Federal Agency for
Cartography and Geodesy

On the usage of RTCM Multiple Signal Messages in GNSS Real-Time Processing

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RTCM MSM

- RTCM Special Committee 104 „DGNSS“ defines standardized formats for GNSS data
- „Legacy“ formats RTCM 2.x (e.g. message types 18, 19) and RTCM 3.x (e.g. message types 1001-1004, 1009-1012)
- For GPS and GLONASS

Radio Technical Commission for Maritime Services

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- For GPS and GLONASS
- Multiple Signal Messages (MSM) for additional GNSS and SBAS, more frequencies and signals

Radio Technical Commission for Maritime Services

RTCM MSM

- Structure with seven different types for each constellation
  - MSM1: Compact GNSS Pseudoranges
  - MSM2: Compact GNSS PhaseRanges
  - MSM3: Compact GNSS Pseudoranges and PhaseRanges
  - MSM4: Full GNSS Pseudoranges and PhaseRanges plus CNR
  - MSM5: Full GNSS Pseudoranges, PhaseRanges, PhaseRangeRate plus CNR
  - MSM6: Full GNSS Pseudoranges and PhaseRanges plus CNR (high resolution)
  - MSM7: Full GNSS Pseudoranges, PhaseRanges, PhaseRangeRate plus CNR (high resolution)
- 1071-1077 GPS, 1081-1087 GLONASS, 1091-1097 Galileo, 1101-1107 SBAS, 1111-1117 QZS, 1121-1127 Beidou

RTCM MSM

- Size (bits) for 16 SVs and 4 signals (Boriskin et al. 2012):
  - MSM1: 1353
  - MSM2: 2121
  - MSM3: 3081
  - MSM4: 3593
  - MSM5: 4841
  - MSM6: 4681
  - MSM7: 5929

RTCM MSM – Example

- STR200AUS0: RTCM3.3 MSM4 (GPS+GLO+GAL+BDS+QZS)

								Client connections		
						Clients	KBytes read	KBytes written		Connected for
/TOW200AUS0	72304888	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:08:54:03	52.64.64.80	21	1370	27118	21	23 minutes
/MAYG00MYT0	72308983	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:08:58:03	192.134.134.3	9	402	3346	9	19 minutes
/TUVA00TUV0	72312193	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:01:03	52.63.154.232	2	661	1316	2	16 minutes
/BRST00FRA0	72313280	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:02:03	192.134.134.3	15	339	5285	17	15 minutes
/GRAS00FRA0	72318371	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:06:33	192.134.134.3	8	224	1675	8	10 minutes and 30 seconds
/GAMB00PYF0	72321656	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:09:33	192.134.134.3	5	151	660	5	7 minutes and 30 seconds
/TONG00TON0	72322803	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:10:33	52.64.64.80	0	666	0	0	6 minutes and 30 seconds
/STR200AUS0	72325490	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:13:03	52.63.154.232	12	224	2563	12	4 minutes
/GAMG00KOR0	72329293	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:16:33	192.134.134.3	2	10	19	2	30 seconds
/HARB0	72329549	132.149.53.72	NTRIP trimble 2.0	08/May/2018:09:16:50	132.149.53.72	3	4	5	3	13 seconds

RTCM MSM – Example

- STR200AUS0: RTCM3.3 MSM4 (GPS+GLO+GAL+BDS+QZS)

							KBytes read	KBytes written	Client connections	Connected for
/TOW200AUS0	72304888	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:08:54:03	52.64.64.80	21	1370	27118	21	23 minutes
/MAYG00MYT0	72308983	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:08:58:03	192.134.134.3	9	402	3346	9	19 minutes
/TUVA00TUV0	72312193	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:01:03	52.63.154.232	2	661	1316	2	16 minutes
/BRST00FRA0	72313280	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:02:03	192.134.134.3	15	339	5285	17	15 minutes
/GRAS00FRA0	72318371	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:06:33	192.134.134.3	8	224	1675	8	10 minutes and 30 seconds
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/TONG00TON0	72322803	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:10:33	52.64.64.80	0	666	0	0	6 minutes and 30 seconds
/STR200AUS0	72325490	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:13:03	52.63.154.232	12	224	2563	12	4 minutes
/GAMG00KOR0	72329293	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:16:33	192.134.134.3	2	10	19	2	30 seconds
/HARB0	72329549	132.149.53.72	NTRIP trimble 2.0	08/May/2018:09:16:50	132.149.53.72	3	4	5	3	13 seconds

