SX3 -

The GNSS R&D SW Receiver with API

SX3

GNSS R&D SW Receiver

GNSS Multi-System and Multi-Frequency Signal and PVT Processing on Single-RF to Multi-RF Front-Ends

Sophisticated Functionality and Real-time Performance with Maximum Flexibility and SW-API Extendability

SX3 GNSS Software Receiver

Features

Supported GNSS Signals

GPS L1 C/A & L1C
GPS L2P & L2C
GPS L5

Galileo E1 B & C
Galileo E5a
Galileo E5b
Galileo E5ab AltBOC
Galileo E6 B & C

GLONASS G1
GLONASS G2

BeiDou B1
BeiDou B2
BeiDou B3

QZSS L1CA & L1C
QZSS L2C
QZSS L5
QZSS L62 (available with v3.5)

NavIC(IRNSS) L5
NavIC(IRNSS) S-band

SBAS L1

Flexible SW Licencing

Licensing of signals as needed

Licensing of specific capabilites

Licensing of different APIs

▶ SX3 Overview

The SX3 GNSS software receiver is a flexible tool to support researchers and engineers in designing and testing of new receiver concepts and algorithms in the field of GNSS. The design is driven to provide the user with maximum flexibility in signal processing and in PVT experimentation. Therefore the SX3 is also a perfect tool for scientists and education at advanced university level.

For the GNSS beginner and non-expert, the user is fully supported through the GUI to setup proper configuration. Also a wide range of example configurations for different applications will be provided to simply start with SX3 experimentation.

For the expert user, advanced features can either be changed manually or by editing the xml based scenario configuration file. For topics beyond the current state-of-the-art, just add your own signal processing or PVT algorithms using the available API (Application Programmers Interface) ensuring maximum flexibility as needed.

▶ SX3 System Setup

The SX3 GNSS Software Receiver consists of two major components. The first one is the SX3 software part of the receiver which runs on a standard MS Windows 10 computer. The second part is the SX3 RF front-end, which digitizes the received analogue RF signals and transfers the digital IF samples to the Windows computer, either for real-time processing or for storage in a IF-sample file. This enables later post-processing of stored IF-samples, thus providing high flexibility in working with the same data, but with different processing configurations.

The figure below shows the system setup with the two elements.

SX3 GNSS Software Receiver

SX3 RF front-end

▶ SX3 Signal Licenses

The SX3 GNSS Software Receiver supports all major GNSS (GPS, GLONASS, Galileo, BeiDou, IRNSS, QZSS and SBAS). With a flexible software licensing scheme, the GNSS signal capabilities but also specific capabilities (e.g. reflectometry) and the APIs, can be unlocked according to the individual needs. A HW dongle connected to the computer enables to license any additional signal and capability, just by eceiving a file update for the HW dongle. This enables the customer a cost-efficient selection of the signals and capabilities, flexible to grow with the customer's needs.

SX3

GNSS SW Receiver

▶ SX3 Front-End RF Chains and Bandwidths

The SX3 RF front-end is a fully programmable front-end hardware, able to cover all current GNSS signals on the L-band and additionally the NavIC(IRNSS) signal on the S-Band, subdivided into five RF-bands:

