SSR Technology for Scalable Real-Time GNSS Applications

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Abstract

SSR Technology for scalable Real-Time GNSS Applications

The use of State Space Representation (SSR) is the most convincing and acknowledged GNSS augmentation technology to cope with the increase of new signals and new constellations in the future.

The synergy of Precise Point Positioning and SSR for RTK networking has been widely addressed. Scalable SSR applications have the goal to support both, global but also regional or local applications.

Concepts are presented working out the benefits of SSR and the consequential splitting of GNSS error components over messages. An essential task is the handling of signal biases in multi-signal multi-constellation applications.

The general approach proposed for SSR is summarized. Finally the presentation will give a short status of the international standardization efforts.

Outline

- GNSS Augmentation in SSR and OSR Domain
- Scalable Services with SSR
- SSR Standardization
- Summary/Outlook

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GNSS Augmentation in the OSR Domain

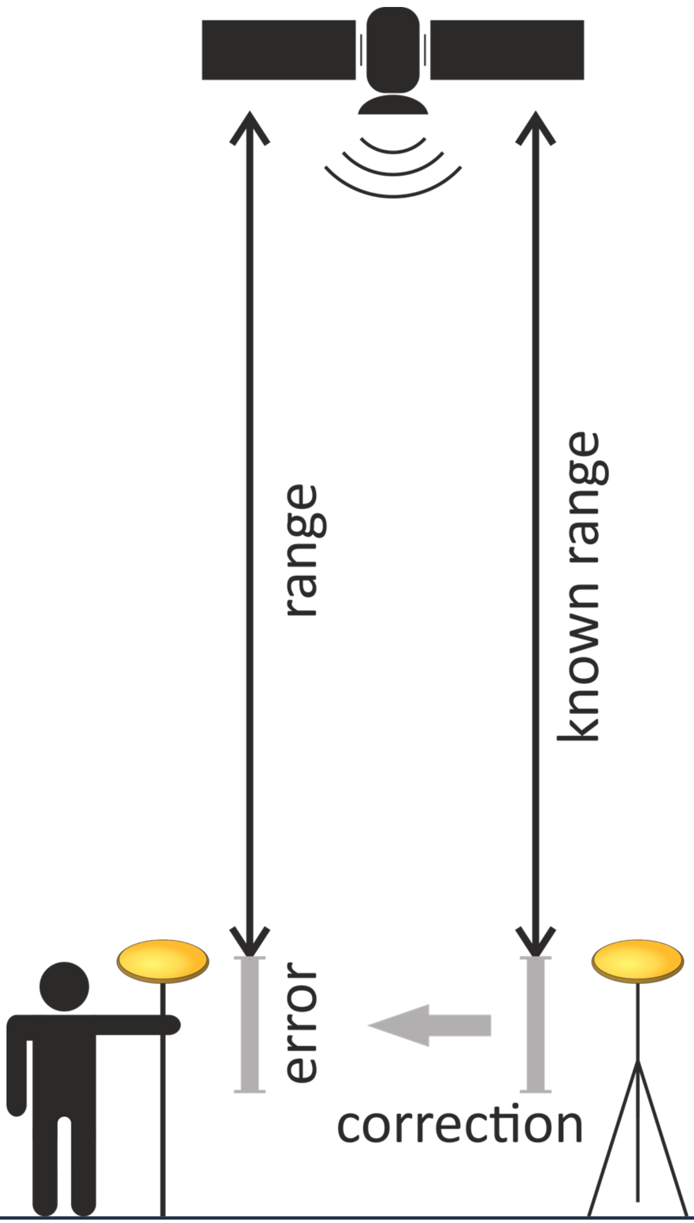
Recall, the simple case of real-time differential GNSS corrections assuming high correlation of **GNSS error components:**

- use known reference station coordinates
- determine lump-sum of GNSS errors

The range measurements of a user's GNSS positioning are improved by applying **GNSS range correction** as measured by a nearby reference station.

