Recording and Playing Back the GPS RF Spectrum

Application Note

Products:

| R&S®TSMW or R&S®FSV |
| R&S®IQR |
| R&S®SMBV 100A |

A GPS L1-frequency signal is recorded using a receiver such as an R&S®TSMW or an R&S®FSV. Then the I/Q data is stored via the digital I/Q interface on an R&S®IQR device. Playback is realized using an R&S®SMBV signal generator that is also connected to an R&S®IQR via a digital I/Q interface.
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1 Introduction

1.1 Overview

Satellite navigation systems, such as Global Positioning System (GPS) modules, are increasingly being integrated into all kinds of devices, such as cell phones, cameras, tablet PCs and entertainment systems. In order to be able to test the integrated GPS modules or their terminal devices in a reproducible manner under realistic conditions, it is necessary to make an RF spectrum available with real GPS data. Besides the American GPS and the Russian GLONASS programs, additional global navigation satellite systems (GNSSs), such as Galileo (EU) and Compass (Peoples Republic of China) will be deployed in the future. This will generate further demand for the corresponding testing systems. Combining universal test and measurement devices from Rohde & Schwarz makes it possible to record and replay real HF spectrums with the corresponding satellite signals in realtime.

The device configuration for this depends on the required bandwidths, which can differ for specific GNSSs and applications. Achieving higher accuracy, for instance, requires making simultaneous recordings of additional correction signals (see [1]) from different frequency ranges, which can then increase the bandwidth requirements.

Fig. 1 shows the commercial spectrums for the different GNSSs.

Fig. 1: Commercial GNSS spectrums in the upper L-band.

This application note describes the recording and playback functions using a GPS L1 signal as an example. With a GPS L1 signal, there is a center frequency of 1575.42 MHz with a bandwidth of 2.046 MHz. Depending on the relevant accuracy requirements it may also be useful to consider sidebands, 2n x 2.046 MHz, [2].
Introduction

Overview

1.0 Rohde & Schwarz

GPS Recording and Playback

Fig. 2: Spectral power density for the receive signal and the noise signal, literature reference [1].

With a bandwidth of 20 MHz, the R&S®TSMW universal radio network analyzer, working in combination with an active GPS antenna, meets these requirements. For recording the GPS spectrum, this results in a combination of an R&S®TSMW with the R&S®IQR I/Q data recorder.

The spectrum recorded as I/Q data can be generated using the R&S®SMBV signal generator. Compared to other generators, the R&S®SMBV offers the advantage that, besides the natural spectrum, it also supports options for generating GNSS signals for GPS and GLONASS satellites [3]. This makes it possible to set up a universal test configuration for real and synthetic satellite signals.

As an alternative, the recorded spectra can also be exported in the form of a digital I/Q-signal that is then analyzed and/or modified using software, such as MatLab, and played back.

Instead of the R&S®TSMW, it is also possible to use a spectrum analyzer, such as the R&S®FSV. This is especially appropriate when bandwidths above 20 MHz and up to 40 MHz are required.
1.2 Requirements

**Firmware and Software versions:**
Please be sure to use latest versions of the equipment and software.

2 Recording

A GPS L1 signal is recorded using a receiver, such as an R&S®TSMW or an R&S®FSV, which transmits data via a digital I/Q interface to the R&S®IQR (recorder mode).

As described in chapter 1.1, the required bandwidth for recording a GPS L1 signal is 2.046 MHz. It is possible, however, for the GPS receiver to utilize an even higher bandwidth to improve signal quality. Therefore the bandwidth is set to 6.138 MHz (see Fig. 2).

2.1 Required Equipment

As the receiver, either an R&S®TSMW or an R&S®FSV can be used together with the R&S®IQR.

- **R&S®TSMW (VAR03) **
  - R&S®TSMW-B1 hardware option
  - R&S®TSMW-K1 software option
  - R&S®TSMW-Z20 set for GPS-RF recording

- **R&S®FSV**
  - R&S®FSV-B17 digital baseband interface
  - R&S®FSV-B24 RF preamplifier, 9 kHz to 13 GHz
  - Active antenna

- **R&S®IQR100**
  - R&S®IQR-B110 SSD memory pack

  Optionally:
  - R&S®IQR-K101 import/export of files to USB
  - R&S®IQR-K101 GPS data recording

*) The R&S®TSMW accessories include an active GPS antenna.
2.2 Setting Up the Equipment Connections

Fig. 4 shows a hardware configuration option with the R&S™ TSMW and the R&S™ IQR. The R&S™ TSMW can be controlled by a PC as well, which is not shown in this figure.