RTCM MSM – Example

- MET300FIN0: RTCM3.3 MSM7 (GPS+GLO+GAL+BDS+QZS+SBAS)

								KBytes read	KBytes written	Client connections: Clients / Connected for
/BRST00FRA0	72313280	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:02:03	192.134.134.3	16	469	7305	18	20 minutes and 30 seconds
/GRAS00FRA0	72318371	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:06:33	192.134.134.3	8	341	2617	8	16 minutes
/GAMB00PYF0	72321656	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:09:33	192.134.134.3	5	262	1214	5	13 minutes
/TONG00TON0	72322803	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:10:33	52.64.64.80	0	1236	0	0	12 minutes
/STR200AUS0	72325490	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:13:03	52.63.154.232	12	527	6195	12	9 minutes and 30 seconds
/GAMG00KOR0	72329293	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:16:33	192.134.134.3	2	130	260	2	6 minutes
/CHTI00NZL0	72330378	161.65.59.99	NTRIP BKG Caster/2.0.29 (relay v2)	08/May/2018:09:17:33	161.65.59.99	16	233	2957	16	5 minutes
/MET300FIN0	72331409	78.46.59.40	NTRIP BKG Caster/2.0.31 (relay v2)	08/May/2018:09:18:33	78.46.59.40	3	443	1048	3	4 minutes

End of source listing (182)

RTCM MSM – Example

- MET300FIN0: RTCM3.3 MSM7 (GPS+GLO+GAL+BDS+QZS+SBAS)

						Clients	KBytes read	KBytes written	Client connections	Connected for
/BRST00FRA0	72313280	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:02:03	192.134.134.3	16	469	7305	18	20 minutes and 30 seconds
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/GAMB00PYF0	72321656	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:09:33	192.134.134.3	5	262	1214	5	13 minutes
/TONG00TON0	72322803	52.64.64.80	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:10:33	52.64.64.80	0	1236	0	0	12 minutes
/STR200AUS0	72325490	52.63.154.232	NTRIP BKG Caster/2.0.27 (relay v2)	08/May/2018:09:13:03	52.63.154.232	12	527	6195	12	9 minutes and 30 seconds
/GAMG00KOR0	72329293	192.134.134.3	NTRIP Caster 2.0.6 (relay v2)	08/May/2018:09:16:33	192.134.134.3	2	130	260	2	6 minutes
/CHTI00NZL0	72330378	161.65.59.99	NTRIP BKG Caster/2.0.29 (relay v2)	08/May/2018:09:17:33	161.65.59.99	16	233	2957	16	5 minutes
/MET300FIN0	72331409	78.46.59.40	NTRIP BKG Caster/2.0.31 (relay v2)	08/May/2018:09:18:33	78.46.59.40	3	443	1048	3	4 minutes

End of source listing (182)

Processing Software RTNet

- Real-time (and post processing) software
- Developed by GPS Solutions Inc. (Boulder, CO)
- Used by BKG since 2006 for orbit and clock correction estimation within the scope of IGS RTS
- 61 stations (mount-points) implemented, either from igs-ip and euref-ip (legacy messages) and from mgex-ip (MSM messages, ~ 15)
- Ambiguity float solution
- Variety of cycle slips reported within the (large) log files of the program, e.g. ‘reported by receiver’

