RINEX Observation Analysis

3PfD

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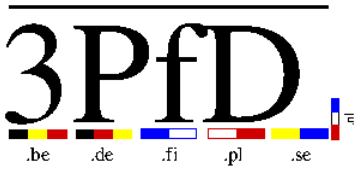
RMA – CISS, M3Systems SPRL



May 4, 2021

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1 Experiment basic information

- **Operators**
  - Pascal De Kimpe
  - Avag Tsaturyan
- **Location / Date**
  - RMA LAB H local 50/14
  - 14 December 2020

- **Short description of Experiment**
  - Set-up
    * RFI jamming on GAL E1 PRS code with 64QAM & CST signals wide bandwidth
    * preservation of Galileo E6 PRS
    * Jammer is VST generator from M3systems and Recorder with Stella Software
    * Laboratory setup using Directionnal coupleur and Splitter Amplifier
  - Receivers used
    * AsteRx SB
    * TURP
    * P3RS2
- **Log files**

AsteRX_SB TURP	H50_14DEC14JammingQAM64_0000.sbf BEGP349(K|L|O).20_.sbf
P3RS2	P3RS-2_RX_R_20203491039_15M_00U_MO.rnx
	P3RS-2_RX_R_20203491054_15M_00U_MO.rnx
	P3RS-2_RX_R_20203491409_15M_00U_MO.rnx
	P3RS-2_RX_R_20203491424_15M_00U_MO.rnx

2 Experiment set-up

Set-up of OS RFI jamming

Parameter	Value
- targeted navigation signal	- PRS E1A
	- GPS C/A @ L1
	- Galileo OS E1BC
- targeted frequency	L1/E1 @ 1575.42 MHz
- targeted bandwidth	40 MHz
- power of targeted signal(s)	$\pm$ (-127) dBm
Preserved navigation service	
- preserved navigation service	- Galileo PRS (single or dual band)
- preserved navigation signals	- PRS E6A
Receivers	TUR-P, P3RS2, AsteRx_SB
- start status	Warm using live signals (PNT & Ephemeris ok)
- logging frequency	1 Hz
- troposphere model	Saastamoinen
- ionosphere model	Klobuchar
Jamming scenario	
- jamming signal	CST @ L1 sweep time $\pm 100 \mu s$, BW 40 MHz, increase power
- interference power	[-100 : 3 : -77 : 2 : - 59 : 1 : -40] dBm
- interference timing	[20 : 10 : 10]
- RFI Start Time	14:10:01
- RFI Scenario file	CST-jamming.csv
Location	
- RMA Antenna	50.8440152778N / 4.3929283333E / 151.39179

Parameter	Value
Metrics	
- Carrier-to-Noise	L1-C/A, Gal OS, Gal PRS E1 / E6
- number of satellites	in PNT fix
- loss of (first) satellites	time & duration
- loss of PNT	time & duration
- reacquisition of (first) satellites	time & duration
- reacquisition of PNT	time & duration
- AGC (automatic gain control)	if available
- PNT accuracy	log vs time
- recovery time or SINR level	time needed during or after scenario

3 Analysis of RINEX Observation file

3.1 Script details

3.1.1 Program information

Script : rnxobs_tabular.py
Run at : 04/05/2021 15:50
Run by : A. Muls
Royal Military Academy

3.1.2 Parameters

RINEX root directory : /home/amuls/RxTURP/RFI/CST/rnx/20349
RINEX observation file : TURX00BEL_R_20203491400_30M_01S_MO.rnx
RINEX version : 3.04
Marker : TURX00BEL
Year/day-of-year : 2020/349

3.1.3 Observation header information

First epoch : 2020/12/14 14:00:00
Last epoch : 2020/12/14 14:30:00
Interval : 1.0

GNSS : E (Galileo)
Frequencies E : 1, 6

Observable types : S (Pseudorange)
: C (SNR)
: D (Doppler)
: L (Carrier)

3.1.4 Logged observables

Observable types E : C1A, C6A, D1A, D6A, L1A, L6A, S1A, S6A

3.2 Analysis of observation statistics for Galileo

statistics observation file : TURX00BEL_R_20203491400_30M_01S_MO_E.obsstat

navigation signals : E1A, E6A

3.2.1 Observables count per navigation signal

The following table represents the number of observations made for each examined navigation signal. The percentages per navigation signal are calculated by dividing by the number of observations obtained from Two Line Elements (TLE) at the recorded interval. The last column represents the number of observations possible during the observed time interval.

PRN	E1A		E6A		TLE_count
E02	1518	84.3%	1801	100.1%	1800.0
E03	1423	79.1%	1801	100.1%	1800.0
E05	1442	80.1%	1801	100.1%	1800.0
E07	397	22.1%	347	19.3%	1800.0
E08	1482	82.3%	1801	100.1%	1800.0
E24	1414	78.6%	1801	100.1%	1800.0
E25	1426	79.2%	1801	100.1%	1800.0
E26	1354	75.2%	1801	100.1%	1800.0
E28	1238	---	1801	---	0

Figure 1 represents the absolute count of observables for each navigation signal set out against the maximum possible observations obtained from the TLEs. The relative observation count is represented in Figure 2.