Since the observations of the reference stations are used directly, this approach is classified as an **observation space representation (OSR)** technique.

Examples include (network)-RTK and DGPS.



GNSS Augmentation in the SSR Domain

A network of reference stations is used to decorrelate the different **GNSS error components:**

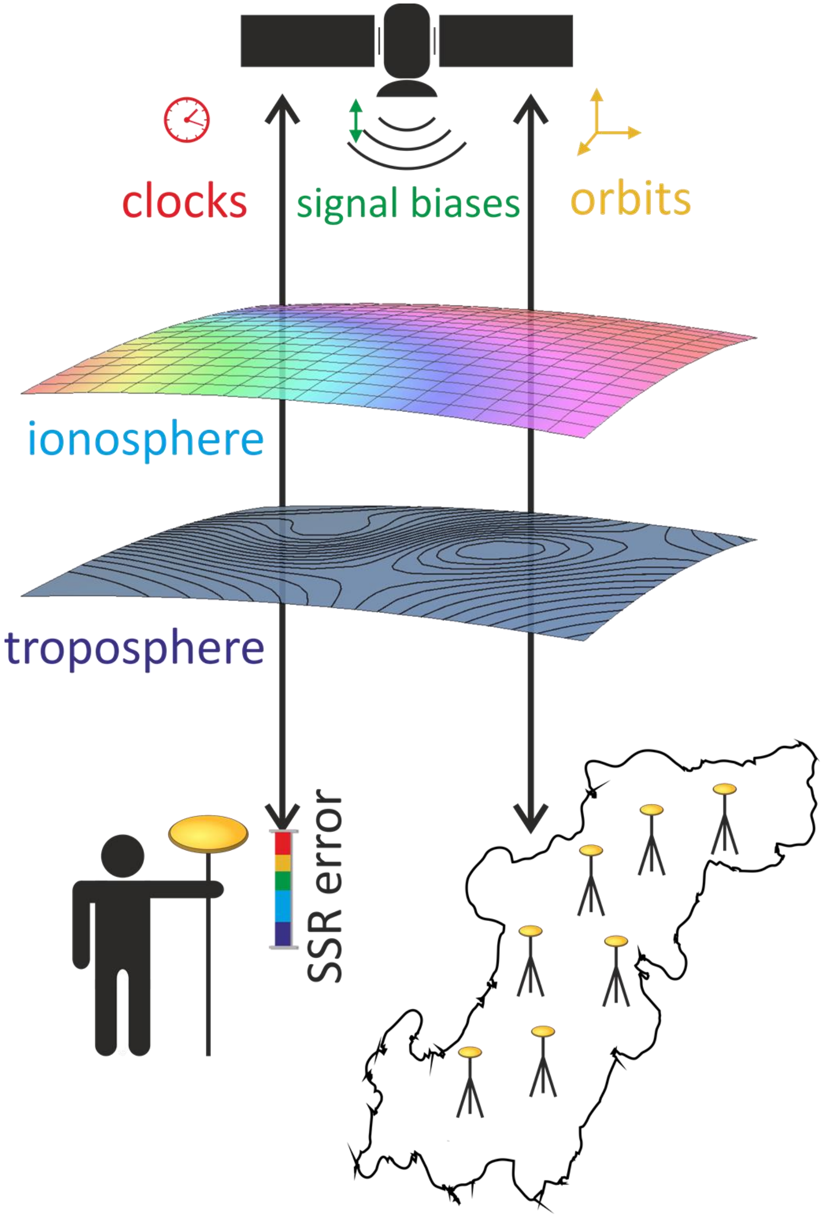
- satellite clocks
- satellite orbits
- satellite signal biases
- ionospheric delay/advance
- tropospheric delay

With this, users can **generate GNSS corrections** valid for their own position.

