SSR & RTCM – Current Status

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Outline

- RTCM SC104 WG’s
- SSR Today
- SSR Formats
  - SC104 RTCM-SSR
  - Geo++ RTCM 4090
- SSR Application Testbed
- Summary/Outlook

RTCM SC104 – Working Groups

BeiDou	ShaoWei Han
Biases	Ken MacLeod
Coordinate Transformation	Martin Schmitz
DGNSS Beacon Services	Al Cleveland
GALILEO	Hans-Jürgen Euler
GLONASS	Alexei Zinoviev
Integrity Monitoring for High Precision Applications	Roberto Capua
Internet Protocol	Dirk Stöcker
Network RTK	Frank Takac (Resigned 2017)
NMEA Messages	Morgan Zhang
Private Services	Ivo Milev (Resigned)
QZSS	Rui Hirokawa
RINEX	Ken MacLeod
State Space	Gerhard Wübbena
Version 3	Cameron Ellum
SBAS for Maritime Applications	Stig Erik Christiansen
Interoperability	David Kelley

RTCM SC104 – Working Groups

- GLONASS,Galileo,BDS,QZSS
  - GNSS specific tasks (signals, IODE, ephemeris, leap seconds, …)
- RTCM 3
  - MSM for new signals (IRNSS, GLONASS CDMA)
  - Maintain the Standard Document
- Network RTK
  - Inactive – not enough interest in MAC, FKP, .. for new GNSS and signals
- Coordinate Transformation
  - 15 Parameter message, service reference system identification
- Private Services (originally a EUPOS initiative) not succeeded
- DGNSS – Version 2.4 – Interoperability testing in progress
- SSR
  - Details following
- Interoperability WG
  - Responsible for all interoperability testing since spring 2017

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SSR – SSR Today

- **S**tate **S**pace **R**epresentation
- different SSR services are in operation, examples are
  - IGS **Precise Point Positioning** (PPP)
    - main state parameters (IGS products)
      orbits, clocks, (VTEC)
  - **SBAS**
    - main state parameters
      orbits, clocks, VTEC
  - **Proprietary Systems** with satellite communication
    - Omnistar, Starfire, Veripos/Terrastar,
      CenterPoint RTX, ...
  - **Network RTK** services based on SSM
    - complete states / conversion to OSR
  - **QZSS – CLAS**
    - complete states / L6 SV transmission
  - **combinations** of above showing up …

SSR – SSR Formats Today

- **current status** of **open** SSR format developments
  - SC104 **RTCM-SSR**
    - standardized RTCM-SSR messages
    - proposed RTCM-SSR messages
  - QZSS **Compact SSR** messages
  - Geo++
    - RTCM3-**4090** Geo++ RTCM messages
      - Geo++ **SSRG** messages
      - Geo++ **SSRZ** format

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Standardization – RTCM-SSR

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 performed interoperability testing
- new Interop-WG established and responsible for new test setup and organisation
- consensus is/may be 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:

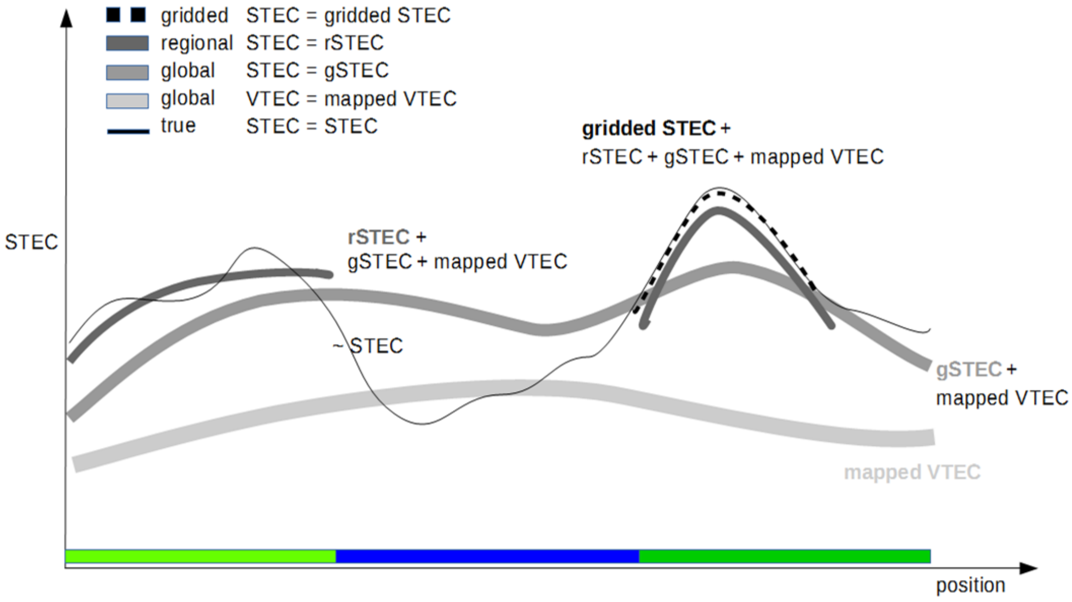
dC1C	=	dt + BC1C						
dC2W	=	dt	+ BC2W					
dC2C	=	dt	+ BC2C					
dC5I	=	dt		+ BC5I				
dL1W	=	dt			+ BL1W			
dL2W	=	dt				+ BL2W		
dL2C	=	dt				+ BL2C		
dL5I	=	dt					+ BL5I	

