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].

Overview



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/Qsignal that is then analyzed and/or modified using software, such as MatLab, and played back.



Fig. 3: Device setup for recording and replaying GPS spectrums.

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.

Recording

Requirements

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 $^{\circ}$ TSMW or an R&S $^{\circ}$ FSV can be used together with the R&S $^{\circ}$ 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.



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.



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 x 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 $^{\circ}$ 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.







- 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).

4		- GPS Configuration	
Init. Interface TSM/VIF	P - Address	(Open GPS Config. Dialog
Release Interface 192.	168.0.2 Connect	Record stream	
GPS Configuration	Streaming Measure	Stream buffer size [MB]:	200
Open GPS Config. Dialog	Open Streaming Dialog	Maximal stream size [MB]:	4000
Measure Settings	Filter Design	Stream file name:	StreamFile
amples Data Format	Design	Description:	
Filter ID Sample Rate	Load from File	 Overwrite existing file 	Start streaming
✓ 6.7518 [MS	S/s]		Stop streaming
Splitter On 📃 Auto Atte	enuationSend to TSM/V	Number of received blocks	N.A.
Use Frontend 1	Use Frontend 2	Number of skipped blocks:	N.A.
Frontend 1 Settings	Frontend 2 Settings	Digital I/Q Interface Stat	us
requency 1575.42 [MHz]	Frequency 1000 [MHz]	Connected	
10000009 1010.42 [mitz]			
ttenuation 0 dB	Attenuation 0 dB	to IQR100 (single channel)	
ttenuation 0 dB	Attenuation 0 dB	to IQR100 (single channel)	
ttenuation 0 dB ♥ Preamp On Calibration hannels 1	Attenuation 0 dB	to IQR100 (single channel)	K1 streaming dial
ttenuation 0 dB v Preamp On Calibration hannels 1 v Channel Frequency Shift	Attenuation 0 dB v Preamp On Calibration Channels 1 v Channel Frequency Shift	Fig. 7: The R&S [®] TSMW-	K1 streaming dial
ttenuation 0 dB Preamp On Calibration hannels 1 Channel Frequency Shift channel 1 0 [MHz]	Attenuation 0 dB v Preamp On Calibration Channels 1 v Channel Frequency Shift Channel 1 0 [MHz]	Fig. 7: The R&S [®] TSMW-	K1 streaming dial
tteruation 0 dB Preamp On Calibration hannels 1 Channel Frequency Shift Channel 1 0 [MHz] Channel 2 0 [MHz]	Attenuation 0 dB v Preamp On Calibration Channels v Channel Frequency Shift Channel 1 0 [MHz] Channel 2 0 [MHz]	Fig. 7: The R&S [®] TSMW-	K1 streaming dial
ttenuation 0 dB v Preamp On Calibration hannels 1 v Channel Frequency Shift Channel 2 0 [MHz] Jannel 3 0 [MHz]	Attenuation 0 dB v Preamp On Calibration Channel 5 v Channel Frequency Shift Channel 1 0 [MHz] Channel 2 0 [MHz] Channel 3 0 [MHz]	fig. 7: The R&S [®] TSMW-	K1 streaming dial
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ttenuation 0 dB	Attenuation 0 dB v Preamp On Calibration Channel Frequency Shift Channel Frequency Shift Channel 1 0 [MHz] Channel 2 0 [MHz] Channel 3 0 [MHz] Channel 4 0 [MHz] Diattel KO Out	fig. 7: The R&S [®] TSMW-	K1 streaming dial



Setting Up the R&S®FSV

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.

Recording

Setting Up the R&S®FSV



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.



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

Fig. 14: Configuring the R&S[®]SMBV.

1.	Set the frequency to:	1.575 42 GHz
2.	Set the level:	
	If the R&S [®] TSMW was us	ed: -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.

Playback

Setting Up the Signal Generator



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: <u>www.drivetest.rohde-schwarz.com</u>

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 Crtl + 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.
 - 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.

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

Stream to: GPS_BW6_130MHz_SR6_7510HHz Duffer Status:	Recorder	IQ Level
Etatus: Ctatus:	kSa 0	0.001 FS •
kSa: 0 0 %		10 485
		Info
Source Instrum. config TSMW TSMW Config Config Config Config Config Config	Formatting config	Storage config Selected
	\frown	09:50:10
Stop	k1_ctrl	Player Main Menu

Fig. 20: Software key for starting the R&S[®]TSMW-K1 software.