Band 1 — GPS L1/Galileo E1/GLONASS G1/BeiDou B1/QZSS L1

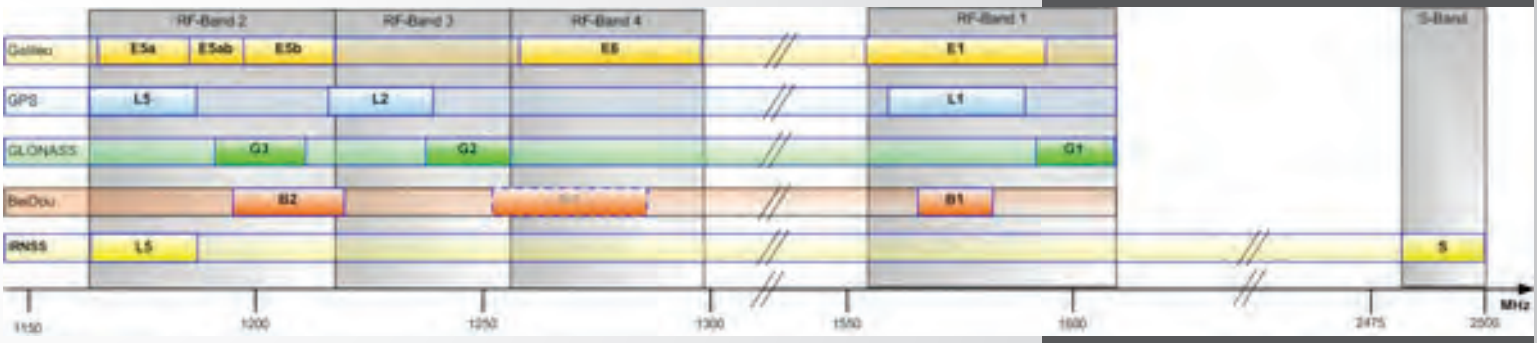
Band 2 — GPS L2/GLONASS G2/QZSS L2

Band 3 — GPS L5/Galileo E5ab/BeiDou B2/NavIC(IRNSS) L5/QZSS L5

Band 4 — Galileo E6/BeiDou B3/QZSS L62

Band 5 — NavIC(IRNSS) S-Band

Every RF-Front-end is equipped with 4 RF-chains. By combining and synchonizing two SX3 front-ends, up to eight 8 RF-chains can be realized. Every RF chain has its own ADC, enabling IF sample bit depths of 2, 4 or even 8 bit. The standard RF filters enable a RF bandwidth of 50 MHz. But on customer request also other RF filter bandwidths (e.g. 70 MHz) are possible.



SX3 RF front-end bands (chains) assigned to GNSS signals

▶ SX3 RF Front-End Series

Currently three types of RF front-ends are available, to meet different user applications. The RF front-ends differ in the number of RF inputs.

▶ SX3 Silver Edition - Single RF Input

The Silver Edition with one RF-IN antenna port is the standard. Its 4 RF chains are usually assembled with filters to support Band 1 to 4 (all L-band signals).

▶ SX3 Black Edition - Dual RF Input

The Black Edition with two antenna ports is used for antenna diversity, heading and reflectometry types of applications. Two RF bands are available per antenna input, with the customer to select the proper bands.

▶ SX3 Red Edition - Quad RF Input

The Red Edition is a completely new version supporting four RF inputs for CRPA types of applications ike interference and spoofing detection and mitigation. The customer selects the band when ordering.

Features

Front-End Characteristics

4 RF-chains with 50 MHz RFBW each

Other RF-bandwidths are possible

ADC sample rate up to 200 MHz

Analog AGC (automatic gain control)

Digital gain control

IF-sample bits: 2, 4 or 8 bits quantization

Real-IF sample rates: 20, 100 and 200 MHz

Front-End (FE) Types

1 antenna RF-IN - Silver Edition

2 antenna RF-IN - Black Edition

4 antenna RF-IN - Red Edition

Typical FE Configurations

Silver Edition with band 1 to 4 (all L-band signals) (standard config.)

Silver Edition with S-band and band 1 - 3 (S-band configuration)

Black Edition with band 1 and 3 (for DFDC GPS/Galileo applications)

Black Edition with band 3 and S-band (dual-ant. NavIC config.)

Red Edition with band 1 (quad ant. CRPA configuration) assembled

Red Edition with band 3 (quad ant. CRPA configuration) assembled

IFEN GmbH

SX3 Software Capabilities

SW Processing

Signal Processing

GNSS signal real-time processing
Post-processing of IF-samples

Closed-loop tracking
Open-loop tracking

Coherent tracking
Non-coherent tracking

Single band tracking
Sideband tracking

High sensitivity capability
Sensor fusion

PVT Processing

Single Point Positioning
Differential Positioning
LSQ based positioning
Extended Kalman Filter positioning

RTK (using integrated RTKlib)
PPP (using integrated RTKlib)

Support of real-time RTCM streams

Heading Determination

With a Dual-RF SX3 RF-FE, determination of heading is supported

Sensor Fusion

Support of Xsens IMUs
Support of magnetometer
Support of barometer data

Integrated via EKF

▶ Real-Time and Post-Processing

The SX3 GNSS software receiver is able to processes the digitized IF-samples from the SX3 RF front-end in real-time or storing the IF-samples on file (GNSS sample recorder). While signal tracking and PVT processing is assigned to the CPU, the signal acquisition is assigned to GPU resources. Therefore, every delivered SX3 computer is always equipped with a specific GPU. Off-loading the signal acquisition to a GPU ensures that tracking and PVT can be processed continuously in real-time with the available CPU resources.