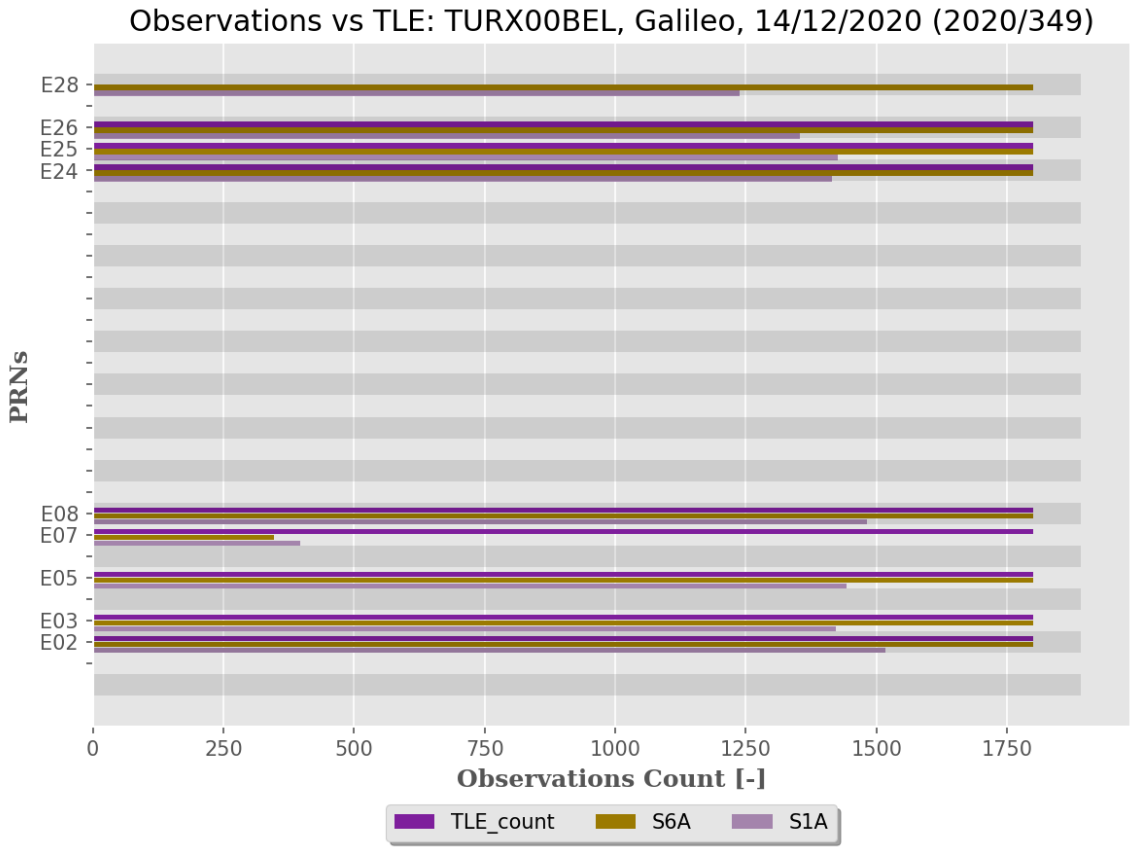


Figure 1: Observables overview for GNSS Galileo

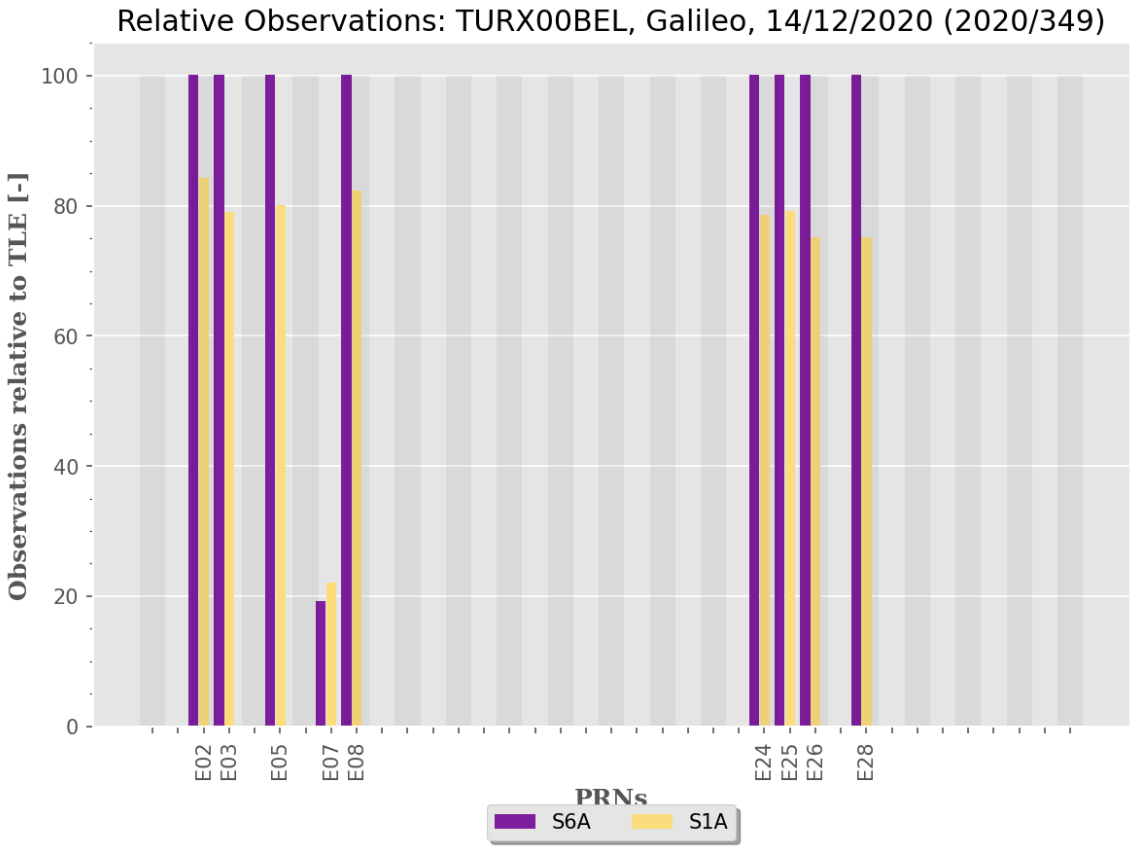


Figure 2: Relative observation count per navigation signal for GNSS Galileo

3.3 Detailed analysis of observation types per navigation signal for Galileo

Observation tabular file	:	TURX00BEL_R_20203491400_30M_01S_MO_E.obstab
Examined satellites	:	E02, E03, E05, E07, E08, E24, E25, E26, E28
Examined navigation signals	:	1A, 6A
Examined observables	:	S1A, S6A

3.3.1 TLE time spans

The table below represents the calculated rise and set times within the observation time span for a PRN based on the TLEs. When a culmination is within this interval, it is represented in the table.

PRN	tle_rise	tle_set	tle_cul	tle_arc_count
E02	14:00:00	14:30:00		1800.0
E03	14:00:00	14:30:00		1800.0
E05	14:00:00	14:30:00		1800.0
E08	14:00:00	14:30:00		1800.0
E24	14:00:00	14:30:00		1800.0
E25	14:00:00	14:30:00	14:17:37	1800.0
E26	14:00:00	14:30:00		1800.0
E28				
E07	14:00:00	14:30:00		1800.0

3.3.2 Navigation signals analysis for Galileo

Analysis of navigation signal E1A

1. Figure 3 represents the observed time span for navigation signal E1A set out against the maximum time span calculated from the Two Line Elements (TLE). If present, the culmination point for a satellite is represented by a triangle. The time span from TLEs is represented by the lighter area while the real observations are represented by the dark super-imposed areas.

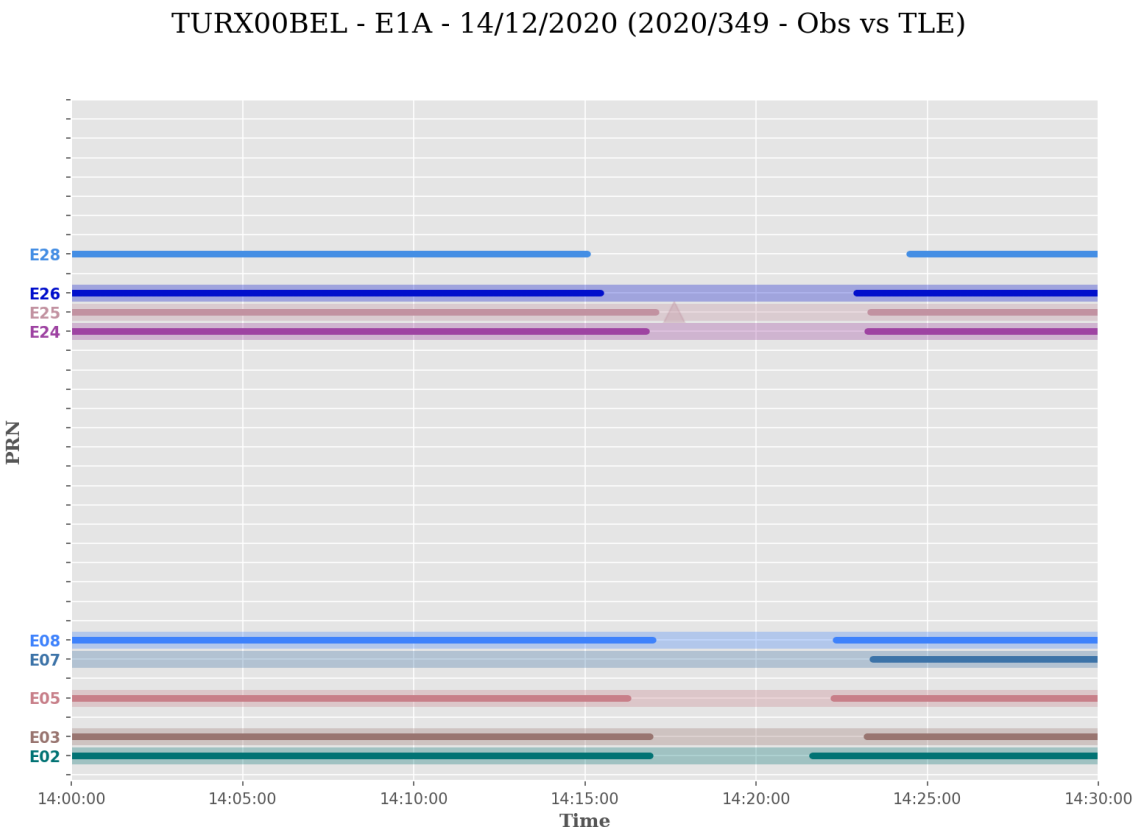


Figure 3: Navigation signal E1A versus TLE time span

2. Figure 4 displays the evolution of observation type S1A.
   The upper plot represents the variation of the observation type while the middle plot (if available) displays the variation of this observable between 2 consecutive epochs. The bottom plot displays the TLE time spans for the satellies.