Additionally, statistical **accuracy information** can be provided to support the user's GNSS positioning algorithm.

Since the state of the GNSS error components is determined, this approach is termed as a **state space representation (SSR)** technique.

Examples include SBAS, PPP and PPP-RTK.



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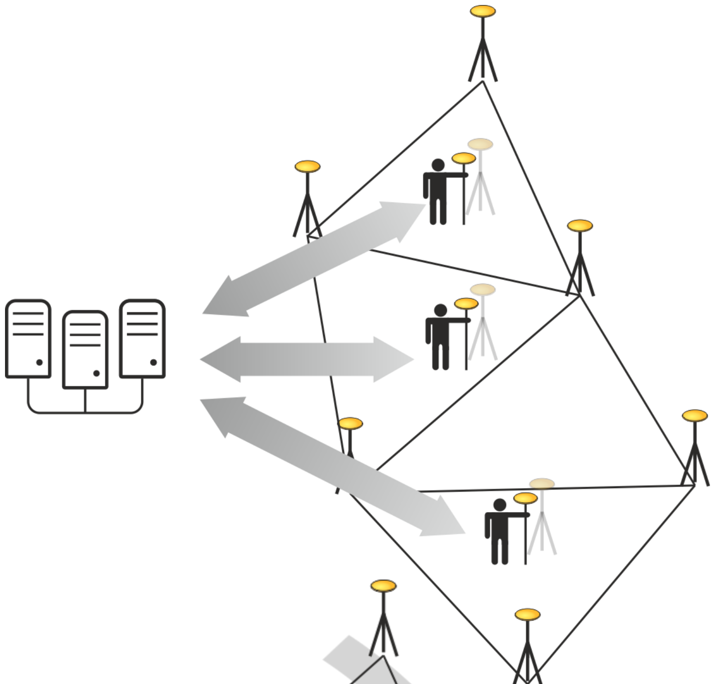
Scalable Services – Communication Link

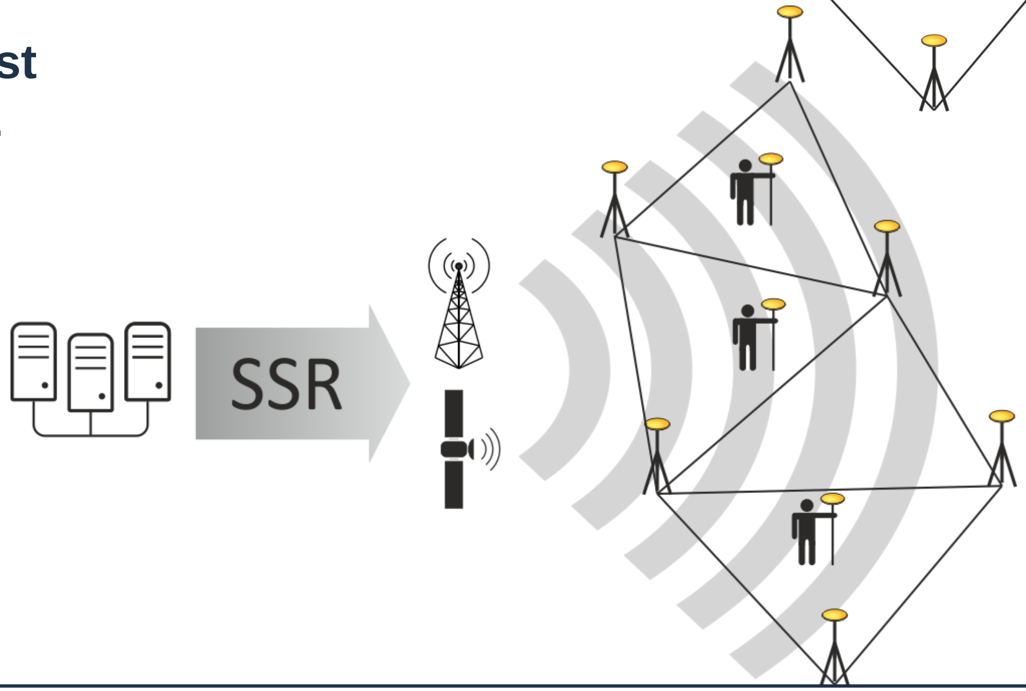
With **OSR**,

- the GNSS corrections are often realized with a so-called pseudo (PRS) or **virtual reference stations** (VRS).
- This requires **one duplex data channel per user**.



