellites are exchanged automatically for long simulation times. However, if the user wishes to have full control over the simulated satellites, "User Localization" can also be used. The SMBV simulates the movement of the receiver along the specified trajectory. In the automated test program, the position reported by the receiver is compared with the simulated position every second (for example) and 2D/3D position errors are calculated. The position errors determined along the different test points are then averaged to get mean 2D/3D position errors.

The moving receiver test is usually repeated with different movement trajectory files to test the receiver under a broad range of conditions, e.g. to examine how it reacts to highly dynamic motion with strong acceleration and/or high velocities. Which movement trajectory file is suitable for testing depends on the application field of a specific receiver. In any case, the SMBV gives the user the possibility to simulate nearly all desired movements – from simple geometric trajectories with constant, moderate velocity to three-dimensional, real-life trajectories with very high dynamics to stress the receiver. The specifications for maximum velocity, acceleration and jerk supported by the SMBV can be found in the data sheet.

Configuration of the SMBV for moving receiver simulation:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: auto localization
send_cmd(SOUR:BB:GPS:SMODE AUTO);

// set number of satellites: 8
send_cmd(SOUR:BB:GPS:SAT:COUNT 8);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// set location: movement trajectory file
send_cmd(SOUR:BB:GPS:LOC:SEL "Waypoints");

// select movement trajectory file
send_cmd(SOUR:BB:GPS:LOC:WAYP:FILE 'Melbourne.txt'

// set playback/read out mode
send_cmd(SOUR:BB:GPS:LOC:WAYP:ROMODE CYCL);

// set date and time (simulation starting point)
send cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);      // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger

// let the receiver acquire a 3D position fix
wait4fix(timeout = 800);
```

```
Loop
{
// get position and time from receiver
meas_coord = get_position();
meas_time = get_time();

// query SMBV for simulated position at time point reported by
receiver
sim_coord = send_cmd(SOUR:BB:GPS:RT:RLOC:COOR:DEC? UTC, %f, %f,
%f, %f, %f, %f; meas time.year, meas time.month, meas time.day,
meas_time.hour, meas_time.min, meas_time.sec);

// calculate position error
position_error = calc_position_error(meas_coord, sim_coord)

// wait 1 second
wait(1);
count = count + 1;

// quit loop, e.g. after 500 iterations
If (count == 500)
{break;}
}
```

Hint: Typically, the TTFF is shorter if the receiver is stationary and not moving. It thus makes sense to remain a while at the start position before actually starting the movement in order to enable the receiver to acquire a position fix more rapidly. The "parking" must be included in the movement trajectory file.

Note that the SMBV supports two kinds of receiver movement simulation:
- Using predetermined trajectories from files such as waypoint, NMEA data, etc. as described above.
- Using remote control to dictate the trajectory in realtime as used in hardware in the loop (HIL) setups. Please see reference [8] for a detailed description of how to operate the SMBV in HIL applications.

5.7 Long-Term Experiment

The purpose of this measurement is to test how reliably the receiver can deliver valid and precise position fixes over a long test period. Such long-term tests run for at least 24 hours but can also last as long as two full days or even more.

For this test, the SMBV simulates a realistic satellite constellation for a static or moving receiver. The "Auto Localization" simulation mode is used, because in this mode the SMBV automatically simulates the satellites that offer the best constellation. As the simulated satellites move in the sky as real satellites do, there is a steady restructuring of visible satellites. While some satellites move across the sky and finally vanish beyond the horizon, other satellites appear on the horizon. The SMBV is able to simulate this situation by automatically exchanging the satellite signals in realtime. The simulation time is thus unlimited, which makes the SMBV ideal for long-term testing. For example, the number of simulated satellites is set to "6". The SMBV will then simulate the six satellites that offer the best constellation (best DOP), e.g. SV-IDs 3, 11, 14, 18, 23, 25. If one satellite gets close to the horizon, it is automatically replaced by a new one, e.g. SV-ID 25 is replaced by SV-ID 15. Over the day, the SMBV thus simulates all SV-IDs as the satellites rotate across the sky.

During the test period, the receiver's performance is constantly monitored. Of special interest is the overall time period during which the receiver delivered a valid position fix. Also the average location accuracy is of interest.

Configuration of the SMBV for a long-term experiment:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: auto localization
send_cmd(SOUR:BB:GPS:SMODE AUTO);

// Optional: select almanac file
// up-to-date almanac files are available on the Internet.
send_cmd(SOUR:BB:GPS:NAV:ALM:GPS:FILE 'GPS_SEM585.txt');

// set number of satellites: 6
send_cmd(SOUR:BB:GPS:SAT:COUNT 6);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

if (moving_receiver == true)
{
// set location: movement trajectory file
send cmd(SOUR:BB:GPS:LOC:SEL "Waypoints");

// select movement trajectory file
send_cmd(SOUR:BB:GPS:LOC:WAYP:FILE 'Melbourne.txt'

// set playback/read out mode
send_cmd(SOUR:BB:GPS:LOC:WAYP:ROMODE CYCL);
}
else      // static receiver
{
// set location: user location
send_cmd(SOUR:BB:GPS:LOC:SEL "User Defined");

// set position coordinates
send_cmd(SOUR:BB:GPS:LOC:COOR:DEC 90, 180, 5.5);
}
```

```
// set date and time (simulation starting point)
send_cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);      // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger
```

5.8 Interference

The purpose of this measurement is to test how unwanted, disturbing signals influence the receiver's performance.