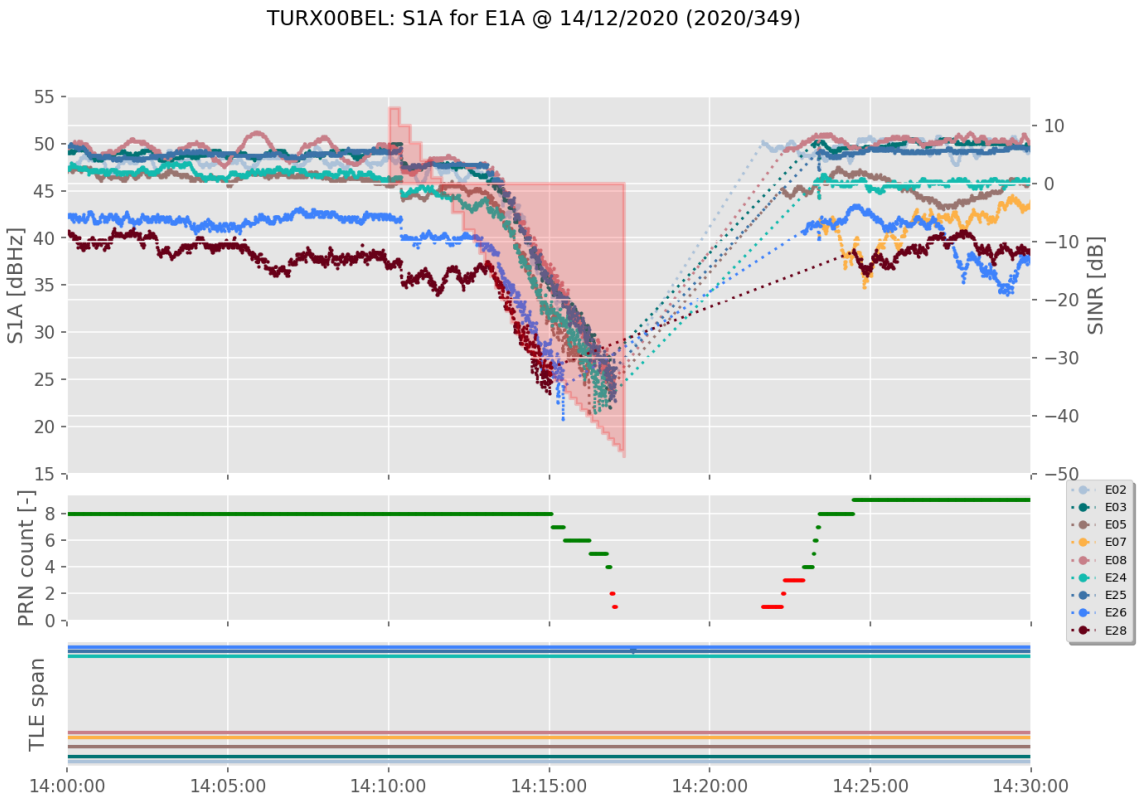


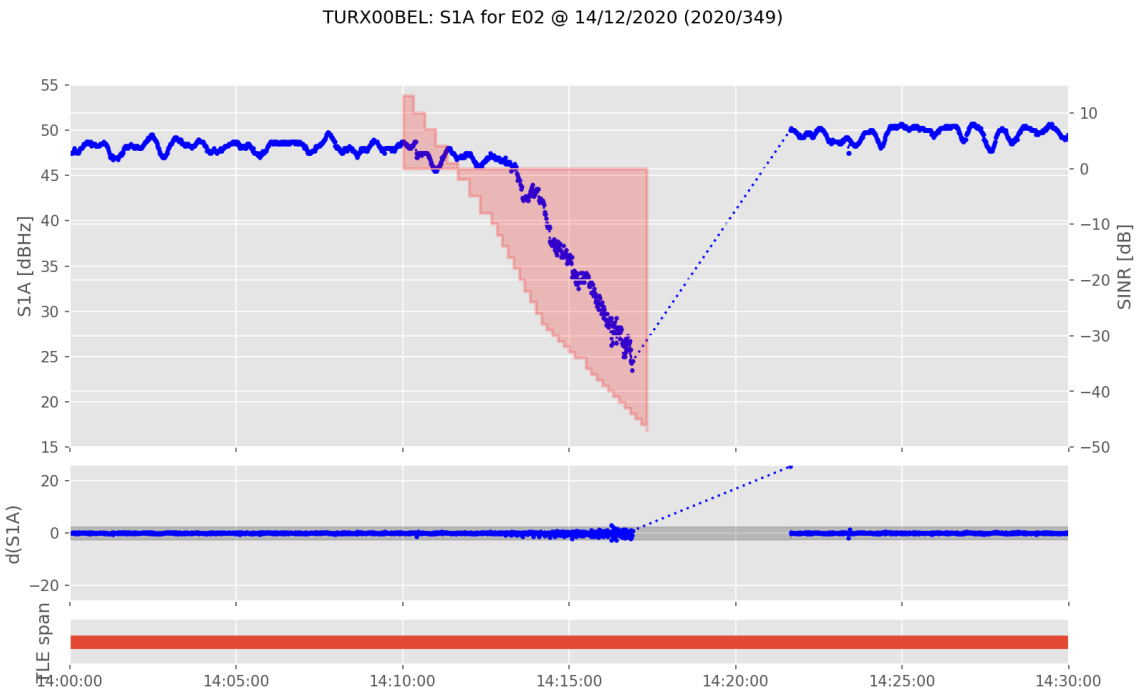
Figure 4: Navigation signal S1A evolution

The table below reports the loss and reacquisition of PNT for observable S1A.

Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:54	Loss	PNT	361.0	2020-12-14 14:22:55

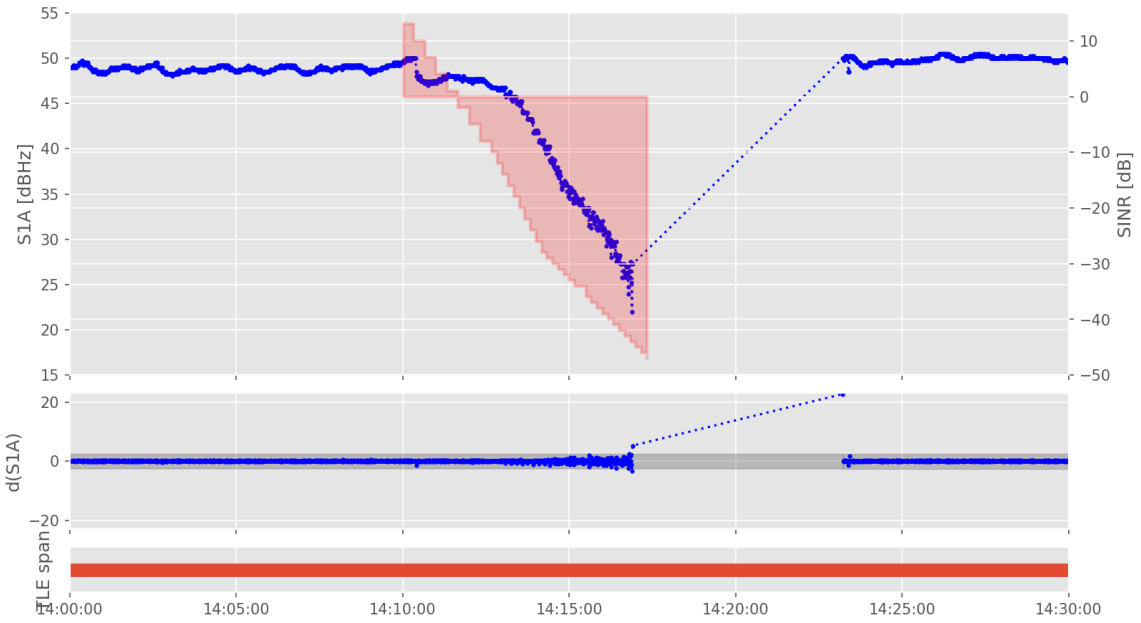
3. Analysis of navigation signal E1A for each observed satellite.
   ewline The following plots display the same information as described above per satellite. Each plot is accompanied by a table displaying the time of loss of lock and reacquisition of the satellite when such events are detected.



Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:54	Loss	E02	284.0	2020-12-14 14:21:38

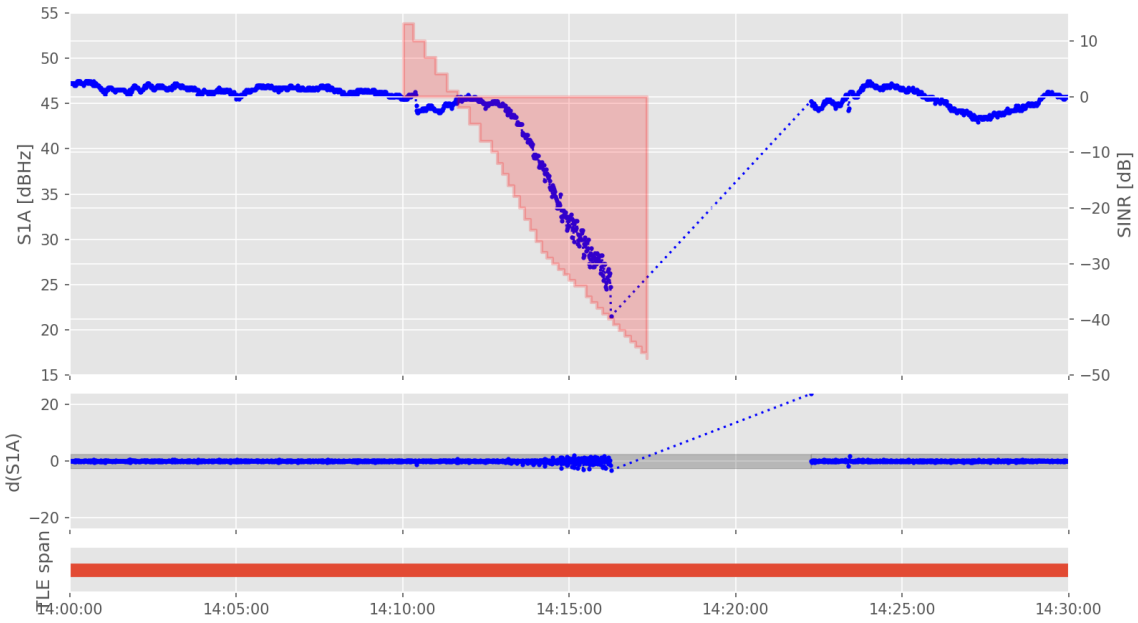
TURX00BEL: S1A for E03 @ 14/12/2020 (2020/349)



Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:54	Loss	E03	379.0	2020-12-14 14:23:13