As a GNSS software receiver, the SX3 is optimized to process new complex signal processing or PNT algorithms as an experimental R&D tool. Usually these new algorithms are not real-time optimized. Therefore the SX3 is also able to work in post-processing on stored IF-samples (by reading the stored IF-samples from file).

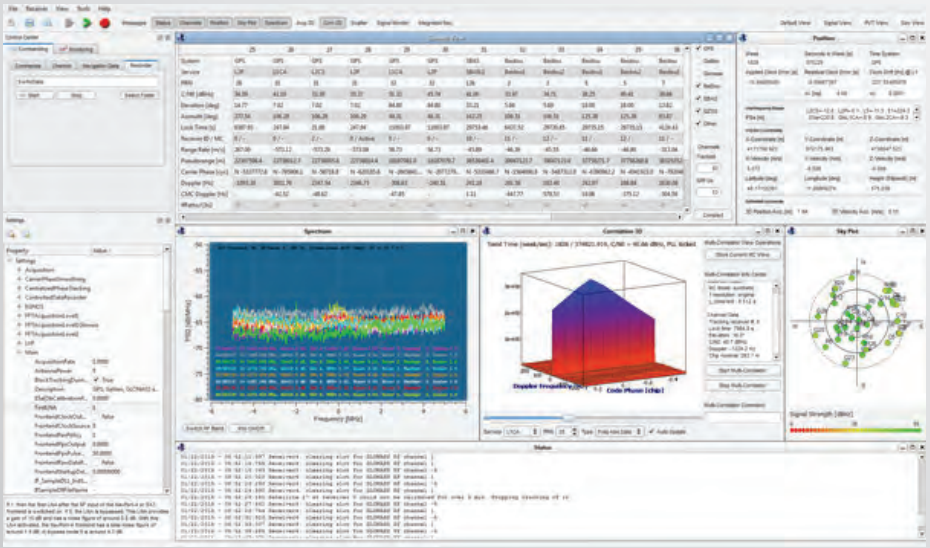
▶ Closed-Loop and Open-Loop Tracking Filter

The standard tracking loop filters of the SX3 are used to close the tracking loops. The user is able to specify the filter order from 1 to 3 and to specify the loop filter bandwidth. The loop filters themselves are able to work with a timely variable update rate.

Open loop tracking can be configured by specifying a loop order of 0.

▶ GNSS Single-Band and Sideband Tracking

Beyond the usual single-band tracking (even available for the wideband Galileo AltBOC signal), also the tracking of side-bands (with coherent combination of the side-bands) is supported (currently used for Galileo E5a and E5b). This enables R&D driven experimentation towards 'metasignals' (usually combination of the major signal lobes, even if they are coming from different signals, e.g. GPS L2 with L5 or Galileo E6 with E5a or E5b). Together with a high flexibility in discrimator settings, this enables to perform a large range of signal experimentation with the SX3.



SX3 user interface with parameter configuration on left side, 'Spectrum' window and '3D -Correlator' window

SX3 R&D Applications

▶ Support for Robust and High-Sensitivity Applications (Sensor Fusion)

The SX3 has already shown tracking capability down to 1.5 dBHz C/N0 in timing applications, taking full advantage of all possible algorithmic optimizations being state-of-the-art. With vector tracking capability and sensor fusion (featuring loose, close and ultra-tight coupling) supporting different sensor types and innovative methods (like µ-trajectory for synthetic aperture processing), also robust navigation in harsh environments can be fully exploited.

▶ Support for Precise Positioning Applications (RTK, PPP)

Beyond SPP point positioning, the SX3 also supports RTK and PPP positioning via the integrated RTKlib library. The SX3 is able to receive real-time streams of RTCM corrections for RTK and PPP. The high precision output of RTK and PPP can also be fed into the EKF, supporting robust and high-sensitivity applications.

▶ Support for Sientific Applications (Reflectometry, Scintillation)

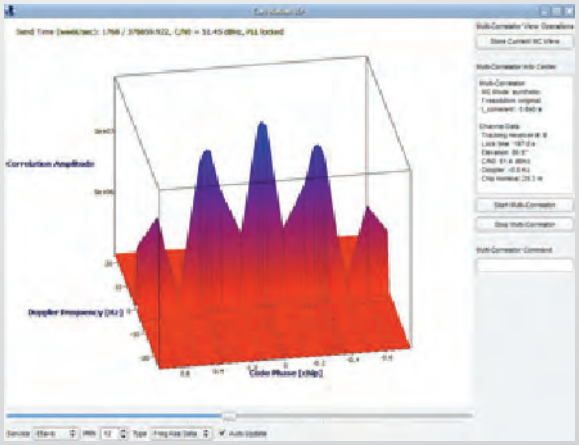
Scintillation monitoring is supported by the SX3 GNSS Software Receiver in the form of a scintillation data collection mechanism to measure and compute the Total Electron Content (TEC) and S4 index parameters.

