Geo++ SSR

for PPP and PPP-RTK

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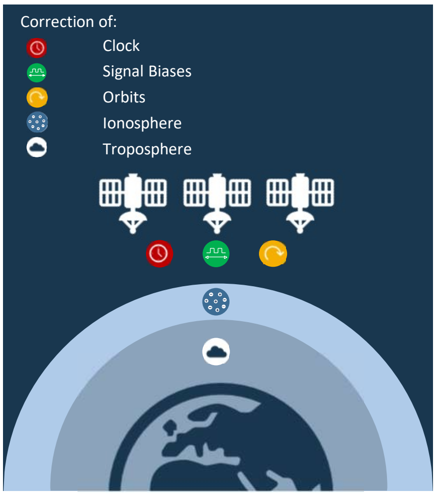
STATE-SPACE MODELLING

GNSS signal errors arise from multiple sources, including satellite orbit and clock errors, hardware biases, and atmospheric effects such as ionospheric and tropospheric delays. In conventional RTK or Network RTK systems, the combined impact of these errors is observed by reference stations and transmitted to the rover as range corrections for each supported combination of station, satellite, frequency and signal.

Systems based on this approach, known as Observation Space Representation (OSR), are in widespread use because they do not require advanced computational techniques. However, OSR methods cannot exploit the distinct stochastic properties of the underlying physical effects.

In contrast, State-Space Modelling (SSM) represents all relevant physical effects through mathematical models, with parameters estimated in real time using network observations. By leveraging knowledge of the temporal and spatial behavior of these effects, SSM allows the information from independent observations to be integrated and utilized optimally.

The State-Space Model can be applied not only to generate optimized OSR corrections for conventional RTK rovers but also to directly provide the state vector to State-Space Representation (SSR) rovers. Geo++ GNSMART (GNSS State Monitoring and Representation Technique) fully exploits these advantages of State-Space Modelling.



SERVICE OPERATOR BENEFITS

LOWER INFRASTRUCTURE REQUIREMENTS

Improved modeling of the spatial behavior of physical effects disturbing GNSS signals enables more accurate error estimation between reference stations. As a result, the inter-station distance can be increased to up to 200 km for RTK applications, compared to only 50–70 km in conventional Network RTK systems. This significantly reduces both initial investment and ongoing maintenance costs.

Another advantage of Geo++ SSM is the ability to consolidate different GNSS systems. Even reference stations that track only a subset of the available GNSS signals can fully contribute to the atmospheric modeling. To estimate satellite signal–specific state parameters, only a small subset of the reference stations needs to be able to track the relevant signals.

Furthermore, in the case of SSR, all users over a large area receive the same set of state parameters, so there is no need to generate individualized corrections for each rover. This simplifies the correction infrastructure, reduces system complexity, and decreases the number of computers required to process and deliver corrections.

MINIMIZED BANDWIDTH

Different error sources have different noise characteristics. For example, satellite clock errors must be updated every few seconds to maintain centimeter-level accuracy, whereas satellite orbit and atmospheric errors vary more slowly and therefore require less frequent updates.

A Geo++ SSR-based service can independently optimize both the update rate and the resolution of each error component, thereby minimizing the overall bandwidth required for

BROADCAST CAPABILITY

In most OSR solutions, the user receiver must first transmit its approximate position to the provider, which then returns OSR corrections valid for that location. This requires a bi-directional (duplex) data connection between the user and the provider.

In contrast, the SSR state vector is valid for the entire service area. As a result, no user input is required to provide correction data, and a one-way (simplex) data connection from the provider to the user is sufficient. Combined with the low bandwidth requirements, SSR is the ideal representation for broadcast services, including satellite-based augmentation systems.

For this reason, Geo++ SSR technology has been selected for transmission on the L6 channel of the Japanese Quasi-Zenith Satellite System (QZSS). The Centimeter Level Augmentation Service (CLAS) provides centimeter-level accuracy within seconds across Japan.

In France, the company Exagone broadcasts its TERIAsat PPP-RTK (SSR) corrections via geostationary satellites.

In Germany, the PPP-RTK satellite positioning service SAPOS® | GEPOS® delivers SSR corrections via both NTRIP (Networked Transport of RTCM via Internet Protocol) and DAB+ (Digital Audio Broadcasting Plus).