Interference can come from a wide variety of sources. Since GNSS signals are extremely low in power, they are particularly prone to interference. When a receiver is exposed to disturbing signals, its performance may be degraded or it may even fail to acquire or track the satellites. For example, in mobile handsets and even chipsets more and more functions are being integrated, making interference testing indispensable. The performance of the GNSS receiver must be tested in the presence of possible interfering sources such as WLAN, Bluetooth[®], FM stereo and various mobile communications standards to ensure proper navigation functionality.

For interference testing, a second signal generator, e.g. a second SMBV, is used. One SMBV generates the GNSS signal, the other SMBV generates the interfering signal. Both signals are added externally by means of an RF power combiner or RF coupler.
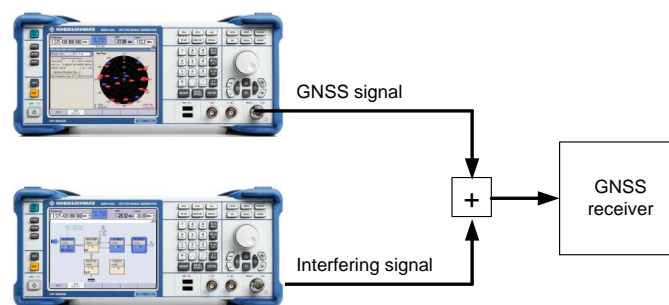
The SMBV is a versatile signal generator capable of generating standard-compliant signals for digital communications standards such as GSM/EDGE, 3GPP WCDMA, LTE, WLAN, WiMAX, Bluetooth[®], etc.; for radio standards such as FM stereo, HD Radio[TM], Sirius and XM Satellite Radio, DAB; and for GNSS standards. In addition, the internal ARB generator of the SMBV can be used to play back any custom waveform to generate user-defined interfering signals. The level of the interfering signal can be adjusted within a large dynamic range. Sweeps are also possible.

For interference testing, a second SMBV is generally used. However, some kinds of interfering signals can also be generated within the satellite simulator itself without a second SMBV. For inter-system interference testing, satellites of other GNSS systems can be simulated simultaneously using a hybrid scenario. For example, a GPS receiver can be tested in the presence of Glonass satellites using just a single SMBV in hybrid mode. It is also possible to internally superimpose a CW interferer signal with definable satellite signal-to-interferer ratio. For example, a CW signal at the L1 frequency can be superimposed on the satellite signal using just a single SMBV equipped with R&S®SMBV-K62 option.

If performance parameters such as TTFF, location accuracy and acquisition/tracking capability are tested in the presence of the interferer, the "Auto Localization" simulation mode is ideal. If only satellite C/N measurements are performed, the "Static" simulation mode is best used.

5.9 Multipath Reception

The purpose of this measurement is to test how multipath reception influences the receiver's performance, particularly to which extent parameters such as location accuracy, TTFF and reacquisition time are degraded.

In real-life scenarios, especially in cities, satellite signals are reflected off buildings and other urban objects. As a consequence, the signal of a satellite reaches the GNSS receiver not only via the direct line of sight but also via multiple paths that are typically different for each satellite. The multiple echoes of a satellite signal arrive at the receiver with different delays and attenuations. Depending on the signal processing implemented in the receiver, a signal echo having a long delay with respect to the received direct satellite signal (LOS signal) does not pose a great problem. However, multipath signals with short delays (100 ns to 10 ns), which typically come from nearby objects, cause problems, since they distort the correlation peak. This leads to errors in the determined pseudorange. Also, if the LOS signal is not received, the receiver will misinterpret the first signal echo as the LOS signal, which can result in major difficulties in the receiver.
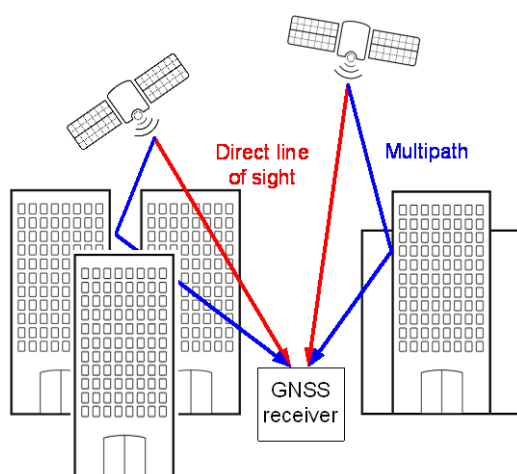
For testing the receiver's multipath mitigation performance, the SMBV can simulate multipath propagation in two ways:

- **Manual mode**: multipath propagation for one or more satellites.
  Manual configuration of settings (user-mode) such as signal attenuation, delay/time shift, Doppler frequency shift and carrier phase for each satellite individually.
- **Automatic mode**: automatic multipath propagation and additional obscuration. Predefined or user-specific configuration of obscuration scenario with automatic simulation of associated multipath propagation based on satellite constellation, receiver position, obstacle position and surface material.