The SX3 Black Edition is a dual-RF front-end SX3 enabling reflectometry applications providing synchronized GNSS IF-samples from two separate antennas. Based on these sample streams the user is able to implement its own reflectometry algorithms either in post-processing or with our API extension even in real-time. The reflectometry extension provides source code and a technical description of a complete reflectometry example implementation.

▶ Support for Signal Monitoring (Spectrum Analyzer, SQM)

The SX3 implements a feature called multi-correlator. By using post-correlation FFT techniques, the two-dimensional correlation function (D Delay-Doppler map) can be generated in a very efficient way. An example of the multi-correlator output is shown below. This is a screenshot from the SX3 GUI.

But also specific spectrum analyzer and SQM algorithms (able to identify interference or spoofing attacks) are available. The spectrum analyzer shows the estimated power spectral density (PSD) of the incoming signal after the ADC.



'3D Correlation' window

SX3
GNSS SW Receiver

Applications

Robustness & Sensitivity

Vector tracking selectable
Sensor fusion using EKF
Long coherent integration times

RTK & PPP High-Precision

RTKlib integrated

Support for Real-time RTCM corrections
Support for post-processing RTCM corrections

Ionospheric Scintillation

Generation of TEC parameters
Generation of S4 index parameters

Reflectometry (optional)

Synchronized IF-samples from 2 antennas (SX3 Black Edition)

Optional algorithms description and Matlab source code (for GPS L1/L2 and L1/L5 combinations)

IF Spectrum Analyzer

Immediate PSD of signal

Computed using the Welsh method with Hanning window

Signal Quality Monitoring

User definable SQM metrics:

- Single sided ratio metrics
- Average ratio metrics (symmetric and asymmetric)
- Delta metrics (symmetric and asymmetric)

SQM applications:

- Multipath investigation
- Interference detection
- Spoofing detection

IfEN GmbH

SX3 Extendability

Features

Application Programming Interface

Standard APIs:

- IF-sample logging and filtering API

Optional APIs:

- Sensor data injection API
- Baseband signal acquisition & tracking API
- Navigation API
- Assistance Data API

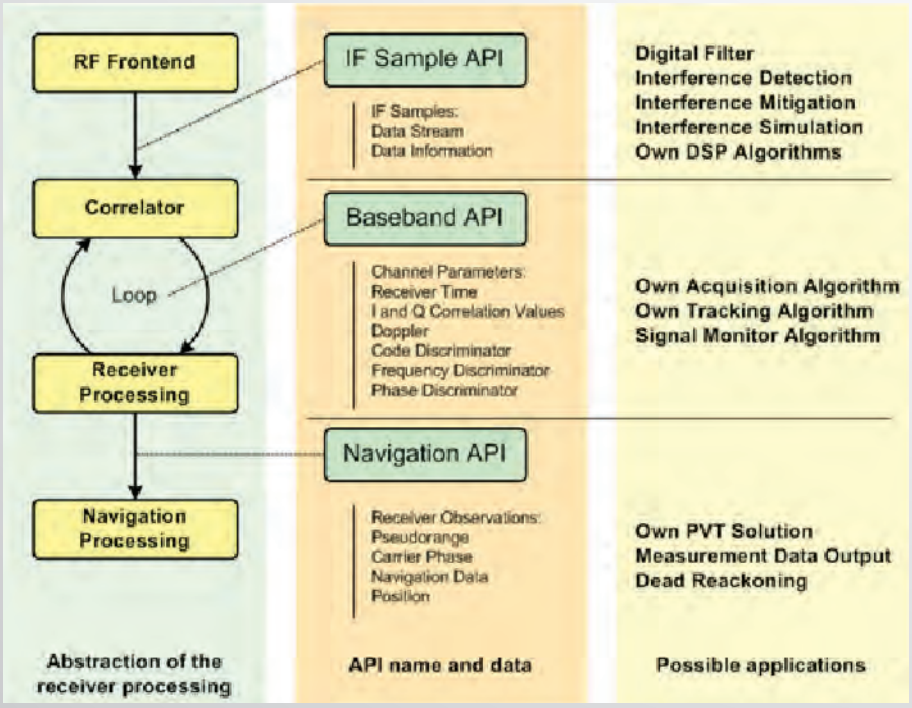
▶ SX3 Application Programming Interface (API)