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.

SSR Standardization – Additional Corrections

- **additional correction** to be considered for **SSR positioning**
  - satellite-receiver **phase wind-up** effect (satellite attitude)
  - (absolute) **satellite antenna** phase and group delay variations (PCV, GDV)
  - **site displacement** effects (plate motion, solid earth tide, pole tide, ocean loading, atmospheric loading, local displacement)
  - **relativistic** effects
  - **higher order ionosphere**
  - (absolute) **receiver antenna** phase and group delay variations (PCV, GDV)

- requires
  - **SSR Standardization** or
  - **definition for specific services**

Remark – Variety of GNSS Signals and Interoperability

- **satellite view**
  - variety of GNSS **signals in space** according to GNSS Interface Control Document (**ICD**), respectively
- **receiver view**
  - variety of **tracked signals** by GNSS receivers

- every **phase and code** signal has inherently a **signal biases**
- consequences
  - **complex** task **for GNSS services**
  - support of legacy and latest technology receivers on the market

GNSS System	# of Frequencies		# of Observations (receiver view*)
GPS	3	L1 L2 L5	9 10 3
GLONASS	3	G1 G2 G3	2 2 3
Galileo	5	E1 E5a E5b E5(E5a+E5b) E6	5 3 3 3 5
BDS	3	B1 B2 B3	3 3 3
QZSS	4	L1 L2 L5 L6	5 3 3 3
SBAS	2	L1 L5	1 3
IRNSS	2	L5 S	4 4

*: according to RINEX 3.03 GNSS Observation Codes

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Reason for Geo++ SSRZ Development

- **RTCM-SSR** developments
  - scalable GNSS correction (stages 1 to 3)
    - focus on SSR content
      - broad consensus/acceptance
      - no exclusion of any SSR approach
  - no emphasis on compression
  - compression (stage 4)

- **Geo++ SSRZ** development
  - full set of state parameters
  - for scalable GNSS correction services
  - compression (entropy codng) for optimized bandwidth (all media, including satellite L-Band links)
  - continuity/compatibility of SSR content(i. e. with standardized/proposed RTCM SSR)

Main Features of Geo++ SSRZ

- satellite and message **grouping** (e. g. no separation of GNSS, low and high rate message)
  - information that can only be used together is in one message
- **asynchronous update** of SSR parameters (e.g. Low rate message @ 30s High rate message @ 5s)
- adaptive/**dynamic resolution** of SSR parameters to fit available bandwith
  - parameter resolution (e. g. optimized for parameter, compression)
  - in time (e. g. update rate)
  - in space (e. g. different grids)
  - especially for atmospheric SSR parameters
- **entropy encoding**
  - use of statistical characteristics of SSR parameters
- **static data** defined in meta-data
  - no mandatory transmission (e. g. download site)
  - support optional transmission (e. g. piggyback)

Geo++ SSRZ Performance Today

- PPP like service
  - including orbits, clocks, code biases, phase biases (2 Signals)
  - low rate data @ 30s / high rate data @ 5s
  - bandwidth required about 4bps / satellite
- Network RTK Services
  - require additionally atmospheric corrections based on grids
  - bandwidth under investigation (expected: <0.1 bps / satellite / grid)

- service specific extensions of SSRZ
  - GNSS **integrity** information
  - **private services**
    - selective access control
    - through message encryption