Manual mode
The test uses the "User Localization" simulation mode. In this mode, the user can separately define multipath propagation for each simulated satellite. The SMBV can simulate up to a total of 24 paths (taps). The available path budget can be distributed among the used satellites. For example, it is possible to simulate 12 GPS satellites with one multipath each, i.e. 12 paths are used for simulating the direct satellite signal, and another 12 paths are used for simulating the respective multipath echo. For each path, the user can set a signal attenuation, a delay/time shift, a Doppler frequency shift and a carrier phase. Several multipath echoes for one satellite can be specified, but generally one or two multipath echoes per satellite are sufficient for testing the receiver. It is also possible to "remove" the direct LOS signal simply by setting delay and attenuation to non-zero values.
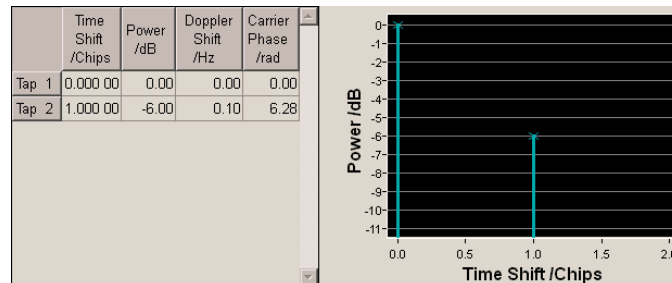
Configuration of the SMBV for multipath testing:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: user localization
send_cmd(SOUR:BB:GPS:SMODE USER);

// set number of satellites: 6
send_cmd(SOUR:BB:GPS:SAT:COUNT 6);

// set location: user location
send_cmd(SOUR:BB:GPS:LOC:SEL "User Defined");

// set position coordinates
send_cmd(SOUR:BB:GPS:LOC:COOR:DEC 90, 180, 5.5);
```

```
// set date and time (simulation starting point)
send_cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);      // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2011, 09, 23);
send_cmd(SOUR:BB:GPS:NAV:SIM:TIME 8, 15, 46.689);

// set reference power, e.g. -130 dBm
send_cmd(SOUR:BB:GPS:POWER:REF -130);

// set power mode for satellite configuration: auto
send_cmd(SOUR:BB:GPS:POW:MODE AUTO);

// set optimal satellite constellation
send_cmd(SOUR:BB:GPS:GOC);      // activates all 6 satellites

// configure multipath simulation
// get satellite ID of the simulated GPS satellites
SV_ID1 = send_cmd(SOUR:BB:GPS:SAT1:SVID?);
SV_ID2 = send_cmd(SOUR:BB:GPS:SAT2:SVID?);
SV_ID3 = send_cmd(SOUR:BB:GPS:SAT3:SVID?);
SV_ID4 = send_cmd(SOUR:BB:GPS:SAT4:SVID?);
SV_ID5 = send_cmd(SOUR:BB:GPS:SAT5:SVID?);
SV_ID6 = send_cmd(SOUR:BB:GPS:SAT6:SVID?);


// no multipath for satellites 1, 2, 3, 4, 5
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE OFF; SV_ID1);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE OFF; SV_ID2);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE OFF; SV_ID3);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE OFF; SV_ID4);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE OFF; SV_ID5);

// multipath for satellite 6: 2 taps
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:STATE ON; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP:COUNT 2; SV_ID6));

// configure tap 1 of satellite 6: (default values)
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP1:TSHIFT 0; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP1:POWER 0; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP1:DSHIFT 0; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP1:CPHASE 0; SV_ID6);

// configure tap 2 of satellite 6:
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP2:TSHIFT 1.2; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP2:POWER -3; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP2:DSHIFT 0.01; SV_ID6);
send_cmd(SOUR:BB:GPS:SVID%d:GPS:MPATh:TAP2:CPHASE 3.14; SV_ID6);

// turn on GNSS baseband signal
send_cmd(SOUR:BB:GPS:STAT ON);
send_cmd(*OPC?);      // synchronize
send_cmd(SOUR:BB:GPS:TRIG:EXEC);      // trigger
```
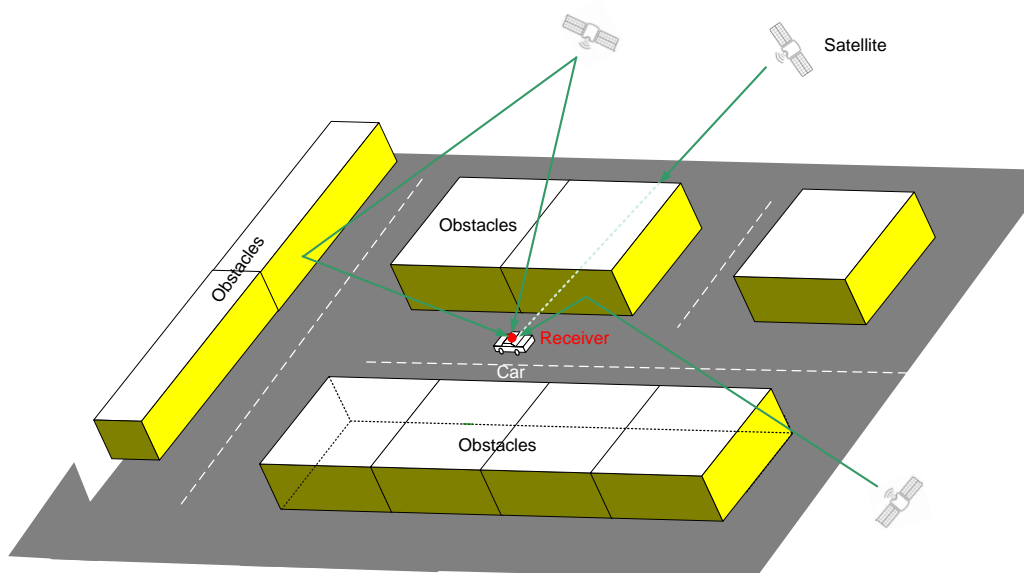
Automatic mode

The test uses the R&S®SMBV-K101 "Obscuration and automatic multipath" option of the SMBV. This option makes it possible to simulate obstacles such as buildings and roadside objects causing obscuration and multipath signals. A multitude of different obscuration scenarios can be configured flexibly and conveniently. For example, a scenario as shown in below schematic can be simulated where a receiver in a car moves through city blocks.

The SMBV automatically simulates the multipath propagation caused by the defined obstacles based on the satellite constellation, receiver position (and movement), and even surface material of the obstacles. A detailed description of this feature can be found in reference [7]. Please see this dedicated application note for further details.

5.10 Atmospheric Modeling

The purpose of this measurement is to test how signal delays caused by the earth's atmosphere influence the receiver's performance, particularly the location accuracy.

On their way from the satellites to the receiver, the GNSS signals travel through the earth's atmosphere, which is composed of different layers. Two of these layers that play a role for GNSS are the ionosphere and the troposphere. The ionosphere is a layer of ionized gas in the upper atmosphere that influences radio wave propagation due to its dispersive nature. The troposphere forms the lowest atmospheric layer – the "weather layer" – and is a non-dispersive medium. A GNSS signal is assumed to travel at the speed of light (true in space vacuum). However, the troposphere and mostly the ionosphere refract and slow down the signal, thus causing a delay in the signal that leads to an error in the receiver's position fix. To minimize the error induced by the ionosphere, the atmospheric conditions are mathematically modeled, i.e. one tries to predict the delay. The up-to-date prediction of the ionospheric delay is broadcasted via the navigation message of every satellite. The receiver can use this information to compensate for this delay and reduce the error in the position fix. Mathematical modeling is also used to predict tropospheric delays, but these predictions are not broadcasted via the navigation message, since tropospheric conditions are very regional. In addition, this modeling of a "standard atmosphere" yields a good estimation for the tropospheric delays (for elevations > 5°).

The SMBV can simulate the propagation characteristics of the satellite signals in the ionosphere and the troposphere using the appropriate models. For GPS, the Klobuchar model is used as ionospheric model. The user can set the 8 Klobuchar coefficients $\alpha 0$ to $\alpha 3$ and $\beta 0$ to $\beta 3$. These coefficients are used for simulating the ionospheric delay and are included in the navigation message of the simulated satellites. If ionospheric modeling is disabled, the set coefficients are nevertheless included in the navigation message generated by the SMBV. Note that setting the 8 Klobuchar coefficients to zero is not equivalent to disabling ionospheric modeling. The STANAG model is used as tropospheric model.

Configuration of the SMBV for simulating atmospheric conditions:

```
// GPS
// set ionospheric model to activate ionospheric modeling
send cmd(SOUR:BB:GPS:ATM:GPS:ION:MODel KLOBuchar);

// set Klobuchar coefficients
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:ALPHa0 5);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:ALPHa1 2);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:ALPHa2 -1);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:ALPHa3 -1);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:BETA0 39);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:BETA1 4);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:BETA2 -1);
send_cmd(SOUR:BB:GPS:ATM:GPS:ION:BETA3 -6);

// set tropospheric model to activate tropospheric modeling
send_cmd(SOUR:BB:GPS:ATM:GPS:TROP:MODel STANAG);

// atmospheric modeling can be disabled with
// send_cmd(SOUR:BB:GPS:ATM:GPS:ION:MODel NONE);
// send_cmd(SOUR:BB:GPS:ATM:GPS:TROP:MODel NONE);
// note: the set Klobuchar coefficients are still transmitted
via the navigation message of the simulated satellites, even if
ionospheric modeling is turned off
```

By activating atmospheric modeling in the SMBV, the receiver's modeling capabilities can be tested. When atmospheric modeling is disabled in the SMBV, it must also be disabled in the receiver to prevent erroneous results.

5.11 Leap Second Insertion

The purpose of this measurement is to test if the receiver is able to handle a leap second insertion event correctly.

The universal time coordinated (UTC) is corrected periodically by a leap second to account for variations in the rotation of the earth. By inserting a leap second, the UTC year is extended by one second. In contrast, the GPS time is continuous and is not corrected by leap seconds. The resulting time difference between the UTC and GPS time is broadcasted via the navigation message. In 2012, this time difference was 16 s. The receiver uses the broadcasted UTC-to-GPS time offset to provide time readings according to UTC. When a leap second insertion event occurs, the UTC-to-GPS time offset increases by one second (i.e. the leap second offset is increased).

A leap second insertion event can be simulated by the SMBV easily and straightforwardly. This makes it possible to test if the receiver is able to detect an insertion event and adjust its displayed UTC time. The SMBV is operated in "User Localization" mode. If the simulated date is in the past, the SMBV can automatically display the date of the next upcoming leap second insertion (with respect to the simulated date) that actually occurred in history.[6] It also displays the corresponding leap second offset. This allows the user to perform tests under realistic (historic) conditions. Nevertheless, it is also possible to set a user-defined date and leap second offset. The SMBV automatically modifies the navigation message that informs the receiver about the week and day number the leap second event will occur and about the current and the next leap second offset. The simulated leap second insertion occurs always at 00:00 o'clock.

Configuration of the SMBV for simulating a leap second insertion event:

```
// preset GNSS standard
send_cmd(SOUR:BB:GPS:PRES);

// set simulation mode: user localization
send_cmd(SOUR:BB:GPS:SMODE USER);

// set a date: we use a time point in the past
send_cmd(SOUR:BB:GPS:NAV:SIM:TBASIS UTC);      // set time basis
send_cmd(SOUR:BB:GPS:NAV:SIM:DATE 2000, 09, 23);

// activate the leap second simulation
send_cmd(SOUR:BB:GPS:NAV:TCON:LEAP:SLST:STAT ON);
```

---

[6] The dates of the leap second insertions are hard-coded in the SMBV.