Processing Software RTNet

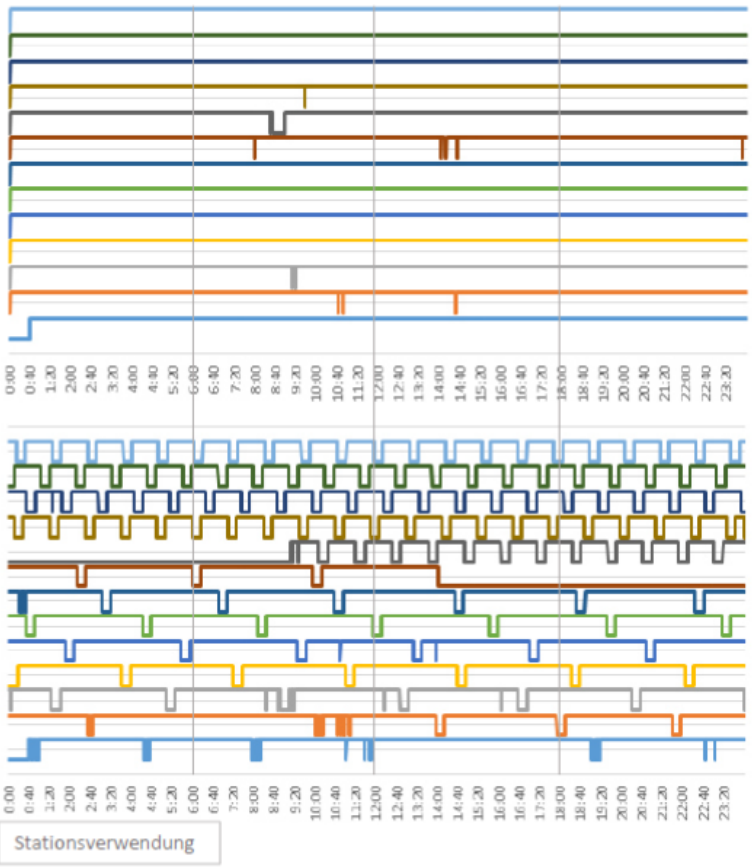
- First implementation of ambiguity fixed solution in three regional networks
  - Germany (GREF) and neighboring countries
    - Approx. 45 stations
    - Consisting of mount-points with legacy messages
  - Baltic Sea
    - Within FAMOS[1)] project
    - Approx. 55 stations
  - NRCan
    - Separate casters for different message types available
- Regional densification with fixed ambiguities mandatory for reaching State Space Representation (SSR) stages 2 and 3

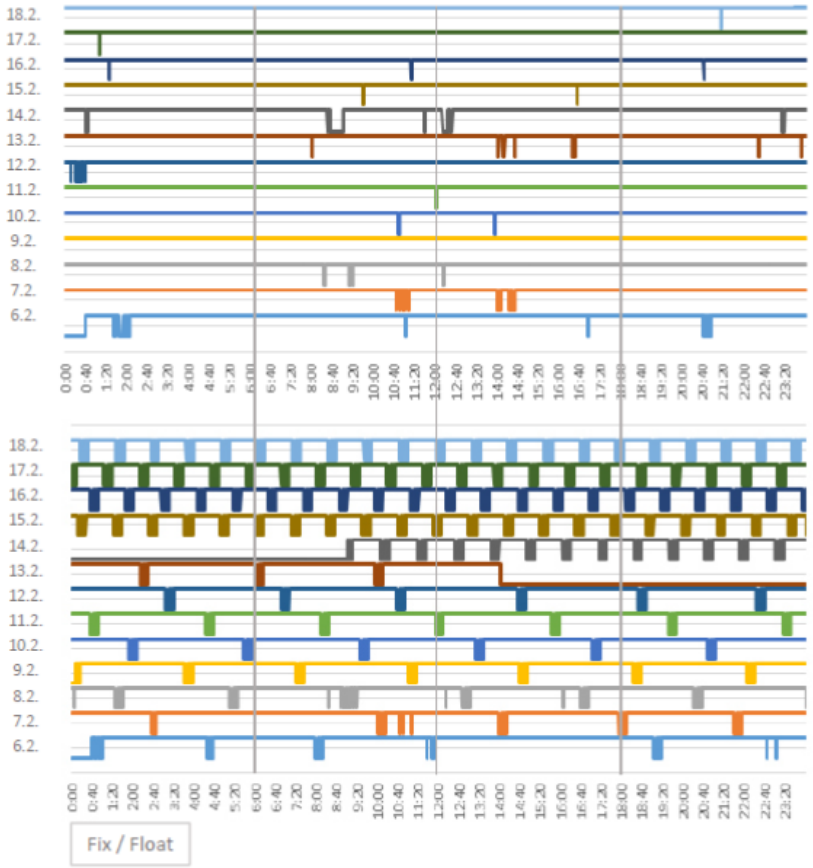
[1)] Finalising Surveys for the Baltic Motorways of the Sea