![Diagram of hardware configuration for recording GPS L1-signals using the R&S™ TSMW.]

Fig. 4: Hardware configuration for recording GPS L1-signals using the R&S™ TSMW.

Fig. 5 shows a hardware configuration that uses an R&S™ FSV. This scenario assumes the use of an active GPS antenna that includes its own power supply. Furthermore, this configuration delivers no direct current (DC) at the R&S™ FSV’s RF1 input.

![Diagram of hardware configuration for recording GPS L1 signals using the R&S™ FSV.]

Fig. 5: Hardware configuration for recording GPS L1 signals using the R&S™ FSV.
2.3 Setting Up the R&S® TSMW

1. The R&S® TSMW K1 has to be installed on an R&S® IQR or on a separate laptop or desktop PC [4] describes how to install the R&S® TSMW-K1. A description of how to install the R&S® TSMW-K1 software on the R&S® IQR is available in chapter 4.1.

2. Make sure that R&S® TSMW's reference frequency is in good condition. To ensure this, connect the accessory GPS antenna to the R&S® TSMW's GPS ANT connector, and keep the R&S® TSMW switched on long enough (at least two minutes) to sync with the GPS PPS signal. Now the GPS PPS LED will blink. This setup only has to be done once (the reference frequency aging per year is \(1 \times 10^{-6}\)).

3. Connect the signal from a pre-amplified GPS antenna to the RF1 input. This can be done by using the accessory GPS antenna in conjunction with a splitter. The R&S® TSMW's GPS receiver supports DC power for the active antenna and keeps the R&S® TSMW synchronized with the GPS PPS signal. Because the R&S® TSMW's RF input does not allow DC power, a DC blocker has to be used in front of it. The R&S® TSMW-Z20 option can be used together with a GPS antenna to set up the connection.  
   **Note:** The R&S® TSMW's RF input cannot supply power to an active antenna.

4. Start the R&S® TSMW-K1's graphic user interface (GUI) – for example on the R&S® IQR (see chapter 4.1):
   - The R&S® TSMW-K1 software has to be installed on the R&S® IQR or on a PC.
   - R&S® TSMW-K1 has to be activated on the R&S® IQR (box source instrument)
     
     ```
     C:/Program Files/RuS_TSMW_K1/demo/K1_crtl.exe
     ```
     (For details on installing R&S® TSMW-K1, please see chapter 4.)
   - Open the R&S® TSMW-K1 software.
   - Press INT. Interface to activate the LAN Interface.
     (The R&S® TSMW has to be connected to the R&S® IQR or PC via a LAN cable.)
   - If the R&S® TSMW's default IP address of was changed, use this IP address in the "TSMW IP" Address field [3,4].
   - Press connect.
5. Use the R&S®TSMW-K1 GUI with the following options:
   a. Design and send the filter to the R&S®TSMW with following settings:
      Filter type = Least-square LP
      Sampling Rate = 6.7518 MSa/s
      (Sample rate = Bandwidth x 1.1; for example: 3 x 2.046 MHz x 1.1 = 6.7518 MSa/s; this will sufficiently suppress aliasing products [6])
      F pass = 3.07
      F stop = 3.8
      For other parameters, the default values are used:
      Select Design Filter.
      Select Save & Close.
      Select Send to TSMW.
      Select Filter ID “1”.
   b. Settings for RF 1:
      Frequency = 1575.42 MHz (center frequency for the GPS L1 spectrum)
      Preamp = On
      Digital I/Q Out = On
   c. Start the Streaming dialog box.
      Note: The Streaming dialog box has to be closed before you can regain access to other K1 dialog boxes.
   d. Start streaming.
   e. The R&S®TSMW-K1’s GUI should be similar to the screenshot shown in Fig. 6 and Fig. 7.