```
// get the (historic) date of the upcoming leap second
insertion, the leap second offset and the sign of the leap
second
send_cmd(SOUR:BB:GPS:NAV:TCON:LEAP:SYNC);
leap_sec_date = send_cmd(SOUR:BB:GPS:NAV:TCON:LEAP:DATE?);
leap_sec_offset = send_cmd(SOUR:BB:GPS:NAV:TCON:LEAP:SEC?);
leap_sec_sign = send_cmd(SOUR:BB:GPS:NAV:TCON:LEAP:SIGN?);

// set date and time close to the insertion event
send cmd(SOUR:BB:GPS:NAV:SIM:DATE leap sec date.year,
leap sec date.month, leap sec date.day);
send cmd(SOUR:BB:GPS:NAV:SIM:TIME 23, 30, 0);

// set optimal satellite constellation
send_cmd(SOUR:BB:GPS:GOC);
```

To check if the receiver detects and processes a leap second insertion event correctly, the UTC time data reported by the receiver is monitored – either by eye or preferably by data log. The reported UTC time should pause for 1 second before continuing, e.g. the seconds may count up as follows: 58 59 60 0 1 2…
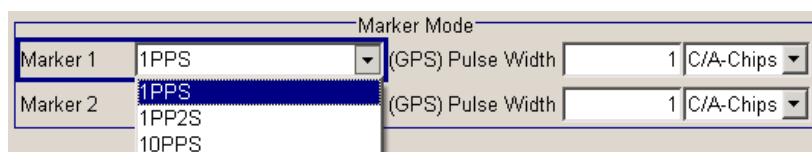
5.12 1PPS Signal

The purpose of this measurement is to test the accuracy of the one pulse per second (1PPS) signal generated by the receiver.

Many GNSS receivers generate a 1PPS output signal – a pulsed TTL signal with a frequency of 1 Hz – that is synchronous to the GPS time (in the case of GPS receivers): The rising edges of the pulses are aligned with the GPS seconds. These timed pulses can be used for synchronizing local clocks, for instance, in communications networks. For example, the CDMA 2000 standard uses the GPS 1PPS signal for time synchronization of base stations.
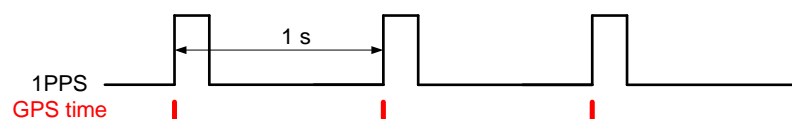

The SMBV can provide the following timing signals at its two marker outputs:
- 1PPS: a pulse is generated each second
- 1PP2S: a pulse is generated every two seconds
- 10PPS: a pulse is generated every 100 milliseconds, i.e. ten pulses per second are generated

The marker signal, i.e. the 1PPS signal generated by the SMBV and the 1PPS signal generated by the receiver, can be compared by means of an oscilloscope (e.g. R&S RTO) and the timing accuracy can be measured. In this setup, the SMBV's 1PPS signal serves as the timing reference.
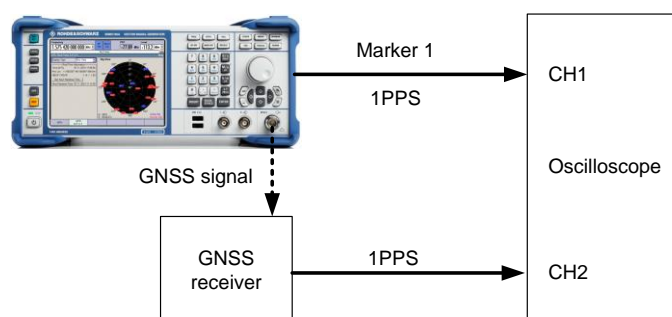
By measuring the time difference between the pulse edges of the two 1PPS signals over a period of time, the pulse stability or jitter can be determined. The precision of the receiver's 1PPS signal is related to the time dilution of precision (TDOP) of the satellite constellation.

Configuration of the marker signal for 1PPS signal generation:

```
// configure marker 1 to output the 1PPS signal
send_cmd(SOUR:BB:GPS:TRIG:OUTPUT1:MODE PPS);