With **SSR**,

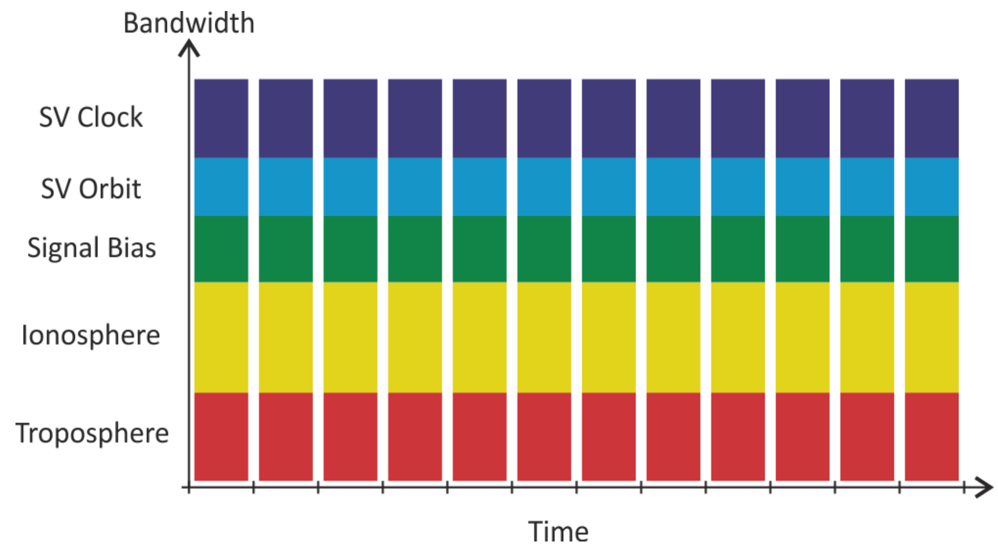
- the GNSS corrections are **broadcast** with **one data stream** for **all users**.
- This enables the use of **simplex communication** media (satellites, digital radio, ...) alternatively to the Internet.

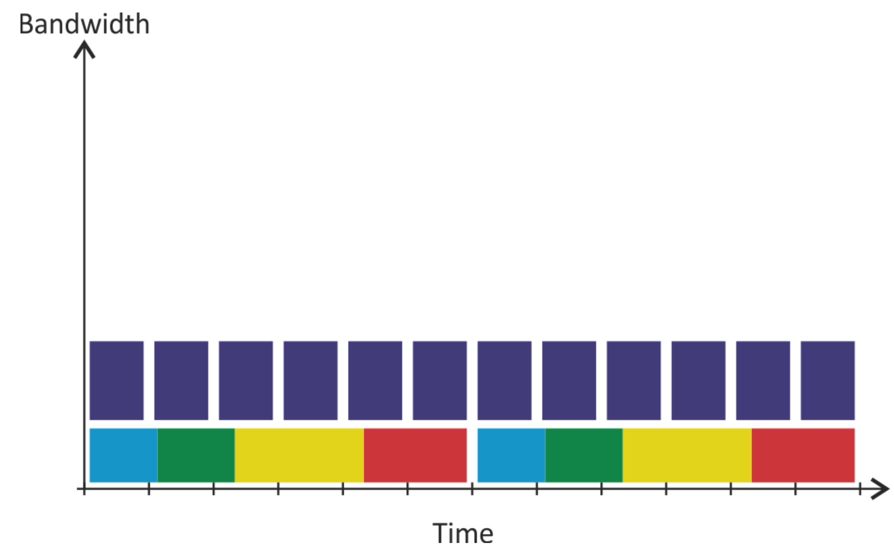


Minimizing Bandwidth – Scaling SSR in Time Domain

Analyzing the **individual characteristics** of the GNSS error components **reveals**:

- Due to **short-term fluctuations** of **satellite clocks**, cm level positioning requires correction data updates approximately every 10 seconds.
- **Other GNSS errors** components change at **lower rates**.
- **Adjusting individual update rates** of SSR components can drastically **reduce the bandwidth requirement** while keeping the **quality the same**.

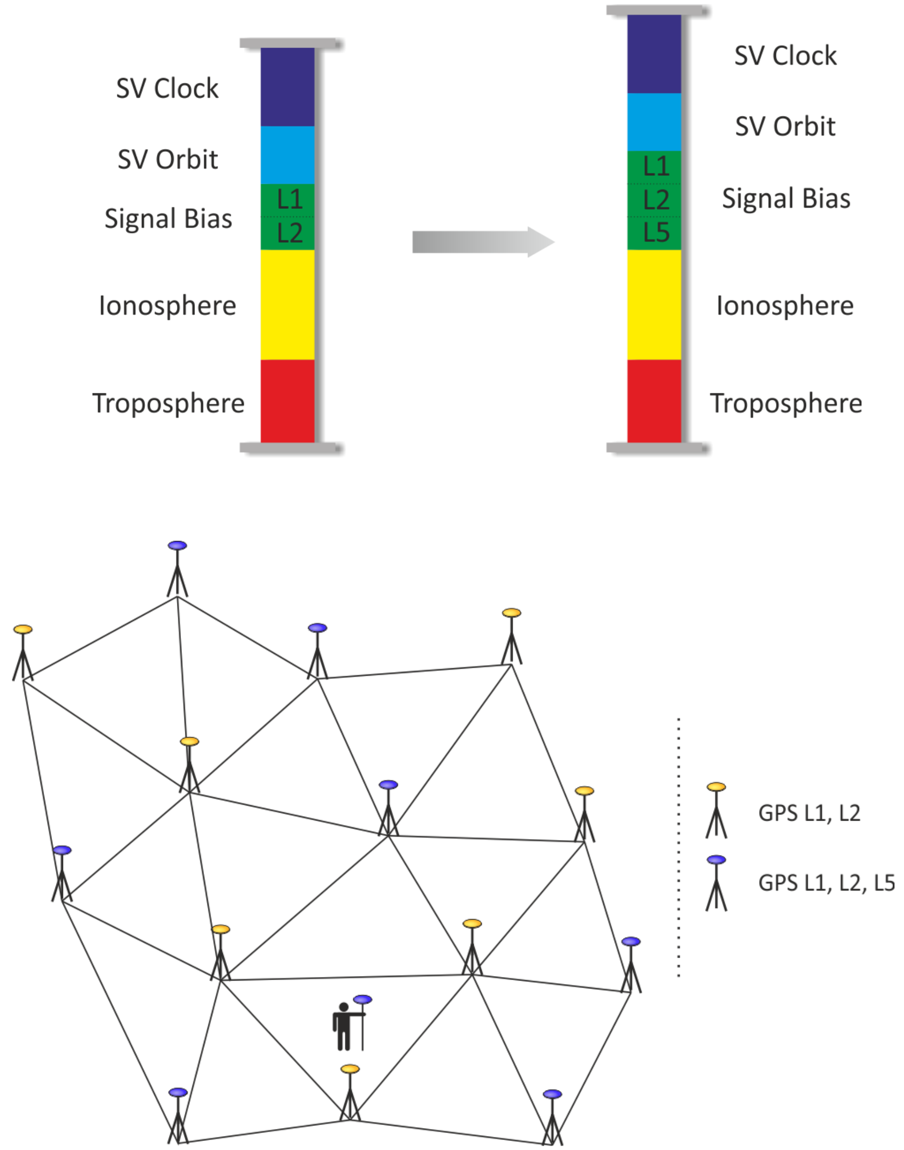




Scalable Services – Scaling Signals

SSR inherently supports the **variety** of **GNSS, frequencies and signals**:

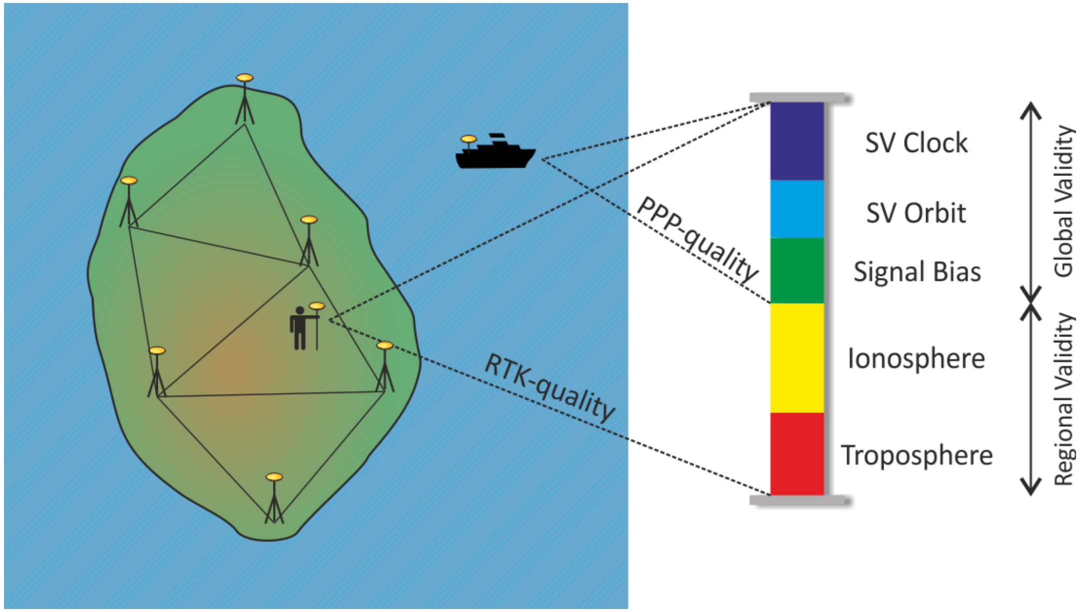
- **Additional GNSS or signals** can be **added** to existing services **seamlessly.**
- There is **no need for the same** reference **station hardware** to support all GNSS and signals.
- The **same SSR service** can be used by
  - mass market **single frequency users**
  - and **high precision** multi-GNSS multi-frequency **users**.