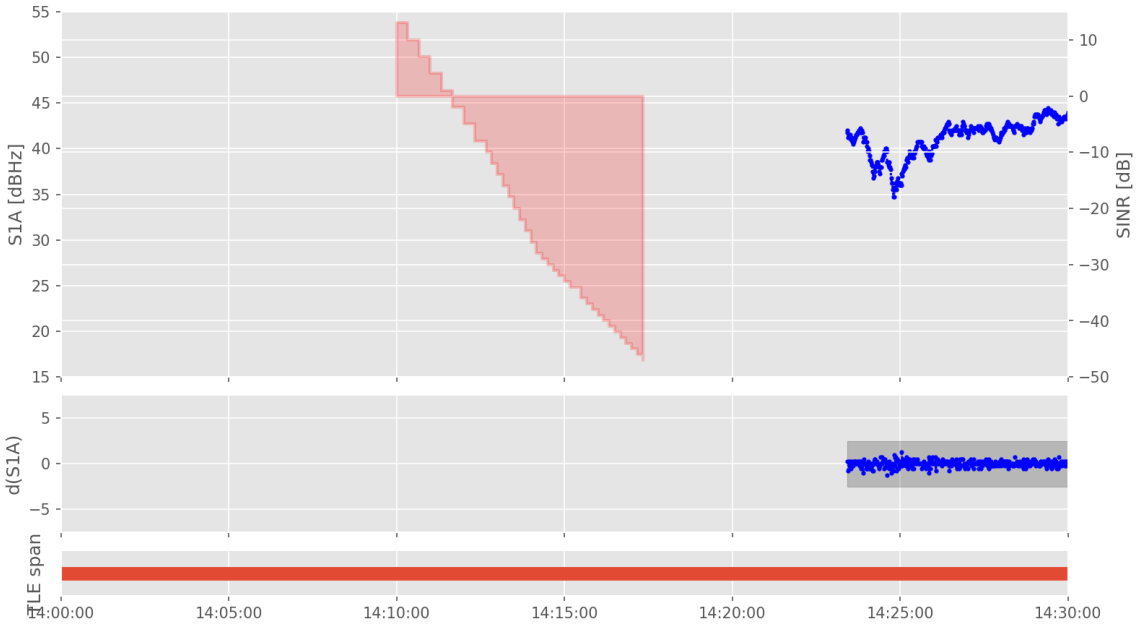
TURX00BEL: S1A for E05 @ 14/12/2020 (2020/349)



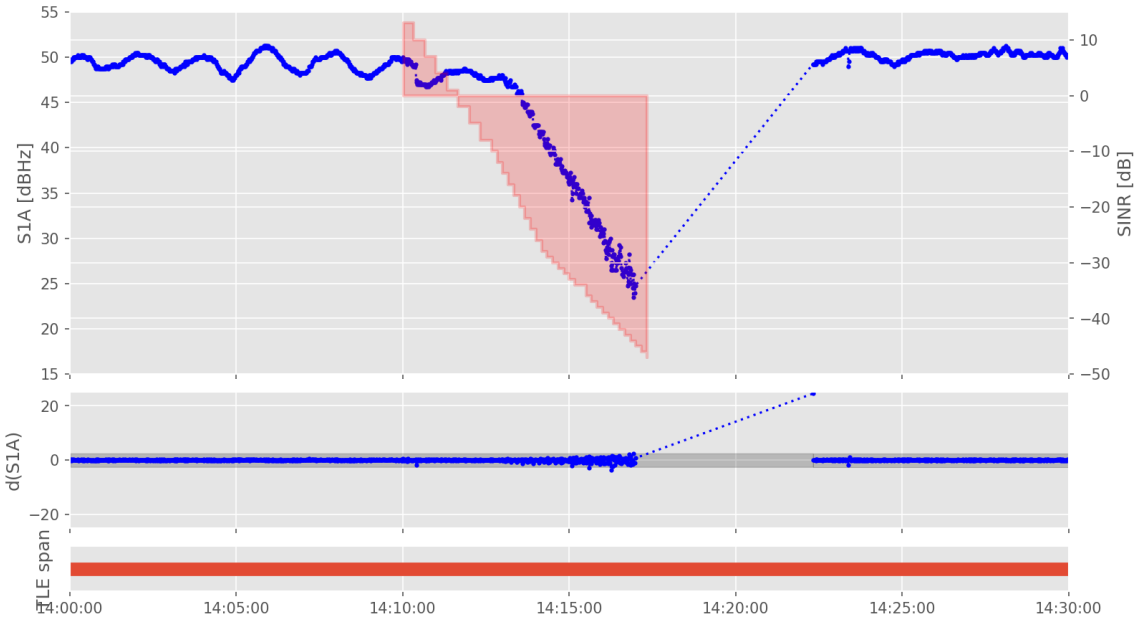
Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:15	Loss	E05	360.0	2020-12-14 14:22:15

TURX00BEL: S1A for E07 @ 14/12/2020 (2020/349)

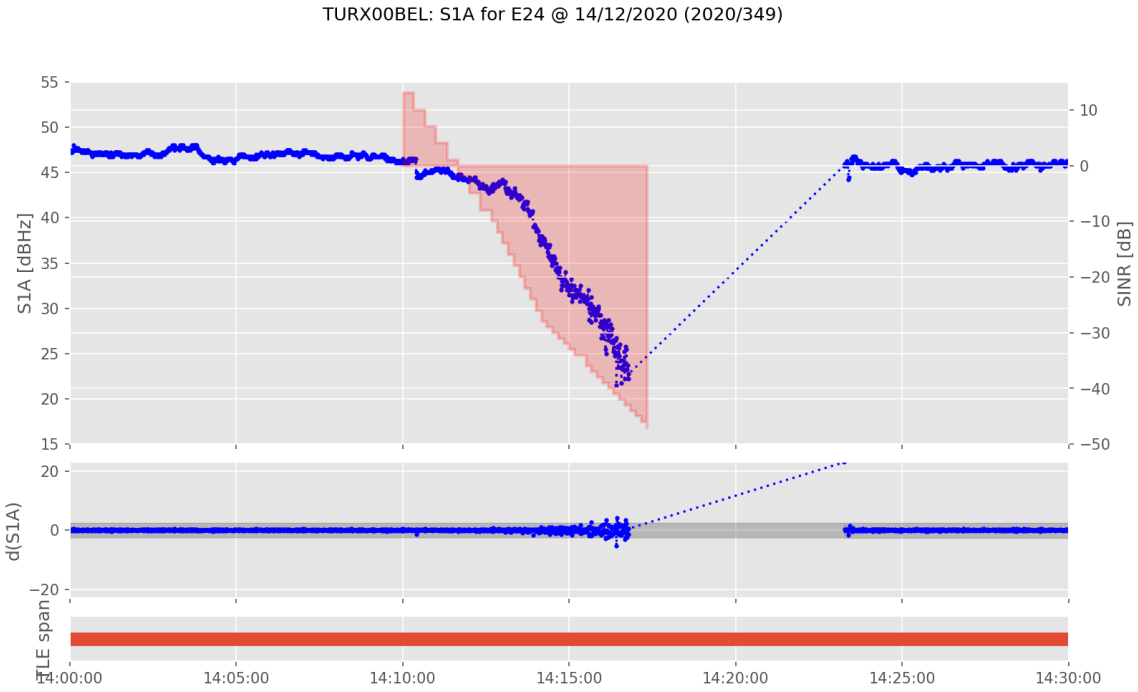


TURX00BEL: S1A for E08 @ 14/12/2020 (2020/349)



Navigation signal 1A

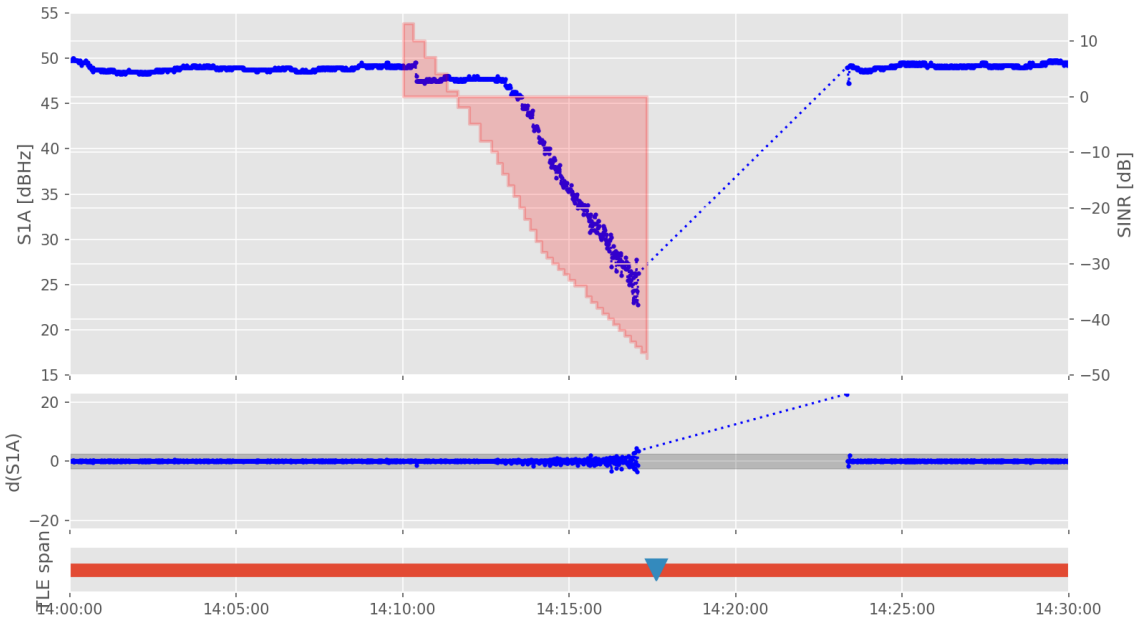
DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:59	Loss	E08	320.0	2020-12-14 14:22:19



Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:16:47	Loss	E24	388.0	2020-12-14 14:23:15

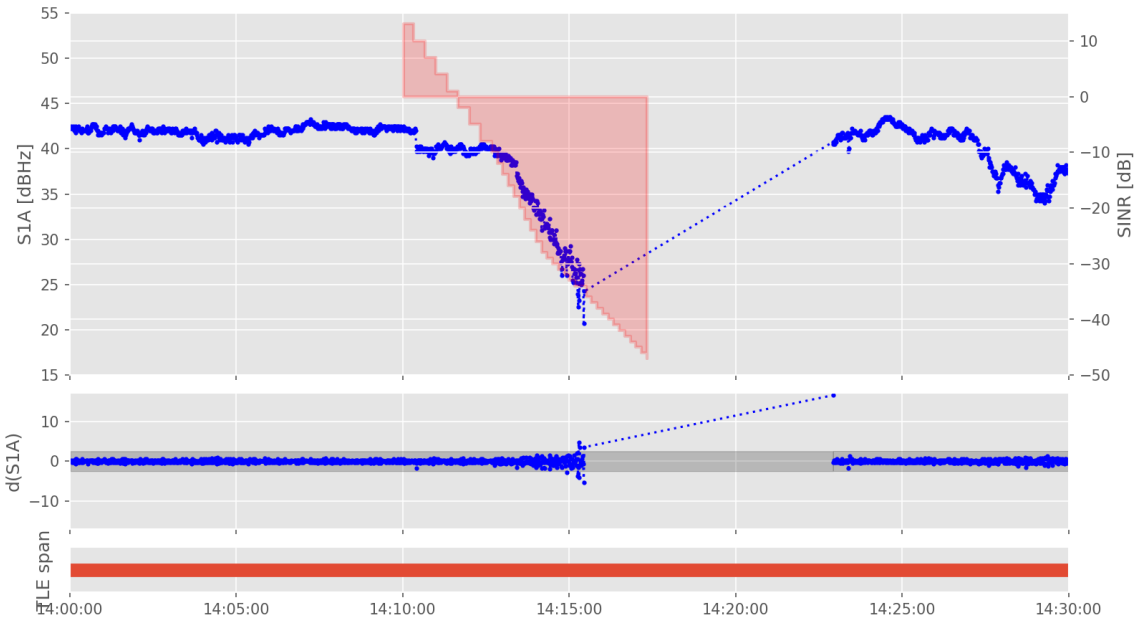
TURX00BEL: S1A for E25 @ 14/12/2020 (2020/349)



Navigation signal 1A

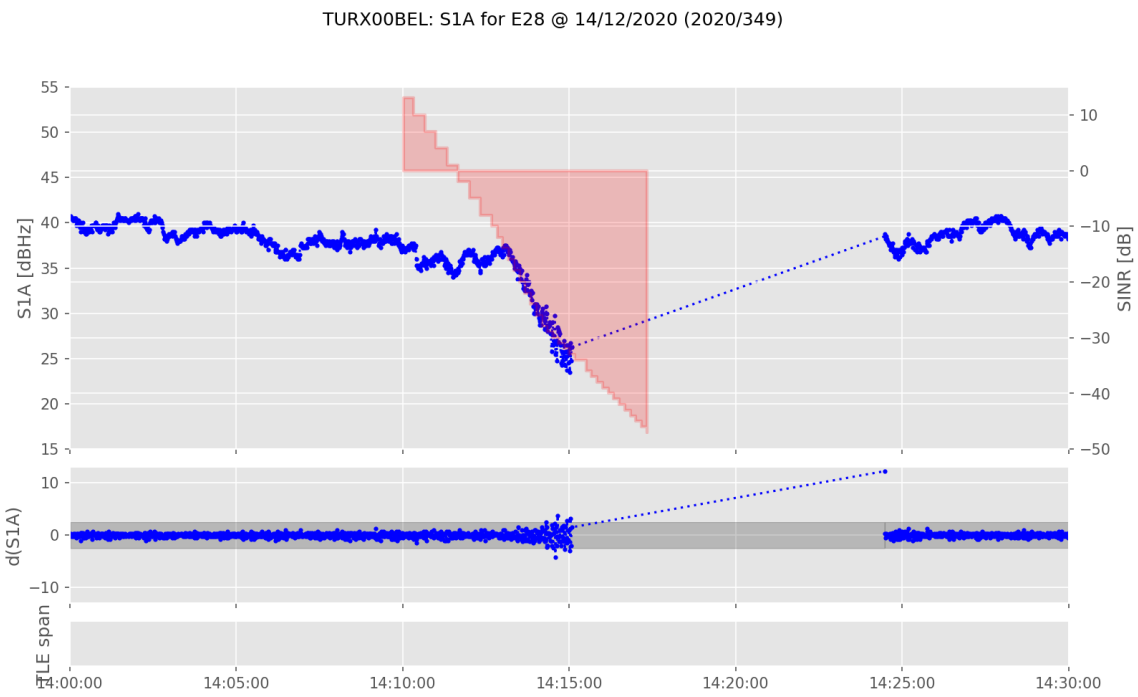
DATE_TIME	event	type	duration	reacq
2020-12-14 14:17:04	Loss	E25	376.0	2020-12-14 14:23:20

TURX00BEL: S1A for E26 @ 14/12/2020 (2020/349)



Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:15:27	Loss	E26	448.0	2020-12-14 14:22:55



Navigation signal 1A

DATE_TIME	event	type	duration	reacq
2020-12-14 14:15:04	Loss	E28	564.0	2020-12-14 14:24:28

4. Chronological overview of detected events for navigation signal E1A

Navigation signal 1A

DATE_TIME	event	type	duration
2020-12-14 14:15:04	Loss	E28	564.0
2020-12-14 14:15:27	Loss	E26	448.0
2020-12-14 14:16:15	Loss	E05	360.0
2020-12-14 14:16:47	Loss	E24	388.0
2020-12-14 14:16:54	Loss	PNT	361.0
2020-12-14 14:16:54	Loss	E02	284.0
2020-12-14 14:16:54	Loss	E03	379.0
2020-12-14 14:16:59	Loss	E08	320.0
2020-12-14 14:17:04	Loss	E25	376.0

Continued on Next Page

Navigation signal 1A

DATE_TIME	event	type	duration
2020-12-14 14:21:38	Reacquisition	E02	nan
2020-12-14 14:22:15	Reacquisition	E05	nan
2020-12-14 14:22:19	Reacquisition	E08	nan
2020-12-14 14:22:55	Reacquisition	PNT	nan
2020-12-14 14:22:55	Reacquisition	E26	nan
2020-12-14 14:23:13	Reacquisition	E03	nan
2020-12-14 14:23:15	Reacquisition	E24	nan
2020-12-14 14:23:20	Reacquisition	E25	nan
2020-12-14 14:24:28	Reacquisition	E28	nan

Analysis of navigation signal E6A

1. Figure 5 represents the observed time span for navigation signal E6A set out against the maximum time span calculated from the Two Line Elements (TLE). If present, the culmination point for a satellite is represented by a triangle. The time span from TLEs is represented by the lighter area while the real observations are represented by the dark super-imposed areas.