// set a pulse width of e.g. 2 C/A chips
send_cmd(SOUR:BB:GPS:TRIG:OUTPUT1:PULSE:WIDTH 2);
```

The marker signal is output as soon as the GNSS baseband signal is turned on.

Note that the 1PPS marker signal can be used by any DUT to synchronize to the SMBV GNSS time.

6 Features Worth Considering…

6.1 Change Settings Without Interrupting Signal Generation

Certain setting parameters can be changed without interrupting signal generation. This means the satellite signals can be modified while they are playing. The following table lists these particular settings parameters.

Adjustments that do NOT interrupt signal generation		
Setting parameter	**SCPI command**[7]	**Description**
Satellite Power	`BB:<GNSS>:SAT<ch>:POW`	The power level of individual satellites (in relation to the reference power) can be changed (in "User Localization" simulation mode with "User" power mode).
Satellite State	`BB:<GNSS>:SAT<ch>:STAT`	Satellites can be turned on and off to change the satellite visibility (in "User Localization" simulation mode).
Pseudorange Bias	`BB:<GNSS>:SAT<ch>:PRB`	A bias for the pseudorange of a satellite can be applied (in "User Localization" simulation mode).

For example, if you want to manually exchange satellites in "User Localization" mode, you can query the current elevation of a particular satellite (see section 6.2) and if it is already poor, you can turn off the satellite, change the SV-ID and turn the satellite on again. Since the SV-ID is changed while the simulated satellite is turned off, this operation is executed without interrupting GNSS signal generation. As a result, the "old" satellite is replaced with a "new" satellite just like in "Auto Localization" mode but now user-dictated.

For example, applying a pseudorange bias makes it possible to perform receiver autonomous integrity monitoring (RAIM) tests. If there are more satellites available than needed to obtain a position fix, the redundant pseudorange measurements can be used to detect faults, e.g. a satellite whose pseudorange differs significantly from the expected value (outlier) due to a satellite clock error. The RAIM technology is of special interest in safety-critical applications, such as in aviation navigation when approaching for a landing. In the SMBV, you can set a pseudorange bias to test the receiver's RAIM algorithm without interrupting GNSS signal generation.

---

[7] Please see reference [1] for detailed information.

6.2 Query Time-Specific Information

The SMBV supports a set of very useful realtime (RT) SCPI commands. These commands can be used to query the SMBV for information related to a specific point in time. For example, the SMBV can be queried for the simulated position at a specified point in time using the command:

`SOUR:BB:<GNSS>:RT:RLOC:COOR:DEC? UTC, <year>, <month>, <day>, <hour>, <min>, <sec>`

RT SCPI queries cause the SMBV to perform a dedicated calculation for the specified time point returning a precise result. The following table lists the available RT queries.

RT SCPI queries	
Query[8]	**Description**
`BB:<GNSS>:RT:<GNSS>:SVID<ch>:AZIM?`	Returns the azimuth of the specified satellite at the specified time point.
`BB:<GNSS>:RT:<GNSS>:SVID<ch>:ELEV?`	Returns the elevation of the specified satellite at the specified time point.
`BB:<GNSS>:RT:<GNSS>:SVID<ch>:TAP<ch>:POW:ABS?`	Returns the absolute power of the specified (multipath) tap of the specified satellite at the specified time point.
`BB:<GNSS>:RT:RLOC:COOR:DEC?`	Returns the position coordinates in decimal format at the specified time point.
`BB:<GNSS>:RT:RLOC:COOR:DMS?`	Returns the position coordinates in DMS format at the specified time point.
`BB:<GNSS>:RT:RATT?`	Returns the attitude parameters (yaw, pitch, roll) of the receiver at the specified time point.
`BB:<GNSS>:RT:SCON?`	Returns the satellites that are active at the specified time point.
`BB:<GNSS>:RT:OCON?`	Returns the satellites that form an optimal constellation at the specified time point.

For example, if you want to manually exchange satellites in "User Localization" mode, you can query the optimal constellation for the current point in time and then set the SV-IDs accordingly.

In addition to the RT SCPI queries in above table, there are special RT commands for HIL operation. Please refer to reference [8] for details.

HIL SCPI commands	
Command	**Description**
`BB:<GNSS>:RT:HILP:MODE:A`	Sets the receiver position coordinates (in ECEF system), kinetic parameters (ECEF), and optionally attitude parameters
`BB:<GNSS>:RT:HILP:MODE:B`	Sets the receiver position coordinates (in WGS 84 system), kinetic parameters (NED), and optionally attitude parameters

---

[8] Please see reference [1] for detailed information.

7 Parsing NMEA Data

This section describes briefly how to extract information from NMEA data delivered by the GNSS receiver. The data is sent as a list of sentences. The structure of a sentence is as follows:

$ sign, "talker ID" (2 characters), "message ID" (3 characters), various data fields (separated by commas), optional checksum (begins with * sign), carriage return/line feed

NMEA data log example:

```
$GPGGA,173032.00,3748.99055,S,14457.98521,E,1,08,0.92,96.7,M,-1.8,M,,*66
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
$GPGSV,3,1,09,05,24,135,47,15,24,060,47,16,23,226,47,18,39,335,47*74
$GPGSV,3,2,09,21,62,240,47,25,22,353,47,26,21,098,47,29,71,079,47*77
$GPGSV,3,3,09,30,,,43*74
$GPGLL,3748.99055,S,14457.98521,E,173032.00,A,A*7C
$GPGRS,173032.00,1,-1.9,1.0,1.1,2.6,-0.8,-4.7,2.0,-0.4,,,,*4A
$GPGST,173032.00,4.5,,,,0.70,0.85,1.3*74
$GPZDA,173032.00,07,11,2010,00,00*66
$GPGBS,173032.00,0.7,0.9,1.3,,,,*49
$GPRMC,173033.00,A,3748.98668,S,14457.98506,E,13.947,358.25,071110,,,A*41
$GPVTG,358.25,T,,M,13.947,N,25.830,K,A*30
$GPGGA,173033.00,3748.98668,S,14457.98506,E,1,08,0.92,96.7,M,-1.8,M,,*6B
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
…
```

The talker ID for GPS is "GP". For Glonass, it is "GL". For Galileo, a talker ID has not yet been defined. The most important message IDs for use with a GNSS simulator are:

- GGA: fix data, e.g. time and position
- GSA: overall satellite data, e.g. DOP
- GSV: detailed satellite data, e.g. satellite C/N ratios
- ZDA: date and time

The following tables explain the structure of the GGA, GSA, GSV and ZDA messages, respectively.

GGA – example	
$GPGGA,173032.00,3748.99055,S,14457.98521,E,1,08,0.92,96.7,M,-1.8,M,,*66	
$GPGGA	GPS fix data
173032.00	UTC time: 17:30:32
3748.99055,S	Latitude: 37° 48.99055' South
14457.98521,E	Longitude: 144° 57.98521 East
1	Fix quality: 1 = valid GPS fix
8	Number of tracked satellites
0.92	Horizontal dilution of position
96.7,M	Altitude above sea level: 96.7 meters
-1.8,M	Height of geoid (sea level) above WGS84 ellipsoid: –1.8 meters

GSA – example	
`$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F`	
`$GPGSA`	GPS overall satellite data
`A`	Auto selection of 2D or 3D fix
`3`	3D fix
`05,15,16,18,21,25,26,29`	Acquired satellites (PRN numbers) used for fix *
`1.88`	PDOP
`0.92`	HDOP
`1.64`	VDOP

* The reserved satellite PRN numbers span the range from 1 to 32 for GPS and from 65 to 96 for Glonass. For example, a PRN of "05" would correspond to the GPS satellite with SV-ID "5" (G5) in the SMBV, and a PRN of "66" would correspond to the Glonass satellite with SV-ID "2" (R2).

GSV – example	
`$GPGSV,3,1,09,05,24,135,47,15,24,060,47,16,23,226,47,18,39,335,47*74`	
`$GPGSA`	GPS detailed satellite data for up to four satellites per sentence
`3`	Number of sentences: the GSV message spans three sentences
`1`	Sentence 1 of 3
`09`	Number of visible satellites
`05`	Satellite PRN number: 05
`24`	Elevation: 24°
`135`	Azimuth: 135°
`47`	Satellite C/N ratio: 47 dB-Hz
`15`	Satellite PRN number: 15
`24`	Elevation: 24°
…	…

ZDA – example	
`$GPZDA,173032.00,07,11,2010,00,00*66`	
`$GPZDA`	GPS date and time
`173032.00`	UTC time: 17:30:32
`07,11,2010`	Date: day, month, year: 7th of November 2010
`00`	Local zone hours
`00`	Local zone minutes

The recommended way to parse received NMEA data is to search for a GGA message as this message appears exactly once for a point in time. Searching for the subsequent GGA message makes it possible to form a block of data containing a complete set of NMEA messages – from GGA to GGA message.

