RTCM-SSR Strategy of Bias Treatment

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RTCM-SC104 SSR Development

- working group established in 2007
- 3 message development stages
  - (1) transmission of **satellite orbit corrections**, **satellite clock corrections**, **satellite code biases** and **URA** values (currently GPS and GLONASS)
    - enables real-time dual frequency code based applications
    - completed in May 2011 and first published as document „*RTCM STANDARD 10403.1 with Amendments 1-5“,* July 1, 2011
  - (2) transmission of **satellite phase biases** and **VTEC** ionosphere
    - VTEC and new stage 1 messages (Galileo, QZSS, …) ready for vote
    - satellite phase biases ready for vote; still some disussions in plenary
    - shall enable real-time phase based applications including ambiguity resolution and real-time single frequency applications
  - (3) transmission of **STEC** and **tropospheric parameters**
    - shall enable real-time applications (centimeters in seconds)
  - (4) **compression** of messages (“first content, then compression”)

Strategy / Concepts for RTCM-SSR Development

- RTCM-SSR shall be a **self-contained** format as far as possible

  i.e. all necessary information for consistent processing shall be contained in the RTCM-SSR stream or shall be specified inf the standard document; the need for external information shall be avoided as far as possible
  - counter example: satellite PCV (tbd)

- the definition of RTCM-SSR contents **shall not limit/restrict** the generation of SSR streams; **no use of particular generation models or approaches**
  - example: conventional approaches with dynamic orbit modeling (IGS) as well as approaches with kinematic orbit modeling shall be supported

- **international conventions for** observation **modeling and/or corrections** shall be applied **as far as necessary** and as long as they are well defined and documented and freely usable
  - example: IERS convention

- do not prevent new ideas, models or approaches!

Strategy / Concepts for RTCM-SSR Development

- the standard shall allow in a flexible way
  different update rates for different state parameters

  Different error states possess different variability with time.
  Slowly changing states need lower update rates as highly variable states.
  This is the key characteristic that allows minimization of stream bandwidth.

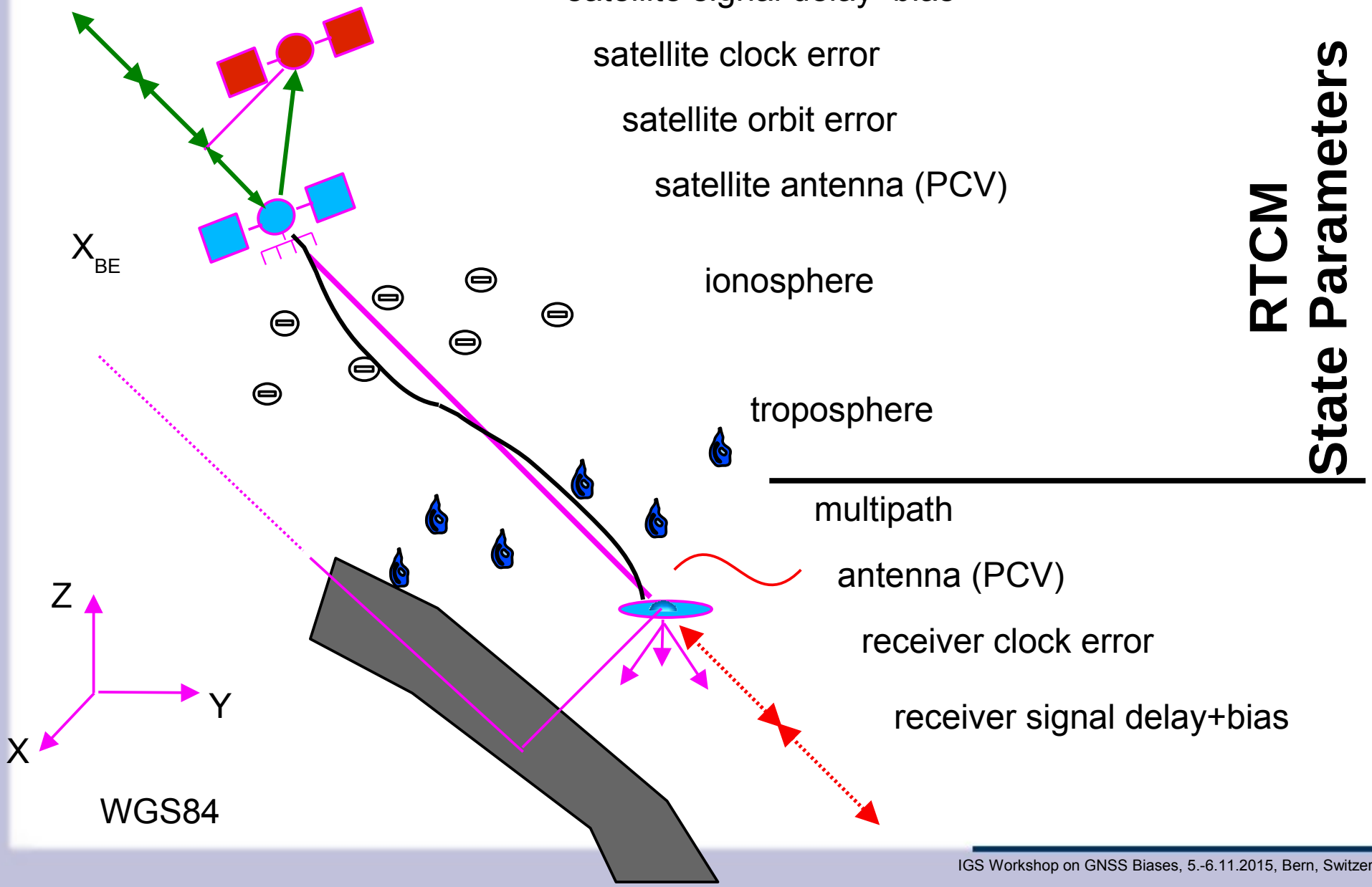
- **self-consistency** of RTSM-SSR streams must be achieved