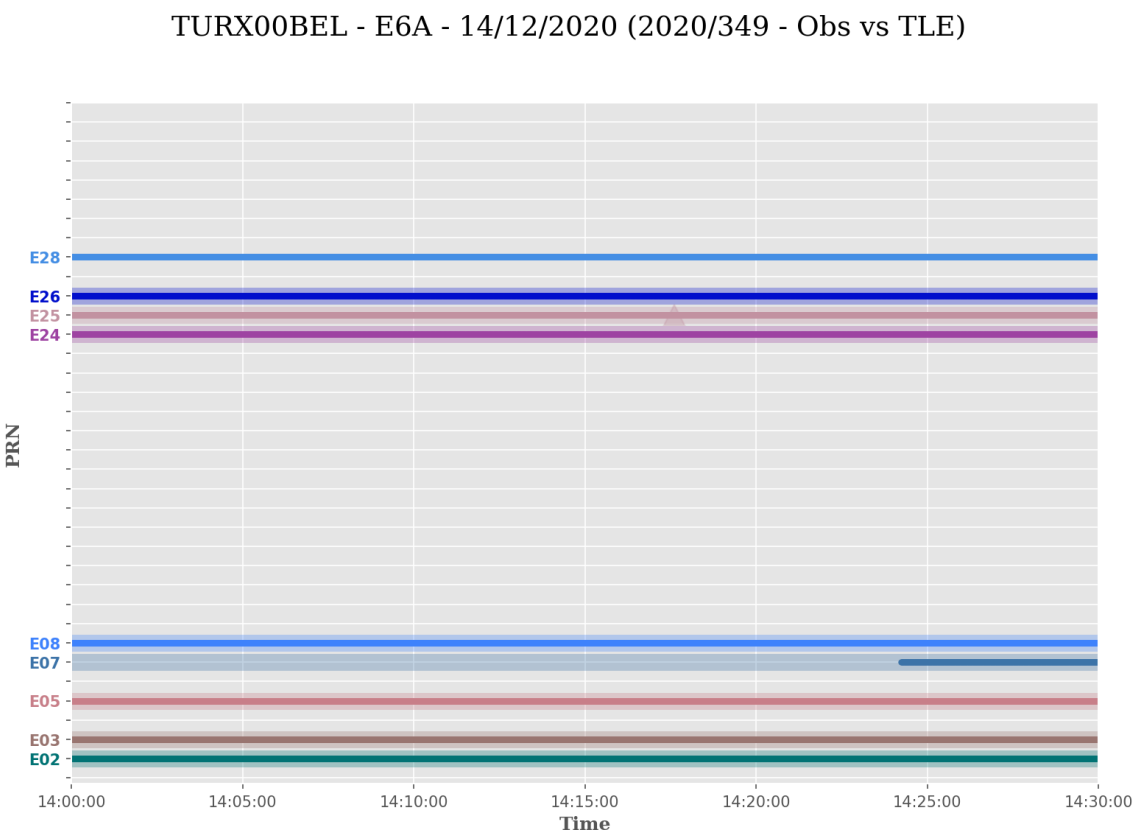


Figure 5: Navigation signal E6A versus TLE time span

2. Figure 6 displays the evolution of observation type S6A.
   The upper plot represents the variation of the observation type while the middle plot (if available) displays the variation of this observable between 2 consecutive epochs. The bottom plot displays the TLE time spans for the satellies.

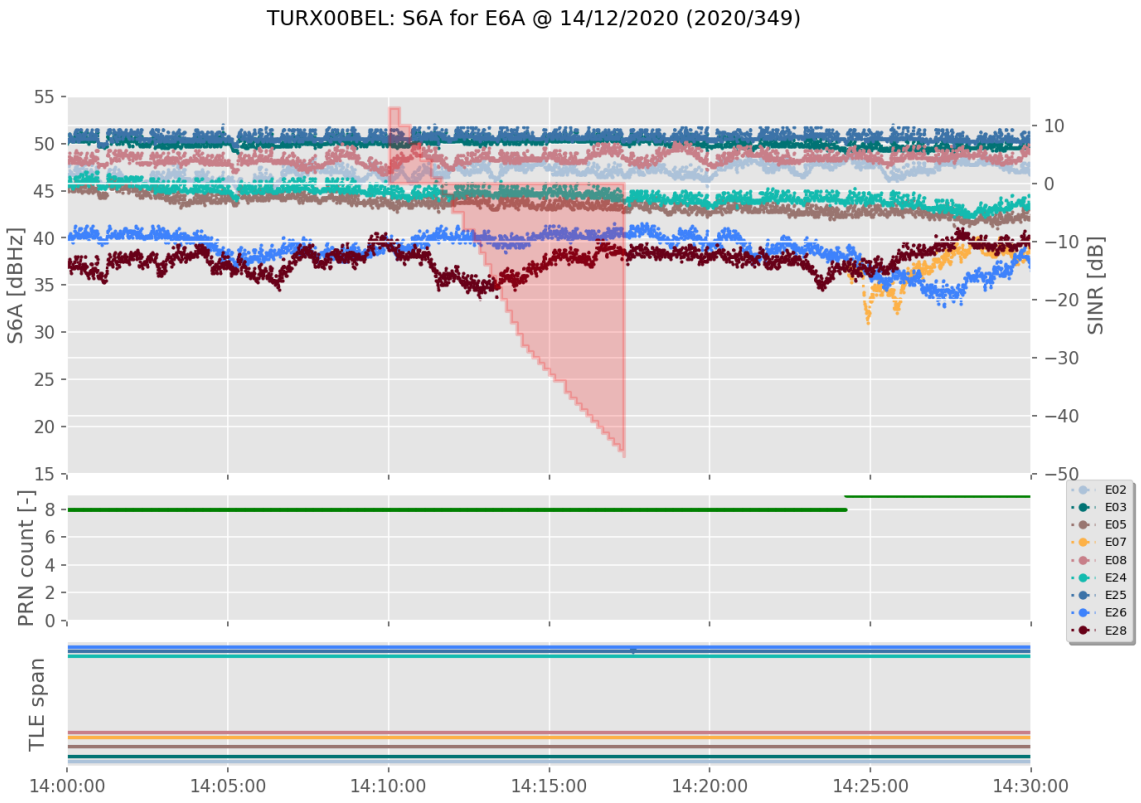
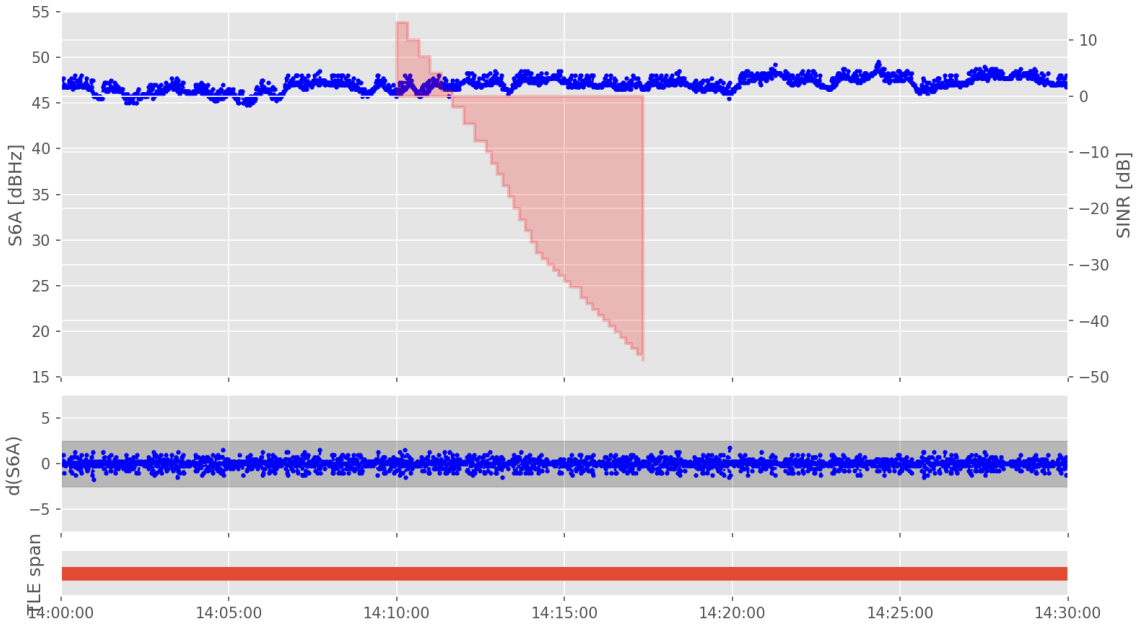


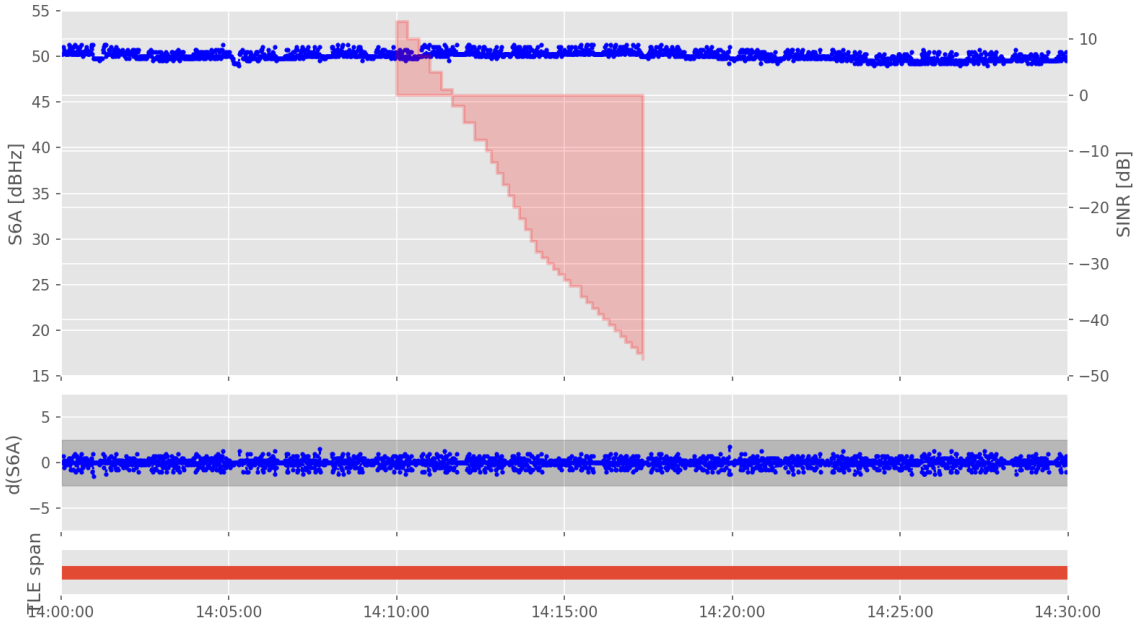
Figure 6: Navigation signal S6A evolution

3. Analysis of navigation signal E6A for each observed satellite.
   ewline The following plots display the same information as described above per satellite. Each plot is accompanied by a table displaying the time of loss of lock and reacquisition of the satellite when such events are detected.