The SX3 GNSS Software Receiver provides also a flexible framework to incorporate user-defined algorithms into the receiver. To accomplish this, a number of APIs have been defined to allow for those user extensions.
The Application Programming Interfaces (APIs) of the SX3 GNSS Software Receiver are one of the main advantages of this software defined GNSS receiver in comparison to traditional hardware-based receivers. The APIs offers the possibility to gain access to all stages of a typical GNSS receiver.

Part of the baseline product is the IF sample API, which allows to manipulate raw-IF samples as they come in from the SX3 RF-frontend as well as may be read from IF sample files stored on a hard drive or flash disk. In contrast to this free API, the Baseband, Navigation and Sensor extension APIs are not part of the baseline product.

The Baseband API enables users to integrate their own acquisition and tracking routines. In this mode the SX3 GNSS Software Receiver does not run its built-in acquisition. Furthermore, the Baseband API provides full control and access to the tracking procedures and parameters of each receiver channel. This is probably the most interesting API giving the advanced user a wide range of possibilities from just monitoring the tracking loop behaviour up to creating its own algorithms for the delay lock loop (DLL), phase locked loop (PLL) and frequency locked loop (FLL). Even user defined vector-delay-lock-loop implementations are possible to test various GNSS/INS integration schemes (from loosely to ultra-tightly coupled systems).

The optional Navigation API enables access to the other raw observations, i.e. pseudorange, carrier phase, code phase and navigation data. It enables to implement capabilities for navigation processing or any other kind of post-processing and positioning algorithms.



SX3 API overview

SX3 Key Specifications

SX3 GNSS SW Receiver

▶ Standard Specification

Performance	
Real-time channels	up to 300 channels on Intel Core i7-7700k (depending of sample rate, bit depth, selected signal processing and PVT algorithms
Measurement rate	up to 25 Hz
Measurement latency	< 70 ms
Acquisition sensitivity	19 dBHz
Tracking sensitivity	10 dBHz
Code accuracy	< 20 cm
Carrier accuracy	< 1 mm
Mean TTFF	< 1 s with ephemeris & position < 10 s with ephemeris < 55 s cold start
Maximum velocity	600 m/s (space user version with higher speed available on request)
Hardware	
Single-RF front-end	4 RF chains simultaneously (with seletcable band support per chain)
Dual-RF front-end	2 RF chains (with seletcable band support per chain)
Quad-RF front-end	1 RF chain (with seletcable band support per chain)
RF bandwidth	50 MHz (higher bandwidths, e.g. 70 MHz, on request)
Computer system	high performance Intel Core-i7 based HW
Software	
Supported operating system	Windows 10
Configuration and control	local GUI or remote via TCP/IP
Interfaces	
Real-time interface from RF front-end to computer	USB 3.0
1 RF in	TNC female (50 Ohm) for Single/Dual-RF, SMA for Quad-RF
1 PPS out	BNC female (50 Ohm)
1 external trigger in	BNC female
10 MHz external oscillator in	BNC female (50 Ohm)
10 MHz internal reference out	BNC female
Additional data sources	external IMU/magnetometer
Output format	RINEX, NMEA and proprietary ASCII logs
Reading of IF-samples for post-processing	from file

▶ Customization

Adding new functionality (signal processing, PVT processing) via the API requires in depth knowledge of the customer concerning either GNSS receiver signal processing or PVT algorithms processing. Especially if real-time performance is required, this is even more challenging. Therefore, also customization of the SX3 processing is possible enhancing the standard implementation, either as extension of already implemented algorithms or by inserting completely new functionality.

Just ask IFEN sales for customizations to provide an optimized R&D solution

IFEN GmbH

For Americas

IFEN Inc.

Mark Wilson

phone: +1.951.739.7331

email: M.Wilson@ifen.com

For EMEA and APAC

IFEN GmbH

phone: +49.8121.2238.20

email: sales@ifen.com

Or visit **www.ifen.com** to find your local representative.

www.ifen.com

IFEN GmbH