GREF network

- Stable ambiguity fixed solution possible
- Few stations showed problems (e.g. unstable internet connection)
- Some stations showed systematic behaviour (e.g. daily restart at the same time)

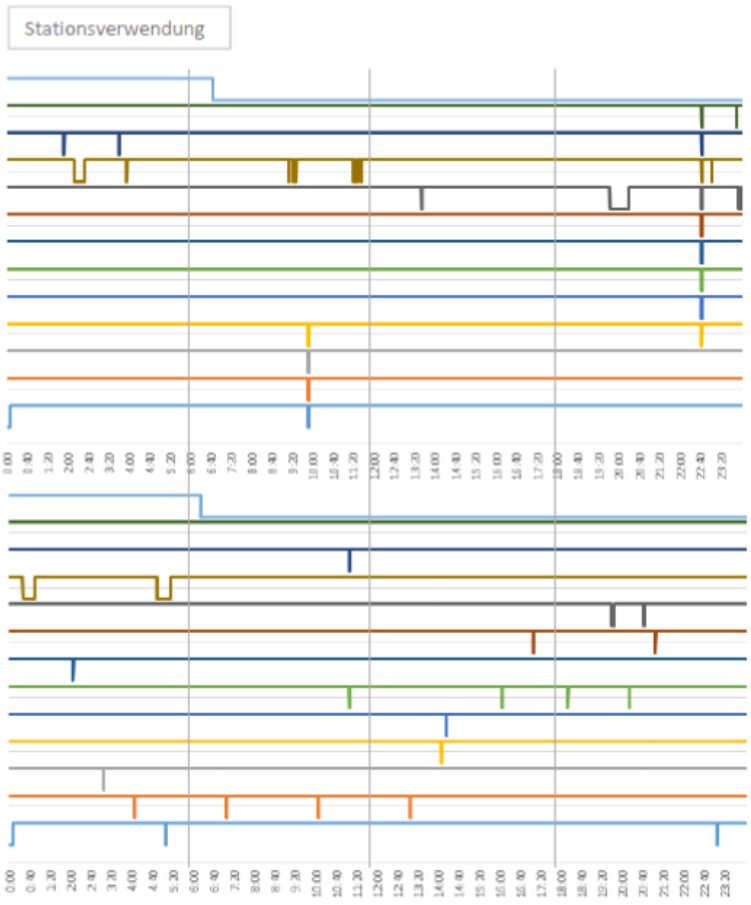
GREF Network

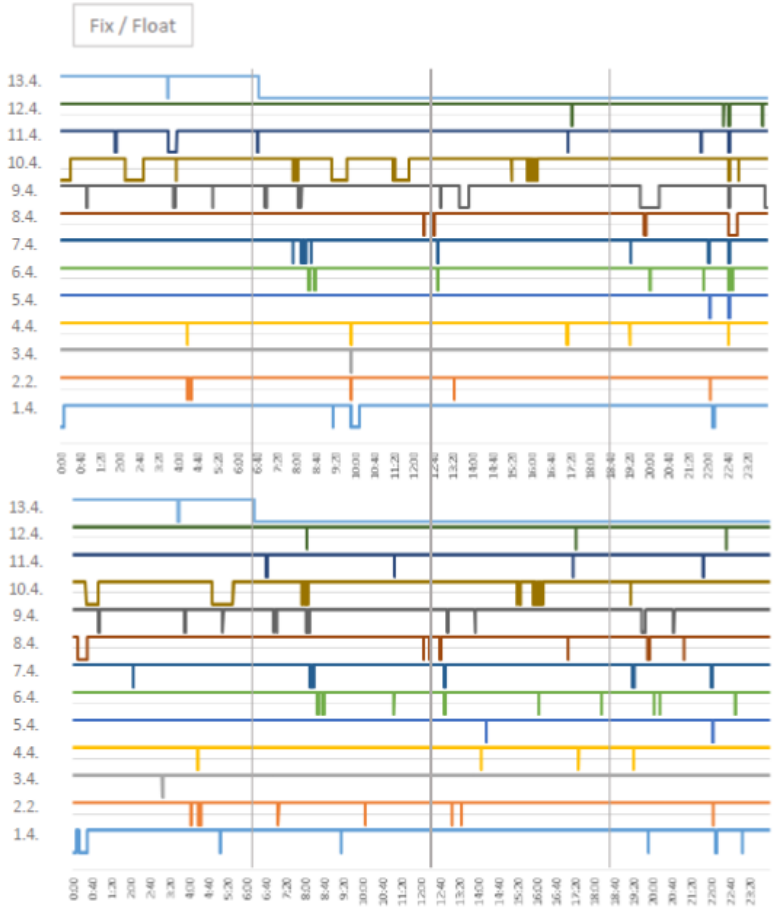




Station
ZIM20
Formataänderung auf MSM5 Keine Auswirkungen erkennbar Umstellung vermutlich am 14 .2.
FFMJ1
Periodenänderung der Stationsverwendung Periode von ca. 210, 17, 210, 17 min auf ca. 53, 17, 53, 17 min Umstellung in der Nacht vom 13. auf 14. Februar **Welche ?**