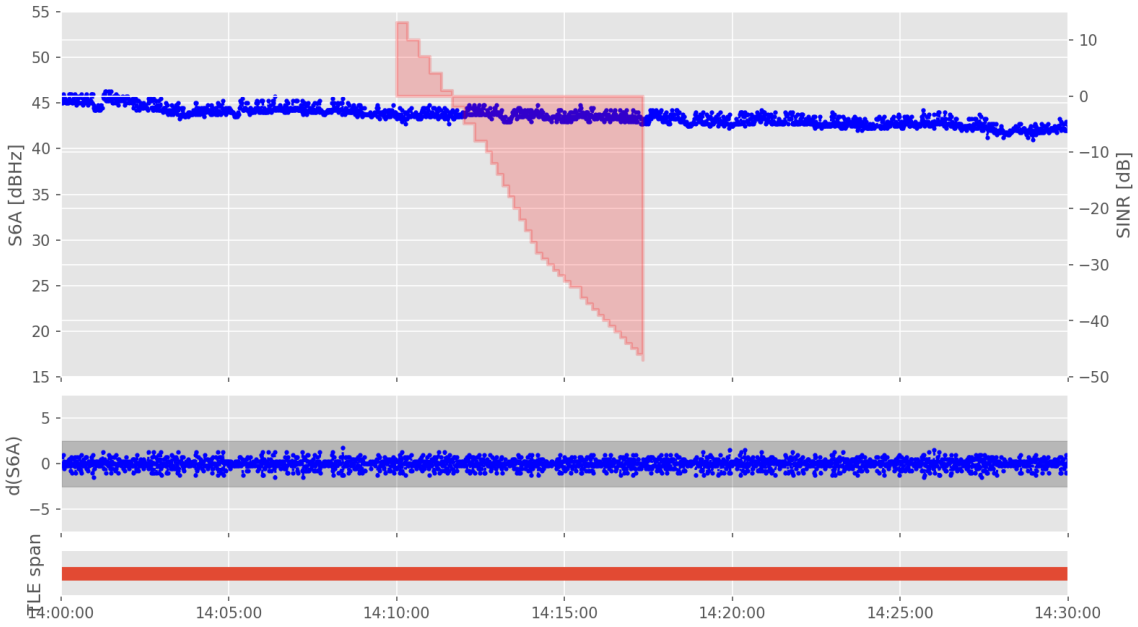
TURX00BEL: S6A for E02 @ 14/12/2020 (2020/349)



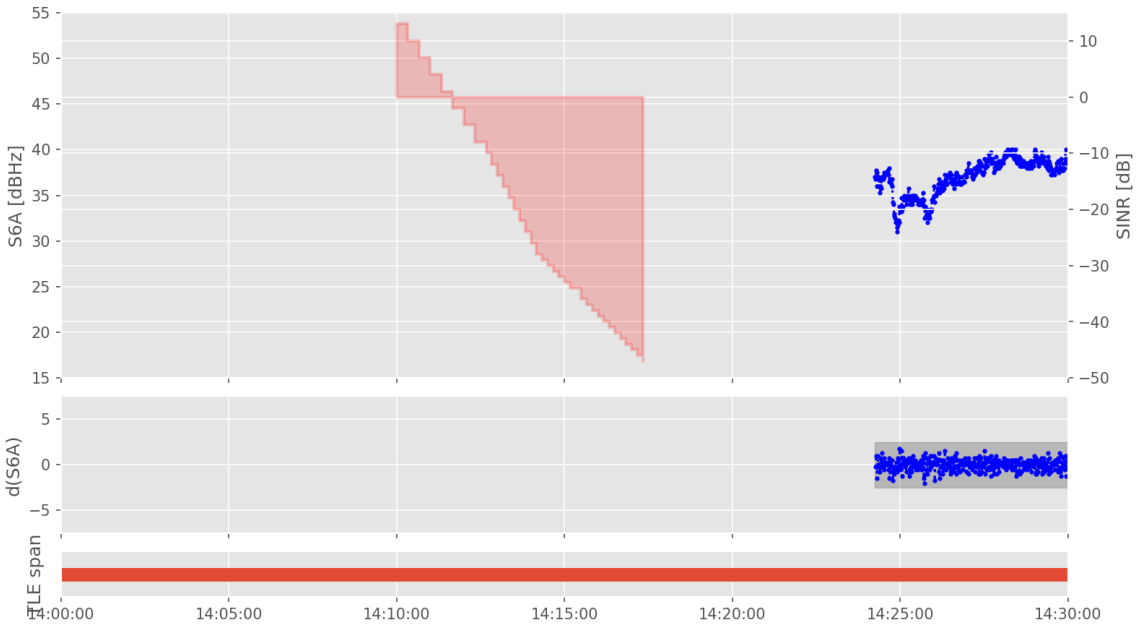
TURX00BEL: S6A for E03 @ 14/12/2020 (2020/349)



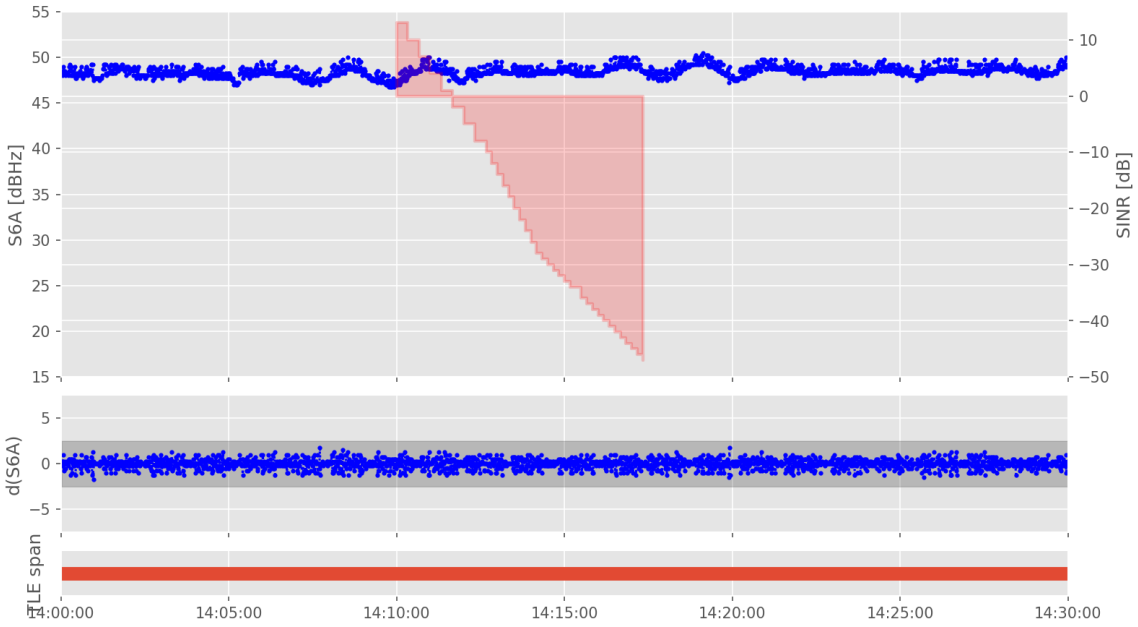
TURX00BEL: S6A for E05 @ 14/12/2020 (2020/349)