- **consistent processing** of SSR stream contents must be ensured

  Consistency is one of the major requirements in order to achieve the desired performance. Consistency of algorithms and computations for reference models must be assured as well as consistency of state parameter sets.

- the RTCM-SSR standard shall support
  scalable global, continental, regional and/or local applications

Major GNSS Error Sources & RTCM State Parameters

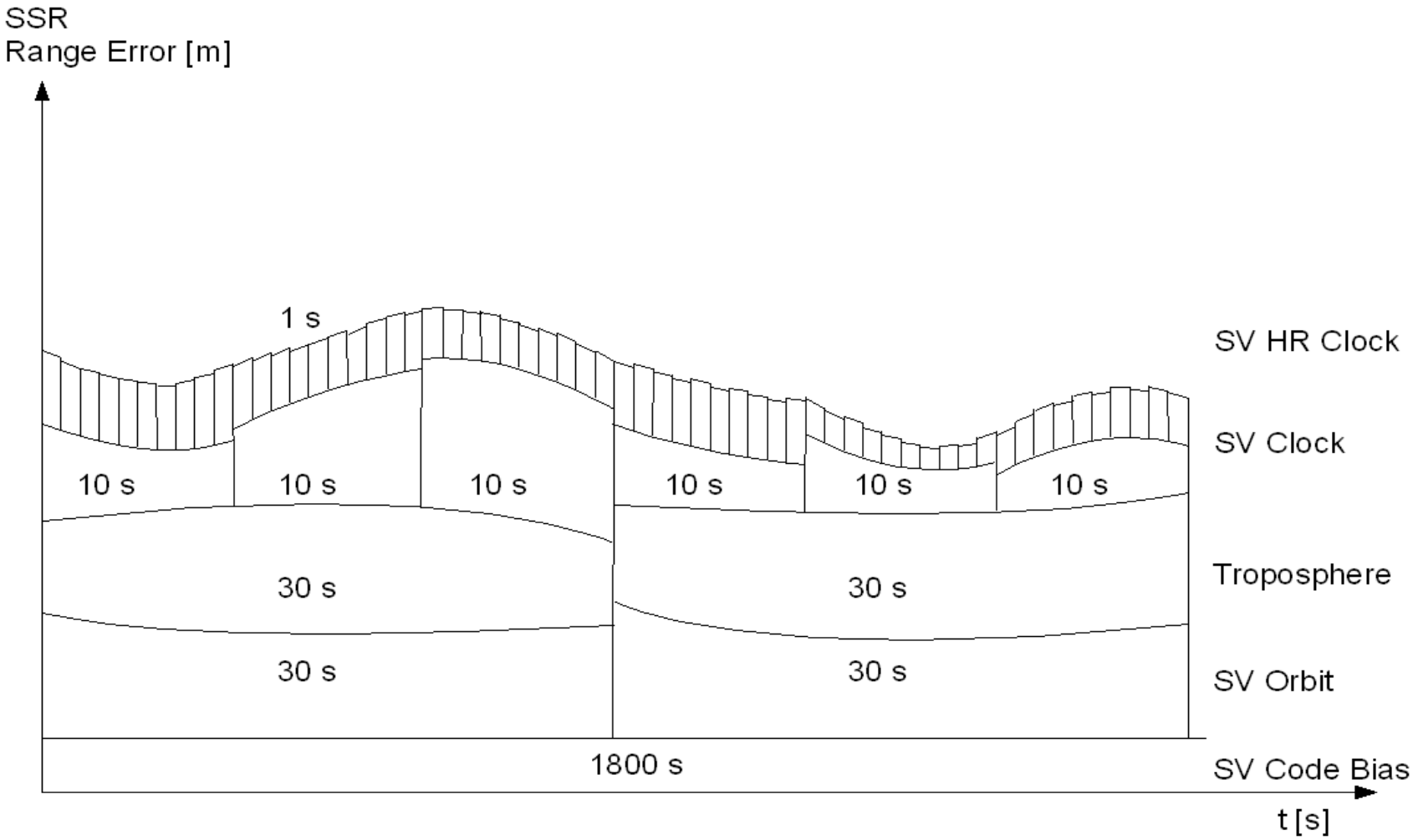


Strategy / Concepts for RTCM-SSR Development

- **multiple stage models**
  - different messages for same state constituent
  - different **messages are added**
  - added messages add accuracy
  - required for RTCM-SSR development
    (e.g. spatial variation of atmospheric parameters)
  - **allows scaling for different applications/accuracies**

- **examples**
  - satellite clock
    - initial component clock polynomial
    - optional component high rate clock
  - ionosphere (one or mor constituents)
    - initial model Vertical TEC spherical harmonics
    - and/or component slant TEC
    - and/or component gridded TEC

RTCM-SSR Consistency Sketch



RTCM-SSR and Signal Biases

- RTCM-SSR messages for **satellite and signal** dependent code and carrier **biases** are (will be) defined as
  - **„absolute biases“** (instead of differential biases)
    - no need to define reference signals or reference linear combinations
    - flexible approach with respect to signal selection
    - SSR generating applications working with Differential Biases (DBs) shall chose absolute values in a way that the DBs a correctly represented and consistency is maintained
- RTCM-SSR biases may contain remaining/average/reference **receiver biases**
  - biases **common to all satellites**
    - easily eliminated through differencing or
    - changing the estimates of corresponding rover parameters
  - in case of **non-common biases** (GLONASS FDMA)
    - a type 1033 message describing the type or instance of a reference receiver/antenna shall be sent with the RTCM-SSR stream

Satellite Code and Phase Biases