GREF Network





Station

SASS

9. und 10.4.
Keine Beobachtungen

~10:00 Restart ?

4.4. Änderung

Stromausfall https://heise.de/-4014125

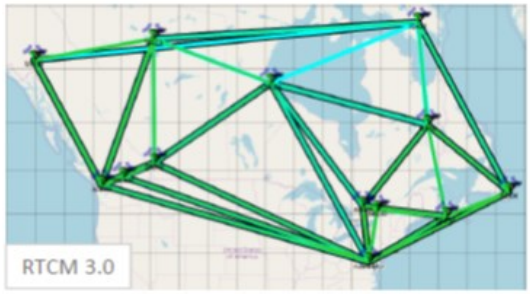
WARN

HB v26, 25

Baltic Sea Network

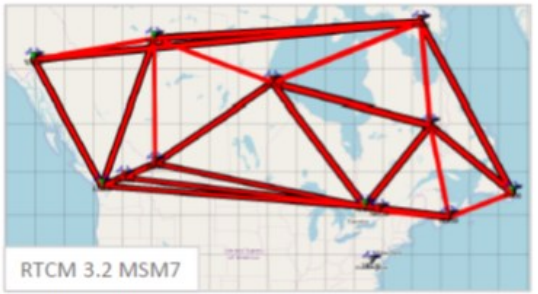
- Network with mixed messages
- Not able to get a stable fixed solution especially for MSM7 mount-points
- Most of the MSM7 streams are coming from one single conversion software – possible point of failure?