```
$GPGGA,173032.00,3748.99055,S,14457.98521,E,1,08,0.92,96.7,M,-1.8,M,,*66
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
$GPGSV,3,1,09,05,24,135,47,15,24,060,47,16,23,226,47,18,39,335,47*74
$GPGSV,3,2,09,21,62,240,47,25,22,353,47,26,21,098,47,29,71,079,47*77
$GPGSV,3,3,09,30,,,43*74
$GPGLL,3748.99055,S,14457.98521,E,173032.00,A,A*7C
$GPGRS,173032.00,1,-1.9,1.0,1.1,2.6,-0.8,-4.7,2.0,-0.4,,,,*4A
$GPGST,173032.00,4.5,,,,0.70,0.85,1.3*74
$GPZDA,173032.00,07,11,2010,00,00*66
$GPGBS,173032.00,0.7,0.9,1.3,,,,*49
$GPRMC,173033.00,A,3748.98668,S,14457.98506,E,13.947,358.25,071110,,,A*41
$GPVTG,358.25,T,,M,13.947,N,25.830,K,A*30
$GPGGA,173033.00,3748.98668,S,14457.98506,E,1,08,0.92,96.7,M,-1.8,M,,*6B
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
…
```

In a next step, this NMEA data block is evaluated line by line. Each line starts with a "$" sign that helps to identify the start of a message. The text between two subsequent "$" signs forms an NMEA sentence, which varies in length.

```
$GPGGA,173032.00,3748.99055,S,14457.98521,E,1,08,0.92,96.7,M,-1.8,M,,*66
$GPGSA,A,3,05,15,16,18,21,25,26,29,,,,,1.88,0.92,1.64*0F
$GPGSV,3,1,09,05,24,135,47,15,24,060,47,16,23,226,47,18,39,335,47*74
```

The content of this sentence is now decoded. First check the message ID of the sentence to determine if this message is of interest and which decoding applies. The easiest method is to write a dedicated parser routine for each message type. The sentence string is passed on to the corresponding routine to parse the message content into a data structure. For example, to get date and time, parse the information contained in the sentence with message ID "ZDA". The decoding description is given in the table above. The individual data fields of a message are separated by commas, which can be used in the parser as delimiter for string split/search operations.

Simplified pseudo code example:

```
// connect to receiver: COM port
COM_handle = open_serial_port();

// read NMEA data from COM port into a data buffer
NMEA_buffer = read(COM_handle, buffer_length);

// search in buffered NMEA data for GGA messages
p1 = str_compare(NMEA_buffer, "GGA", 0);    // search forward
from first character in NMEA buffer and get index position p1 of
first occurrence of GGA
```

```
If (p1 == -1)      // no GGA message found
{return error;}


p2 = p1;


Loop
{
// search in buffered NMEA data for GGA messages
p1 = p2;
p2 = str_compare(NMEA_buffer, "GGA", p1+1);    // search forward
from GGA message and get index position p2 of next GGA message


If (p2 == -1)     // NMEA data set not complete
{break;}


// form data block that contains a complete set of NMEA data
NMEA block = str copy(NMEA buffer, p1-3, p2-p1);    // copy p2-
p1 characters starting at p1-3
}    // end loop


// Evaluate latest NMEA data block
If (! NMEA_block)
{break;}


p2 = 0;


Loop
{
// search in NMEA data block for $ sign
p1 = p2;
p2 = str_compare(NMEA_block, "$", p1+1);


If (p2 == -1)     // end of NMEA data block reached, quit loop
{break;}


// extract one sentence
NMEA_sentence = str_copy(NMEA_block, p1, p2-p1);


// get message ID
ID = str_copy(NMEA_sentence, 3, 3);    // extract e.g. GGA from
$GPGGA