Note: The exact sample rate used by the R&S®TSMW can be seen in the filter response plot (see Fig. 7 and Fig. 8).
Fig. 8: The R&S®TSMW-K1 button for opening the filter response plot.

Fig. 9: The R&S®TSMW-K1 filter response plot.
2.4 Setting Up the R&S®FSV

1. Make the settings shown in Fig. 10:
   a. Press PRESET
   b. Press MODE
   c. Press IQ Analyzer
2. Make the settings shown in Fig. 11:
   a. Select FREQ
      Set Center Frequency to 1.57542 GHz
   b. Select AMPT
      Set Ref Level to -50 dB
      Set Preamp On
      Set RF Atten Manual to 0 dB
   c. Select MEAS
      Set Data Acquisition, Sample Rate to 8 MHz
      Set Digital Output, Enable Digital Output Stream On

Fig. 12 shows the R&S®FSV after the setup has been completed.

![Fig. 10: R&S®FSV setup 1.](image)
Fig. 11: R&S®FSV setup 2.

Fig. 12: The R&S®FSV after setup is finished.
2.5 Setting Up the R&S®IQR

The R&S®IQR is set up to record the data coming from the R&S®TSMW (it takes at least several minutes to make synchronization with the GPS possible at all). The R&S®IQR’s reference frequency source setting does not influence the recording.

1. Set the recorder parameters (switch to Recorder if not already in that mode):
   a. Choose the filename to be used for recorded data and select the Terminate Condition as desired
   b. Set the trigger conditions (input box):
      – Run Mode: Single
      – Source: e.g. Manual
   c. Activate Armed (check the sample rate and I/Q level).

2. Recording
   – Start recording (2)

   (Check the sample counter and progress bar.)

3. After some time, you can stop the recording process, or it will stop once the pre-defined recording time has elapsed (3).
3 Playback

To transmit the recorded signal, the R&S®IQR is used together with the R&S®SMBV signal generator. The signal is evaluated with a GPS receiver.

3.1 Required Equipment

- **R&S®IQR100:**
  - R&S®IQR-B110 SSD memory pack

  Optionally:
  - R&S®IQR-K101 import/export of files to USB
  - R&S®IQR-K101 GPS data recording

- **R&S®SMBV100A**
  - R&S®SMBV-B10
  - R&S®SMBV-B92
  - R&S®SMBV-K18
  - R&S®SMU-Z6 (additional I/Q cable)

3.2 Setting Up the Equipment Connections

*Fig. 13: Hardware configuration for playback with the R&S®SMBV.*
3.3 Setting Up the Signal Generator

1. Set the frequency to: 1.57542 GHz
2. Set the level:
   - If the R&S®TSMW was used: –70 dBm
   - If the R&S®FSV was used: –50 dBm
3. Switch on:
   a. BB Input
   b. I/Q Mod
   c. RF/A Mod
4. Configure the BB In/Out:
   a. Left click on configure (see Fig. 15).
   b. Select Baseband Input Settings.
   c. Take over the configuration:
      - If the R&S®TSMW was used, see Fig. 16.
      - If the R&S®FSV was used, see Fig. 17.
   d. For the Sample Rate, set Source to Digital I/Q in.
Fig. 15: R&S® SMBV, BB In/Out configuration 1.

Fig. 16: R&S® SMBV, BB In/Out configuration with the R&S® TSMW.

Fig. 17: R&S® SMBV, BB In/Out configuration with the R&S® FSV.
3.4 Setting Up the R&S®IQR

1. Make sure that Expert Mode is used:
   a. Select Main Menu.
   b. Select Setup, Expert Mode…
   c. Make sure that Expert Mode is enabled.
2. Switch to Player view.
3. Select the recorded file for playback (see Fig. 18, screenshot 1).
4. Select use of an external reference (see Fig. 18 and Fig. 19).
5. Set the sampling rate:
   a. For the R&S®TSMW, set this value exactly as used by the R&S®TSMW (see Fig. 8, Fig. 9 and Fig. 19).
   b. For the R&S®FSV, set this value to 8 MS/s to get a bandwidth of 6 MHz.
6. Once the signal generator setup is done, select Armed.
7. Press Play.