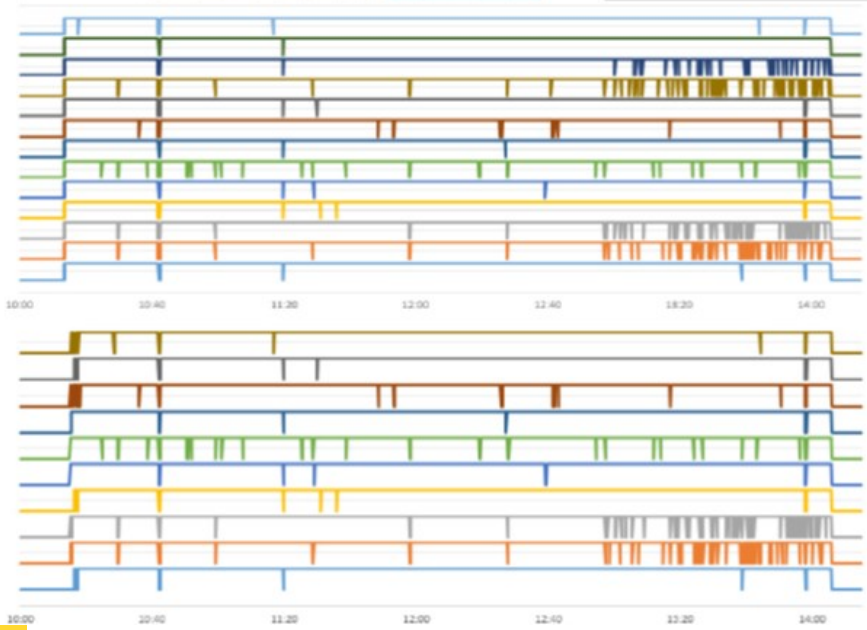
NRCan Network

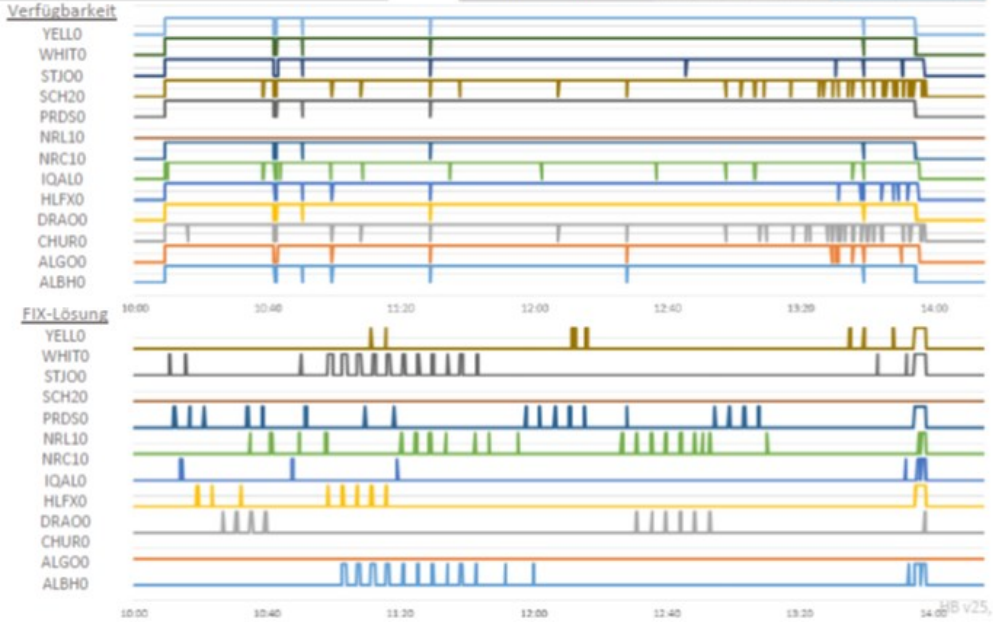


caster : 205.193.187.3
network : IGS
generator : NRCanRTCM
format : RTCM3.0, RTCM 3.2 (MSM7)