Literature References

4.2 Literature References

Literature reference table		
Index	Description	
1	www:wikipedia.de, GPS	
2	u-blox AG: "GPS und GNSS: Grundlagen der Ortung und Navigation mit Satelliten"	
3	R&S®TSMW Operating Manual	
4	R&S®TSMW-K1 Software Manual	
5	R&S®IQR User Manual	
6	R&S®TSMW Digital I/Q Interface Option K1 (Application Note 1SP55)	
7	Application Note: GPS with the R&S [®] SMBV is in preparation	

5 Ordering Information

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

R&S [®] TSMW		
R&S®TSMW	Universal Radio Network Analyzer (V03)	1503.3001K03
R&S®TSMW-B1	R&S®Digital I/Q Interface (hardware option)	1514.4004.02
R&S®TSMW-K1	Digital I/Q Interface	1503.3960.02
R&S®TSMW-Z20	Set for GPS Recording	1506.9775.02
Optionally:		
R&S®TSMW-Z1	R&S [®] TSMW External Power Supply Input: 90 to 260 V AC, 47 Hz to 63 Hz, 120 W	1503.4608.02
R&S [®] IQR		
R&S [®] IQR20	IQ Recorder with touch screen (20 MSa/s) • Recording and streaming of IQ data;	1513.4600K02
or	 1x IQ channel, max. 20 Msa/s, 80 Mbyte/s; Removable power supply, 100 V to 240 V 	or
R&S [®] IQR100	With 1x IQ cable and 4x BNC cables	1513.4600K02
	IQ recorder with touch screen (66 Msa/s)	
R&S [®] IQR-B110	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)	1513.4717.10
Optionally:		
R&S [®] IQR-K101	Import/Export of wv-Files and Meta data via USB	1513.5001.02
R&S [®] IQR-K102	 GPS data recording on the R&S[®]IQR in a meta data file. Data sources: R&S[®]TSMW via LAN (this requires the R&S[®]TSMW-K1 software), or A GPS USB receiver 	1513.5018.02
R&S [®] SMBV		
R&S [®] SMBV100A	Vector Signal Generator	1407.6004K02
R&S [®] SMBV-B103	9 KHz to 3.2 GHz	1407.9603.02
R&S [®] SMBV-B10	Baseband Generator, incl. digital mod.+ARB	1407.8607.02
R&S [®] SMBV-B92	Hard Disk	1407.9403.02
R&S [®] SMBV-K18	Digital Baseband Connectivity	1415.8002.02
R&S [®] SMU-Z6	Cable for Connecting the R&S [®] Digital I/Q Interface	1415.0201.02

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

R&S [®] FSV	Alternative to the R&S [®] TSMW	
R&S [®] FSV	Signal Analyzer, 10 Hz to 3.6 GHz	1307.9002K03
R&S [®] FSV-B17	Digital Baseband Interface	1310.9568.02
R&S [®] FSV-B22	RF Preamplifier 9 kHz to 7 GHz	1310.9616.02
Optionally		
R&S [®] TSMX-PPS	uBlox GPS Module for Drive Test	1503.4850.02
	Applications without an R&S [®] TSMW (e.g. with	
	an R&S [®] FSVx)	
	 Incl. external active uBlox antenna 	
	 With PPS output, USB connector 	
	This requires the R&S [®] IQR-K102 software	
	option	
GPS antenna		

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

R&S [®] PSDC-B200	DC Power Supply for an R&S [®] IQR – Input: 10 V to 30 V DC, 200 VA	1513.4617.02
R&S®TSMW-Z1	R&S [®] TSMW External Power Supply Input: 90 to 260 V AC, 47 Hz to 63 Hz, 120 W	1503.4608.02



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.

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



Regional contact

Europe, Africa, Middle East +49 89 4129 137 74 customersupport@rohde-schwarz.com

North America 1-888-TEST-RSA (1-888-837-8772) customer.support@rsa.rohde-schwarz.com

Latin America +1-410-910-7988 customersupport.la@rohde-schwarz.com

Asia/Pacific +65 65 13 04 88 customersupport.asia@rohde-schwarz.com

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Rohde & Schwarz GmbH & Co. KG Mühldorfstraße 15 | D - 81671 München Phone + 49 89 4129 - 0 | Fax + 49 89 4129 – 13777

www.rohde-schwarz.com