3.5 Setting Up the R&S®IQR GPS Receiver

Cold starting the GPS receiver can be useful for speeding up position estimation with recorded data.
4 Additional Information

This application note and the associated software are updated from time to time. For the latest information, please visit the R&S®TSMW web page at: www.drivetest.rohde-schwarz.com

4.1 Installing the R&S®TSMW K1 Software on an R&S®IQR

1. Install the R&S®TSMW-K1 on an R&S®IQR:
   a. Save latest version of the R&S®TSMW K1 software on a USB Stick and connect the stick to the R&S®IQR.
   b. Connect a keyboard and mouse to the R&S®IQR.
   c. Press the Windows key + the "E" keys (or Ctrl + Esc).
   d. Navigate to the R&S®TSMW K1 software on the USB stick.
   e. Start the installation and follow the on-screen instructions.
   f. Information about the program folder to be used is required later.
   g. After installation is finished, reboot the R&S®IQR.
   h. For a detailed description of how to install the R&S®TSMW-K1 software, see reference [4].

2. Configure the R&S®IQR's network settings:
   a. From the Windows desktop, go to: Start->Settings->Network Connections.
   b. Open the Local Area Connection.
   c. Open the Internet Protocol (TCP/IP) Properties.
   d. Manually define an IP address to enable communication with the R&S®TSMW, which by default has the IP address: 192.168.0.2
      For example, set the R&S®IQR's IP address to: 192.168.0.3
   e. Save these settings, and switch back to the R&S®IQR application.
   f. For a detailed description of how to configure network settings on the R&S®IQR, see reference [5].

3. Configure the R&S®IQR
   a. Switch to Recorder mode.
   b. In Source Instrum., select "config…"
   c. Select Browse… at the top of the screen.
   d. Select the file: <folder_TSMW_K1>/demo/k1_ctrl.exe
   e. Select Open.

Now the R&S®TSMW-K1 software can be started by pressing the software key at the bottom of the R&S®IQR's screen.
Fig. 20: Software key for starting the R&S®TSMW-K1 software.
4.2 Literature References

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<th>Description</th>
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<td><a href="http://www.wikipedia.de">www.wikipedia.de</a>, GPS</td>
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<tr>
<td>2</td>
<td>u-blox AG: &quot;GPS und GNSS: Grundlagen der Ortung und Navigation mit Satelliten&quot;</td>
</tr>
<tr>
<td>3</td>
<td>R&amp;S®TSMW Operating Manual</td>
</tr>
<tr>
<td>4</td>
<td>R&amp;S®TSMW-K1 Software Manual</td>
</tr>
<tr>
<td>5</td>
<td>R&amp;S®IQR User Manual</td>
</tr>
<tr>
<td>6</td>
<td>R&amp;S®TSMW Digital I/Q Interface Option K1 (Application Note 1SP55)</td>
</tr>
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<td>7</td>
<td>Application Note: GPS with the R&amp;S®SMBV is in preparation</td>
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## Ordering Information