Erzeugung : Parallelbetrieb mit separaten BNC und RTNet Instanzen auf cassini



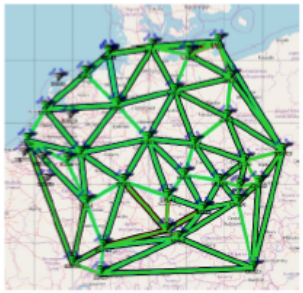




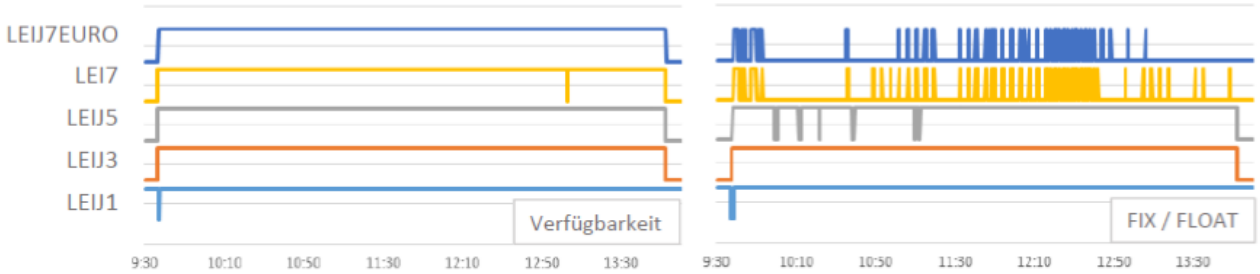
GREF Network

- Parallel implementation of five RTNet jobs with one mount-point (LEIJx) changed
  - LEIJ1: JAVAD TRE_G3TH Delta, RTCM3.0, converted from LEIJ0 JPS-RAW format by so-called NtripS13 box
  - LEIJ3: LEICA GRX1200+GNSS, RTCM3.0, from receiver
  - LEIJ5: JAVAD TRE_G3TH Delta, RTCM3.2 MSM5, converted from LEIJ0 JPS-RAW format by so-called NtripS13 box
  - LEIJ7: JAVAD TRE_G3TH Delta, RTCM3.2 MSM7, converted from LEIJ0 JPS-RAW format by so-called NtripS13 box
  - LEIJ7EURO: JAVAD TRE_G3TH Delta, RTCM3.2 MSM7, converted from LEIJ0 JPS-RAW format by software EURONET

GREF Network



Parallelbetrieb des Stationsnetzes mit separaten RTNet Instanzen und den unterschiedlichen LEIJ-Strömen



Realtime GNSS Software RTNet output (DEBUG)		LEIJ1	LEIJ3	LEIJ5	LEIJ7	LEIJ7EURO
Empfänger		JAVAD TRE_G3TH Delta	LEICA GRX1200+GNSS	JAVAD TRE_G3TH Delta	JAVAD TRE_G3TH Delta	JAVAD TRE_G3TH Delta
Stream-Format		RTCM3.0	RTCM3.0	RTCM3.2, MSM5	RTCM3.2, MSM7	RTCM3.2, MSM7
Erstellung		basierend auf Ntrip$13-Box + LEIJ0 (JPS-RAW)	basierend auf Empfänger	basierend auf Ntrip$13-Box + LEIJ0 (JPS-RAW)	basierend auf Ntrip$13-Box + LEIJ0 (JPS-RAW)	basierend auf EUREF-Software + LEIJ0 (JPS-RAW)
Beobachtungen - GPS-Satellit		2 5 7 8 9 13 15 20 21 27 28 30	5 7 8 9 13 15 20 21 27 28 30	2 5 7 8 9 13 15 20 21 27 28 30	2 5 7 8 9 13 15 20 21 27 28 30	2 5 7 8 9 13 15 20 21 27 28 30
obs marked out: mis_marked						
obs marked out: ele_marked						
obs marked out: orb_com_marked						
Verwendete Beobachtungen in Epochenlösung						
cycleslips (reported by receiver) [frq]						
10:57:40	58164,456713	1		1	1 125 12	1 12 125 12
10:57:50	58164,456829	1		1	1 125 12	1 125 12
10:58:00	58164,456944	1			1 12 12	1 12
10:58:10	58164,457060	1		1	1	1
10:58:20	58164,457176	1			1 12	1 12
10:58:30	58164,457292	1			1	1
10:58:40	58164,457407	1			1 12 12 125	1 12 12 125
10:58:50	58164,457523	1			1 12 5	1 12 125
10:59:00	58164,457639	1			1 125 12	1 125
10:59:10	58164,457755	1		1	1 12	1 12
10:59:20	58164,457870	1		1	1 12	1 12
10:59:30	58164,457986	1			1	1
10:59:40	58164,458102	1			1 12	1 12
10:59:50	58164,458218				12 125 12	12 12 125 12