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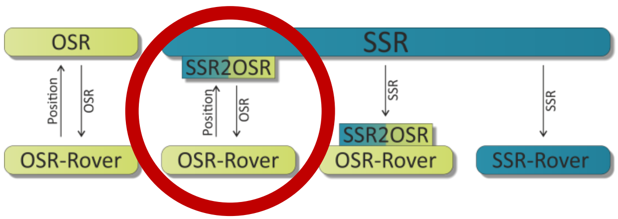
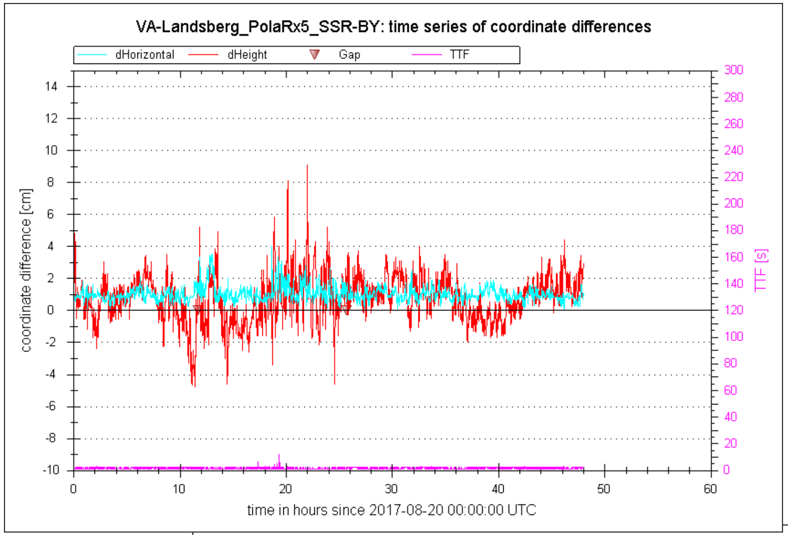
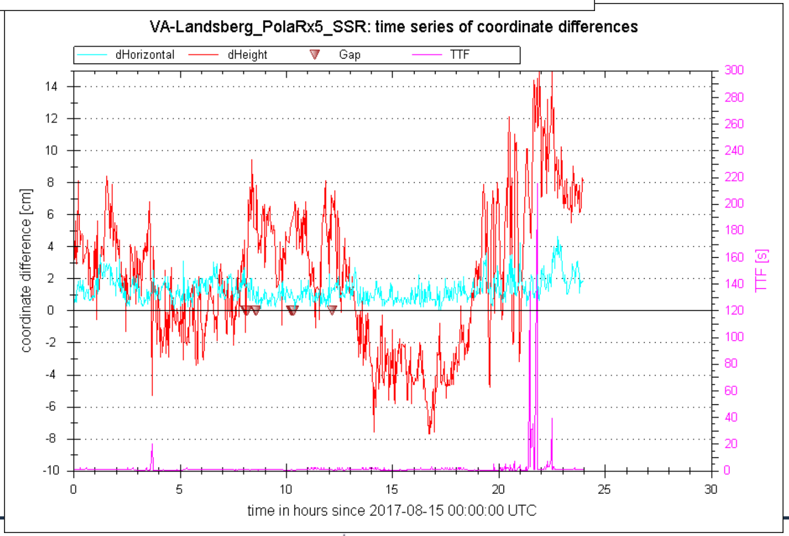
SSR Application – SSR2OSR

- **RTCM-SSR-Testbed of the AdV**
- AdV’s project group „Precise Point Positioning“ (PPP) is operator of a **German-wide SSR-Testbed** (and Bavaria-wide)
- testing of **“from-the-shelf”** standard **GNSS RTK receivers**
  - differently “scaled” SSR (corrected states/reference station density)
- demonstration/**verification** of SSR2OSR for **legacy rovers**







- top: Bavarian-wide SSR, closest station 28 km, no complete ionospheric, with tropospheric correction
- bottom: German-wide SSR, closest station 70 km, no complete ionospheric, without tropospheric correction

AdV: Working Committee of the Surveying Authorities of the Laender of the Federal Republic of Germany, www.adv-online.de

plots: courtesy of Martin Freitag, SAPOS Bayern

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Summary/Outlook

- State Space Representation (**SSR**) is most convincing **GNSS augmentation** technology **to cope with the increase of new signals and new constellations**.
- **SSR can replace OSR techniques** for all types of GNSS positioning applications with better performance and less costs.
- **SSR** can serve mass market applications (broadcast)
- SSR **standardization is challenging**.
- **RTCM-SSR** standarization delayed
- **other standardization organisations** or industry groups will come up with an alternative non-RTCM standard