- **every transmitted GNSS signa**l component experiences **a specific signal delay** (bias) in satellite HW/SW
- applies to satellite **code and phase signals**

- example:
  - GPS dual frequency observations: **code** (**P1, P2**) and **carrier** (**L1, L2**)
  - error components: **satellite clock error dt** and **code biases BP**i and **phase biases BL**i
  - combined clock and signal signal delay error at satellite antenna:

$$
\begin{aligned}
dP1 &= dt + BP1 \\
dP2 &= dt + BP2 \\
dL1 &= dt + BL1 \\
dL2 &= dt + BL2
\end{aligned}
$$

linear dependency between clock and bias terms
==> **only** 4 (**n_signal -1**) **independent parameters**

Satellite Code and Phase Biases

- **no** specific **reference bias/signal used** in RTCM-SSR, which allows **maximum flexibility** for service providers
- example
  - complete support of **reference bias/signal** like ionospheric free linear combination of P1, P2 (**GPS/IGS**)
  - **BR** defined to be bias-free gives biased clock and “differential” signal biases:

$$
\begin{aligned}
dC1W &= (dt + BR) + (BC1W - BR) \\
dC2W &= (dt + BR) + (BC2W - BR) \\
dL1W &= (dt + BR) + (BL1W - BR) \\
dL2W &= (dt + BR) + (BL2W - BR)
\end{aligned}
$$

or

$$
\begin{aligned}
dC1W &= dt' + BC1W' \\
dC2W &= dt' + BC2W' \\
dL1W &= dt' + BL1W' \\
dL2W &= dt' + BL2W'
\end{aligned}
$$

- **individual signal** component **(code or carrier)** can be utilized, if corresponding and **consistent bias** is transmitted

Satellite Code and Phase Biases

- valid for any number of signals
- 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**

Satellite Code and Phase Biases

- concept of RTCM-SSR satellite biases
  - all software dependent bias concepts are expected to be mapped to RTCM-SSR approach
- verification
  - e.g. theoretical analysis

    Teunissen, P. J. G. and Khodabandeh, A. (2015). Review and principles of PPP-RTK methods. Journal: Journal of Geodesy, Vol 86, No 3, 217-240.

  - e.g. practical application

    Laurichesse, D. (2015). Handling the Biases for Improved Triple-Frequency PPP Convergence. Innovation, GPS World, April.

Thank you for your attention