RTCM MSM Specifications

RTCM 10403.3 — Table 3.5-72. Contents of the MSM Message Types

	DATA FIELD	MSM1	MSM2	MSM3	MSM4	MSM5	MSM6	MSM7
Satellite Data	The number of integer milliseconds in GNSS Satellite rough ranges				DF397	DF397	DF397	DF397
	Extended Satellite Information					*		*
	GNSS Satellite rough ranges modulo 1 millisecond	DF398	DF398	DF398	DF398	DF398	DF398	DF398
	GNSS Satellite rough Phaserange Rates					DF399		DF399
Signal Data	GNSS signal fine Pseudoranges	DF400		DF400	DF400	DF400	DF405[1]	DF405[1]
	GNSS signal fine Phaserange data		DF401	DF401	DF401	DF401	DF406[1]	DF406[1]
	GNSS Phaserange Lock Time Indicator		DF402	DF402	DF402	DF402	DF407[1]	DF407[1]
	Half-cycle ambiguity indicator		DF420	DF420	DF420	DF420	DF420	DF420
	GNSS signal CNRs				DF403	DF403	DF408[1]	DF408[1]
	GNSS signal fine Phaserange Rates					DF404		DF404

[1] With extended resolution * GNSS-specific field

DF402 GNSS Phaserange Lock Time Indicator

LOC Loss of Continuity

Loss of lock detection:
p = Minimum Lock Time in milliseconds, as reconstructed at previous epoch
n = Minimum Lock Time in milliseconds, as reconstructed at current epoch
dt = Time Interval in milliseconds between current epoch and previous epoch

if (p > n)		LOC
if (p = n)	and (dt ≥ p)	LOC
if (p = n)	and (dt < p)	ok, tracking was continuous
if (p < n)	and (dt ≥ (2n-p))	LOC
if (p < n)	and (n < dt < (2n-p))	LOC (possible)
if (p < n)	and (dt ≤ n)	ok, tracking was continuous

DF407 GNSS Phaserange Lock Time Indicator with Extended Range and Resolution

Loss of lock detection:
p = Minimum Lock Time in milliseconds, as reconstructed at previous epoch
n = Minimum Lock Time in milliseconds, as reconstructed at current epoch
a = Supplementary Coefficient, as reconstructed at previous epoch
b = Supplementary Coefficient, as reconstructed at current epoch
dt = Time Interval in milliseconds between current epoch and previous epoch

(Some combinations of (p,n,dt) are not possible. The algorithms provided below do not explicitly check for such inconsistencies.)

if (p > n)			LOC
if (p = n)	and (dt ≥ a)		LOC
if (p = n)	and (dt < a)		ok, tracking was continuous
if (p < n)	and (b > p)	and (dt ≥ (n+b-p))	LOC
if (p < n)	and (b > p)	and (n < dt < (n+b-p))	LOC (possible)
if (p < n)	and (b > p)	and (dt ≤ n)	ok, tracking was continuous
if (p < n)	and (b ≤ p)	and (dt > n)	LOC
if (p < n)	and (b ≤ p)	and (dt ≤ n)	ok, tracking was continuous

Conclusions

- Handling of Lock Time Indicator within RTNet software to be refined (default values not optimal)
- From scientific point of view, MSM7 seems to be the best possible with the most information
- From operational point of view, MSM5 might be adequate for network processing, e.g. within IGS RTS
- Internet connection seems to be an under-estimated factor for GNSS real-time processing (same holds for the PC)
- Implementation of multiple, parallel casters for different message types seems to be useful (e.g. Sweden, Canada)

Thank you for your kind attention!

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