// get information
If (ID == "GGA")     // get time and position
{fix_data_struct = parse_GGA_data(NMEA_sentence);}


If (ID == "GSA")     // get satellites and DOPs
{overall_sat_data_struct = parse_GSA_data(NMEA_sentence);}


If (ID == "GSV")     // get satellite positions and C/N ratios
{sat_data_struct = parse_GSV_data(NMEA_sentence);}
```

```
If (ID == "ZDA")      // get date
{date_struct = parse_ZDA_data(NMEA_sentence);}
}      // end loop over sentences in NMEA block

// close COM port
close_serial_port();
```

```
// function: parse_ZDA_data

return_structure parse_ZDA_data (NMEA_sentence)
{
struct date;        // struct date
                    // {
                    //    int year;
                    //    int month;
                    //    int day;
                    //    int hour;
                    //    int min;
                    //    double sec;
                    // };

// get position of time-date delimiter
p1 = 0;       // index position
p1 = str_compare(NMEA_sentence, ",", 7);     // search forward
from 7th character in NMEA sentence (leaving out "$GPZDA, ")

// get time
date.hour = atoi(str_copy(NMEA_sentence, 7, 2));     // copy 2
characters starting at position 7 in the NMEA sentence string
date.min = atoi(str_copy(NMEA_sentence, 9, 2));
date.sec = atof(str_copy(NMEA_sentence, 11, p1-11));

// get date
date.day = atoi(str_copy(NMEA_sentence, p1+1, 2));
date.month = atoi(str_copy(NMEA_sentence, p1+4, 2));
date.year = atoi(str_copy(NMEA_sentence, p1+7, 4));

return date;
}
```

The returned data structure, e.g. containing the date and time information as variables, can then be used in the subsequent program code. For example, the date and time can be used together with the commands presented in section 6.2 to query time-point-specific information from the SMBV.

```
simulated_coordinates = send_cmd(SOUR:BB:GPS:RT:RLOC:COOR:DEC?
UTC, %f, %f, %f, %f, %f, %f; date.year, date.month, date.day,
date.hour, date.min, date.sec);
```

8 Summary

GNSS receivers can be tested easily, reliably and cost-efficiently by using the SMBV as satellite simulator. GPS, Glonass, Galileo, and BeiDou signals for up to 24 satellites can be generated in realtime with a single standalone instrument. This sets new standards in the field of satellite simulation for R&D and production.

In this application note, we explained how to perform automated receiver tests. Various fundamental tests including TTFF, sensitivity and location accuracy as well as moving receiver, interference and multipath tests are described. For each test, we provided a basic remote control example to show how to correctly configure the SMBV.

9 Abbreviations

|	
2D	Two-dimensional
3D	Three-dimensional
A-GPS	Assisted GPS
AWGN	Additive white Gaussian noise
BeiDou	BeiDou (Chinese satellite navigation system)
CW	Continuous wave
C/A code	Coarse acquisition code
C/N	Carrier to noise
DC	Direct current
DOP	Dilution of precision
GDOP	Geometric DOP
HDOP	Horizontal DOP
PDOP	Positional DOP
TDOP	Time DOP
VDOP	Vertical DOP
DUT	Device under test
ECEF	Earth centered, earth fixed
ENU	East north up
Galileo	Galileo (global navigation satellite system of the European Union)
Glonass	Globalnaja Nawigazionnaja Sputnikowaja Sistema (global navigation satellite system of the Russian Federation)
GNSS	Global navigation satellite system (stands for all satellite-based navigation systems)
GPIB	General purpose interface bus
GPS	Global positioning system (of the United States of America)
GPS CA	Global positioning system coarse acquisition code
GUI	Graphical user interface
HIL	Hardware in the loop
ID	Identifier
KML	Keyhole markup language
LAN	Local area network
LNA	Low noise amplifier
LOS	Line of sight
NED	North east down
NMEA	National Marine Electronics Association
P code	Precision code
R&D	Research and development
RF	Radio frequency
RAIM	Receiver autonomous integrity monitoring
RINEX	Receiver independent exchange format
USB	Universal serial bus
UTC	Universal time coordinated
SCPI	Standard commands for programmable instruments
SPOT	Satellites and position online tracker (in the SMBV)
SV-ID	Space vehicle ID
TTL	Transistor–transistor logic
VNC	Virtual network computing
XML	Extensible markup language

10 References

[1] Rohde & Schwarz, "Satellite Navigation Digital Standard for R&S®SMBV and R&S®WinIQSIM2™" Operating Manual

[2] Rohde & Schwarz Application Note, "Time Synchronous Signals with Multiple R&S®SMBV100A Vector Signal Generators" (1GP84)

[3] Rohde & Schwarz Application Note, "R&S ARB Toolbox Plus" (1GP88)

[4] Rohde & Schwarz Application Note, "R&S dB Calculator" (1GP77)

[5] Rohde & Schwarz Application Note, "Top Ten SCPI Programming Tips for Signal Generators" (1GP79)

[6] Rohde & Schwarz Application Note, "Connectivity of Rohde & Schwarz Signal Generators" (1GP72)

[7] Rohde & Schwarz Application Note, "Simulating Automatic Obscuration and Multipath for Realistic GNSS Receiver Testing" (1GP101)

[8] Rohde & Schwarz Application Note, "Hardware in the Loop (HIL) Tests with a GNSS Simulator" (1GP102)

Up-to-date almanac data can be downloaded for example at:
www.navcen.uscg.gov
www.celestrak.com/GPS/almanac/

11 Ordering Information

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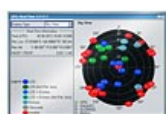
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