### 5.1 Basic Configuration for One-Channel Recording at a Power of 220 V

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<tr>
<th>Description</th>
<th>Model</th>
<th>Specification</th>
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</thead>
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<tr>
<td><strong>R&amp;S®TSMW</strong></td>
<td>Universal Radio Network Analyzer (V03)</td>
<td>1503.3001K03</td>
</tr>
<tr>
<td><strong>R&amp;S®TSMW-B1</strong></td>
<td>R&amp;S®Digital I/Q Interface (hardware option)</td>
<td>1514.4004.02</td>
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<tr>
<td><strong>R&amp;S®TSMW-K1</strong></td>
<td>Digital I/Q Interface</td>
<td>1503.3960.02</td>
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<tr>
<td><strong>R&amp;S®TSMW-Z20</strong></td>
<td>Set for GPS Recording</td>
<td>1506.9775.02</td>
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<tr>
<td><strong>Optionally:</strong></td>
<td>R&amp;S®TSMW External Power Supply</td>
<td>1503.4608.02</td>
</tr>
<tr>
<td><strong>R&amp;S®IQR</strong></td>
<td>IQ Recorder with touch screen (20 MSa/s)</td>
<td>1513.4600K02</td>
</tr>
<tr>
<td>or</td>
<td>1x IQ channel, max. 20 Msa/s, 80 Mbyte/s; Removable power supply, 100 V to 240 V AC;</td>
<td>1513.4600K02</td>
</tr>
<tr>
<td><strong>R&amp;S®IQR100</strong></td>
<td>With 1x IQ cable and 4x BNC cables IQ recorder with touch screen (66 Msa/s)</td>
<td>1513.4600K02</td>
</tr>
<tr>
<td><strong>R&amp;S®IQR-B110</strong></td>
<td>IQR Memory Pack, 1 Tbyte (SSD) High speed and rugged solid state memory – High data rates; max. 300 Mbyte/s, – Mobile use (e.g. for drive tests)</td>
<td>1513.4717.10</td>
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<tr>
<td><strong>Optionally:</strong></td>
<td>Import/Export of wv-Files and Meta data via USB</td>
<td>1513.5001.02</td>
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<tr>
<td><strong>R&amp;S®IQR-K102</strong></td>
<td>GPS data recording on the R&amp;S®IQR in a meta data file. Data sources: R&amp;S®TSMW via LAN (this requires the R&amp;S®TSMW-K1 software), or A GPS USB receiver</td>
<td>1513.5018.02</td>
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<td><strong>R&amp;S®SMBV</strong></td>
<td>Vector Signal Generator</td>
<td>1407.6004K02</td>
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<td><strong>R&amp;S®SMBV-B103</strong></td>
<td>9 KHz to 3.2 GHz</td>
<td>1407.9603.02</td>
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<tr>
<td><strong>R&amp;S®SMBV-B10</strong></td>
<td>Baseband Generator, incl. digital mod.+ARB</td>
<td>1407.8607.02</td>
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<td><strong>R&amp;S®SMBV-B92</strong></td>
<td>Hard Disk</td>
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<td><strong>R&amp;S®SMBV-K18</strong></td>
<td>Digital Baseband Connectivity</td>
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<td><strong>R&amp;S®SMU-Z6</strong></td>
<td>Cable for Connecting the R&amp;S® Digital I/Q Interface</td>
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Further R&S®IQR and R&S®TSMW Accessories for Drive Tests

### 5.2 Further R&S®IQR and R&S®TSMW Accessories for Drive Tests

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<th>R&amp;S®FSV</th>
<th>Alternative to the R&amp;S®TSMW</th>
<th>Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;S®FSV</td>
<td>Signal Analyzer, 10 Hz to 3.6 GHz</td>
<td>1307.9002K03</td>
</tr>
<tr>
<td>R&amp;S®FSV-B17</td>
<td>Digital Baseband Interface</td>
<td>1310.9568.02</td>
</tr>
<tr>
<td>R&amp;S®FSV-B22</td>
<td>RF Preamplifier 9 kHz to 7 GHz</td>
<td>1310.9616.02</td>
</tr>
<tr>
<td>Optionally</td>
<td>uBlox GPS Module for Drive Test Applications without an R&amp;S®TSMW (e.g. with an R&amp;S®FSVx)</td>
<td></td>
</tr>
<tr>
<td>R&amp;S®TSMX-PPS</td>
<td>– Incl. external active uBlox antenna</td>
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</tr>
<tr>
<td></td>
<td>– With PPS output, USB connector</td>
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<tr>
<td></td>
<td>This requires the R&amp;S®IQR-K102 software option</td>
<td>1503.4850.02</td>
</tr>
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</table>

GPS antenna

**DC Power Supply for an R&S®IQR**
- Input: 10 V to 30 V DC, 200 VA

**R&S®TSMW External Power Supply**
- Input: 90 to 260 V AC, 47 Hz to 63 Hz, 120 W

**R&S®PSDC-B200**
- 12V DC
- Input: 100-240V AC 50-400 Hz

**R&S®TSMW-Z1**
- 12V DC
- 100-240V AC 50-400 Hz
- 1x IQ
- 1x IQ
- 2x LAN

**PSDC-B200**
- 12V DC
- 100-240V AC 50-400 Hz
- 1x IQ
- 2x LAN
5.3 Further R&S® SMBV Accessories for Generating Synthetic GPS Signals

See the application note cited in literature reference [7].
About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established more than 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

Environmental commitment
- Energy-efficient products
- Continuous improvement in environmental sustainability
- ISO 14001-certified environmental management system

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