Scalable Services – Scaling Service Areas

With SSR,

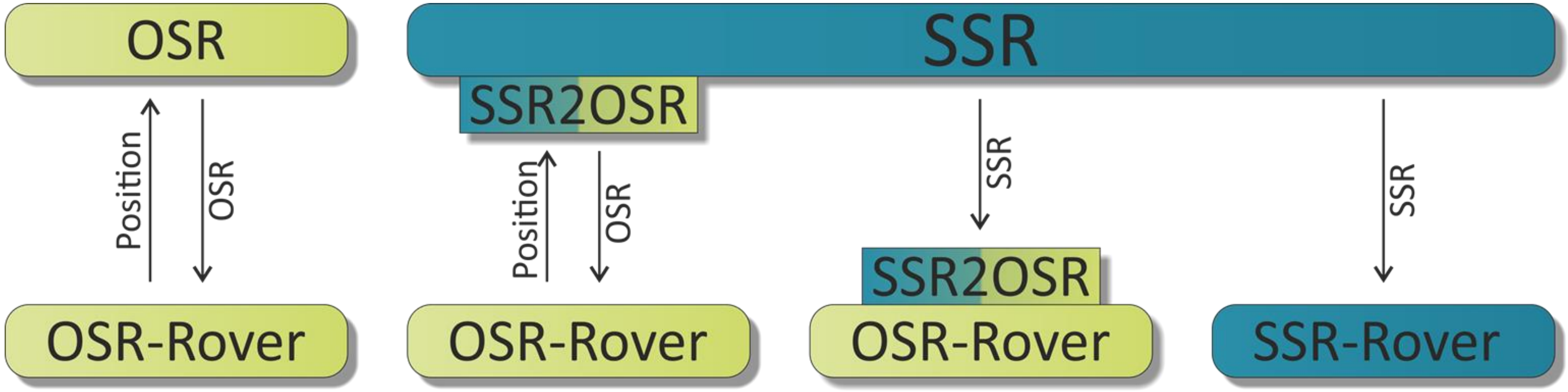
- **various quality levels** of GNSS positioning
- **for different regions**
- can be represented with a **single data stream**.



For example, a GNSS correction service

- could supply a **region with high** reference **station density** with an **RTK quality** service,
- while **all adjacent regions** are provided with **PPP quality**.

Scalable Services – Backward Compatibility



- **Legacy GNSS positioning** can be supported **via SSR2OSR conversion** either on the server or rover side.
- **Optimal performance** will be reached once the **SSR corrections** with accompanying accuracy information are **directly incorporated** in the positioning engine.

- GNSS Augmentation in SSR and OSR Domain
- Scalable Services with SSR
- **SSR Standardization**
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SSR Standardization by the RTCM

Since 2007 the SSR working group of the Radio Technical Commission for Maritime Services (**RTCM**) **S**pecial **C**ommittee **104** is developing a standard message format for SSR messages.

Goals of RTCM-SSR development are

- that messages are self-contained, flexible and non restricting
- and serve scalable GNSS applications with different accuracy requirements.

Status of standardization

- is slowed down, because of missing agreement on interoperability testing (new WG established).
- Consensus is expected after testing of a complete set of SSR messages.

Standardized (2011)+	Proposed (since 2013)	In Preparation (since 2016)
Orbits*	Phase Biases	Slant TEC (STEC)
Clocks*	Vertical TEC (VTEC)	Troposphere
Code Biases*		Compressed Messages
User Range Accuracy		

+: RTCM-SSR first published in „RTCM STANDARD 10403.1 with Amendments 1-5“, July 1, 2011
*: for GPS and GLONASS only, messages are proposed for Galileo, QZSS, BDS & SBAS

SSR Standardization - Satellite Biases

Every transmitted GNSS signal component experiences **a specific signal delay** (bias) **in every satellite** hardware/software.

Satellite Biases are **defined**

- as “**absolute biases**“
  (may contain remaining/average/reference receiver biases),
- for satellite **code and phase signals,**
- which inherently supports relative biases.

It is expected, that **all** software dependent **bias concepts can be mapped to the RTCM-SSR** approach.

example

- error components:
  satellite clock error dt and
  code biases B*i and **phase biases B*i**
- combined clock and signal signal delay error at satellite antenna:

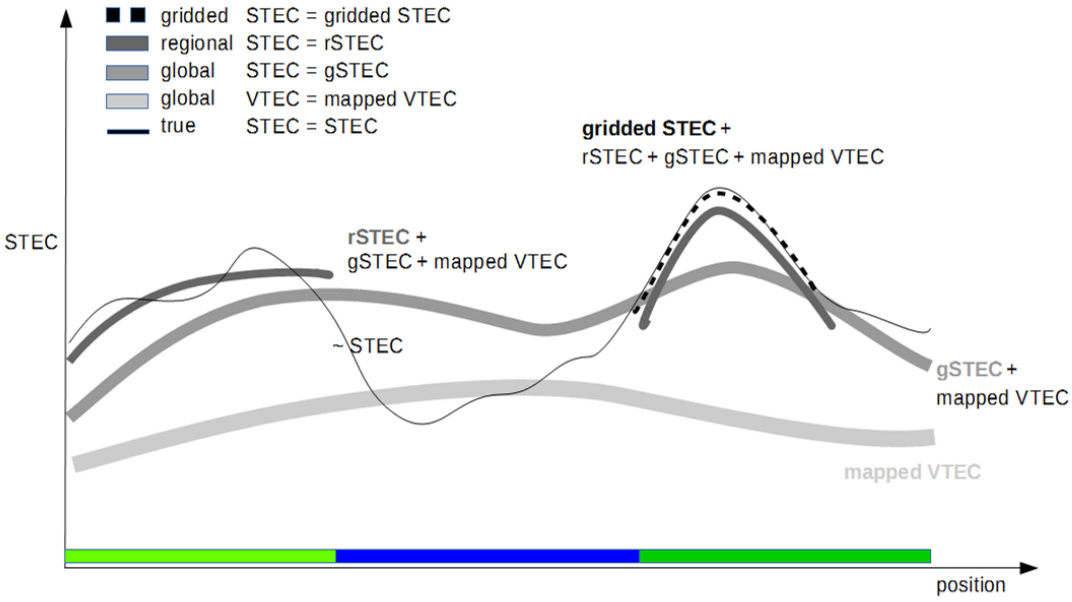
dC1C	=	dt	+ BC1C					
dC2W	=	dt		+ BC2W				
dC2C	=	dt		+ BC2C				
dC5I	=	dt			+ BC5I			
dL1W	=	dt				+ BL1W		
dL2W	=	dt					+ BL2W	
dL2C	=	dt					+ BL2C	
dL5I	=	dt						+ BL5I

linear dependency between clock and bias terms
==> **only** 7 (**n_signal -1**) **independent parameters**

SSR Standardization - Proposed Multi-Stage Concept

The **multi-stage model**

- utilizes **different messages** for the same GNSS error component.
- **constituents** from different messages **are added**, which **adds accuracy**.
- is **required** for e.g. **spatial variation** of atmospheric parameters or optimal **data compression**
- and allows different service applications/accuracies.



An example is the ionosphere, which consists of one or more constituents provided as

- an initial Vertical TEC spherical harmonics model
- and/or slant TEC components
- and/or a gridded TEC component.

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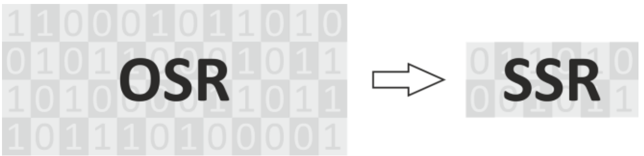
Summary/Outlook (1)

SSR technology provides

- broadcast GNSS corrections
- minimized bandwidth
- scalable GNSS services concerning
  - variety of GNSS and signals
  - positioning accuracy
  - service areas
- backward compatibility to GNSS applications

which are **essential benefits** for

scalable real-time GNSS applications



Summary/Outlook (2)

- State Space Representation (**SSR**) is most convincing **GNSS augmentation** technology **to cope with the increase of new signals and new constellations**.

- SSR **standardization is challenging**.

- **SSR can replace OSR techniques** for all types of GNSS positioning applications with better performance and less costs.

SSR – Fusion of GNSS Augmentations

GNSS augmentation with **SSR combines** the **accuracy of RTK** with the **broadcast** and low bandwidth benefits **of PPP**.

It is backward compatible to all legacy augmentation methods and can be **universally** adopted **to any reference station network**, no matter if

- global or regional
- high density or low density
- single, double or triple frequency.