SCALABLE SERVICES

Geo++ SSR provides network operators with a high degree of flexibility. Networks can be tailored precisely to the needs of the end customer. For example, a network may include regions with inhomogeneous reference station densities—delivering the highest accuracies where required while keeping costs lower in areas where intermediate performance is sufficient.

Providers may also choose to transmit only a subset of the SSM state vector, valid for a specific area, accuracy level, or application. This enables a high degree of versatility in defining products and services.

	PPP	PPP-RTK
Satellite orbits	provided	provided
Satellite clocks	provided	provided
Satellite biases	provided	provided
Ionosphere	corrected by rover	provided
Troposphere	estimated by rover	provided
Iono-free ambiguities	provided	provided
Ambiguities	not possible	provided

provided · estimated by rover · corrected by rover · not possible

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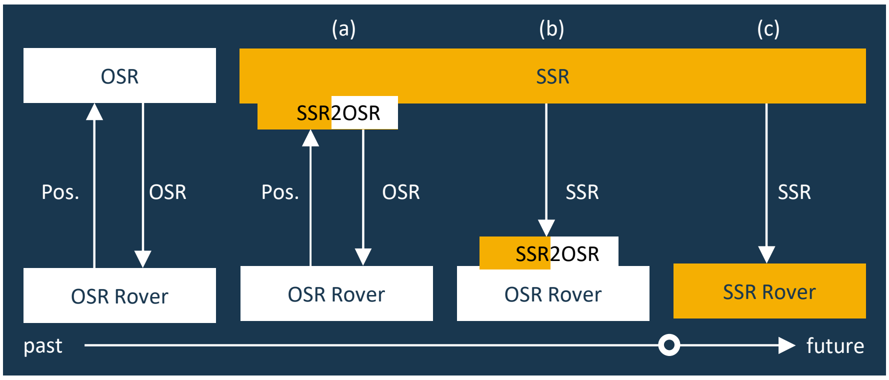
FROM OSR TO SSR

To support legacy rovers that do not natively process SSR corrections, it is necessary to convert SSR information into OSR. In the early stages, this conversion was carried out on the provider's server (a). However, to take advantage of SSR's low bandwidth requirements and broadcast capability, the conversion must be performed on the rover side (b). With ongoing standardization and continued rover development, an increasing number of devices will be able to use SSR data directly (c). As a result, OSR is expected to become obsolete.



COMPARISON OF COMMON REPRESENTATION TECHNIQUES

	OSR		SSR	
	RTK	Network RTK	PPP	PPP-RTK
Broadcast possible	✓	✗	✓	✓
Accuracy	~ cm	~ cm	< dm	< cm
Time Required[(1)]	< 5 s	< 5 s	~ 20 min	< 5 s - 1 min [(2)]
Service Area	local	regional	global	global / regional
Required bandwith	medium	medium	low	low – medium

Geo++ GNSMART can support all representation techniques
[(1)] No multipath
[(2)] Depends on update rate

SSRZ HARDWARE INTEGRATION STATUS

- Geo++ SSR2OBS executable for Windows and Linux OS
- Geo++ SSR2OSR Android App
- CNH PCM modem
- Teltonika TRB142 modem
- Alberding A10-RTK GNSS receiver
- TERIA PYX GNSS receiver
- Hi-Target T800 GNSS receiver
- Hi-Target HT Farmstar F3
- CHCNAV PA-5 GNSS receiver

OPEN SSR FORMATS SUPPORTED BY Geo++

SSR Basic Parameters	Multi-stage/ Scalability		RTCM-SSR	IGS SSR (1.0) 4076	SSRG Geo++ 4090.2	3GPP-LPP (Release 16)	SPARTN (2.0) u-blox	SSRZ (1.1) RTCM Geo++ 4090.7
Supported GNSS			G,R	G,R,E,C,J	G,R,E,C,J,S,I	G,R,E,C,J,S,I	G,R,E,C,J	G,R,E,C,J,S,I
SV **clock**	high-rate clock		available	available	available	available	available	available
	low-rate clock		available	available				available
SV **orbit**			available	available	available	available	available	available
SV code **bias**			available	available	available	available	available	available
SV phase **bias**			available	available	available	available	available	available
ionosphere	global	VTEC		available			available	available
	global	STEC		in preparation				available
	regional	STEC	interop-testing			available	available	available
	residual	gridded	interop-testing		available	Available	available	available
troposphere	regional		interop-testing	in preparation		available	available	available
	residual	gridded	interop-testing		available	available	available	available
complete SSR model			yes	no	yes	yes	yes	yes

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