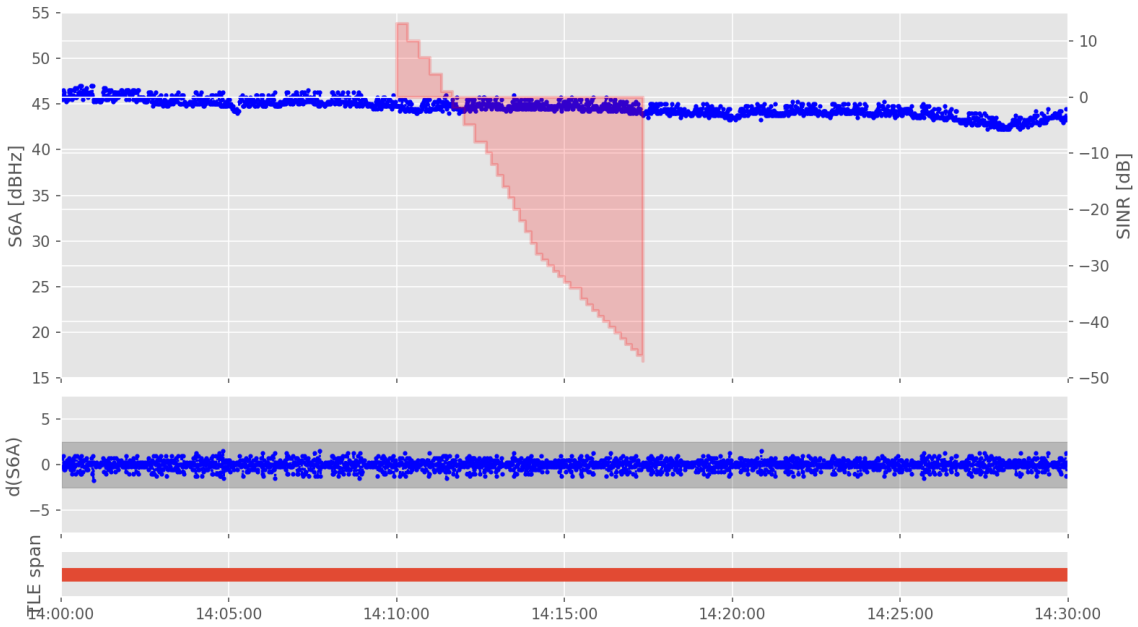
TURX00BEL: S6A for E07 @ 14/12/2020 (2020/349)



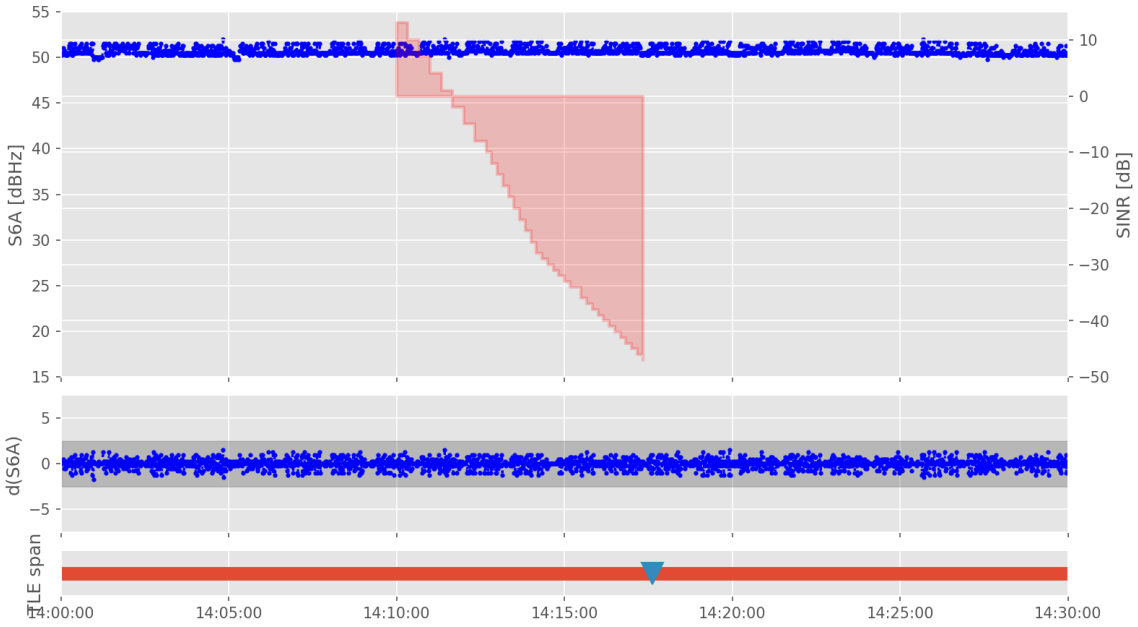
TURX00BEL: S6A for E08 @ 14/12/2020 (2020/349)



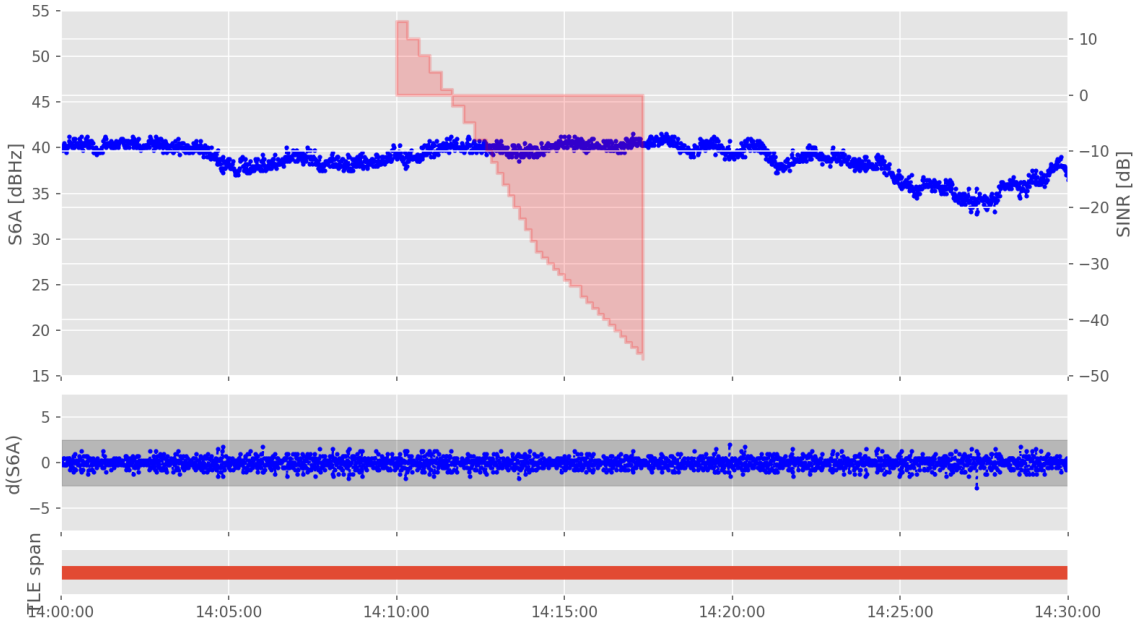
TURX00BEL: S6A for E24 @ 14/12/2020 (2020/349)

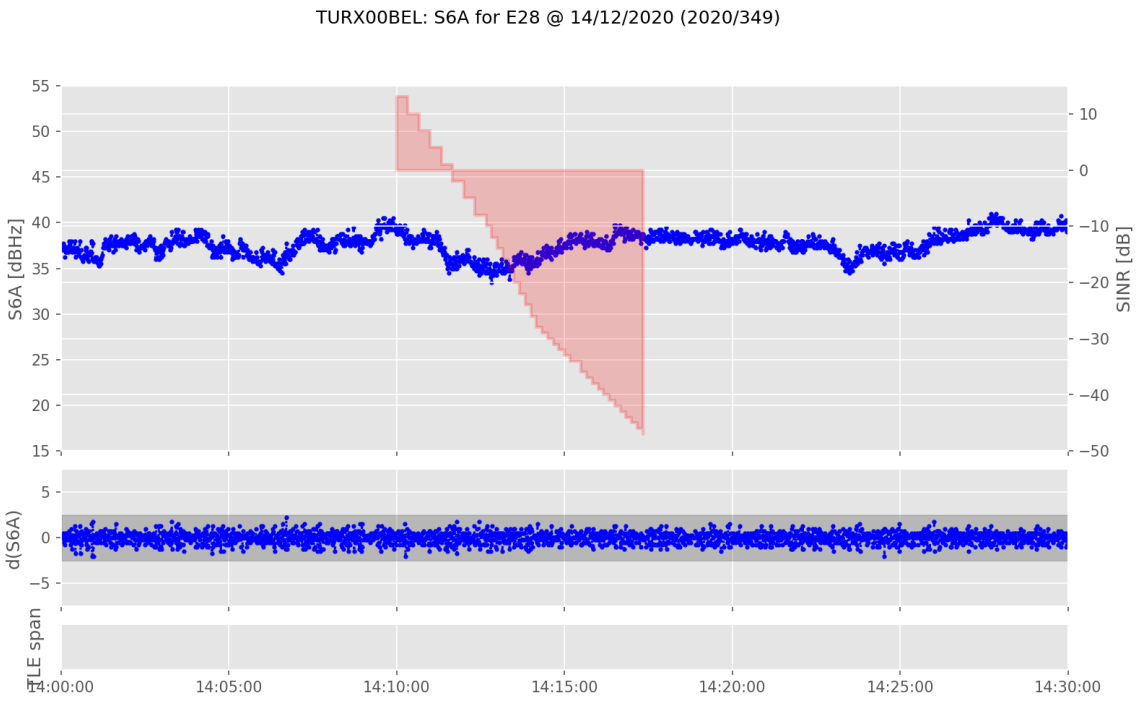


TURX00BEL: S6A for E25 @ 14/12/2020 (2020/349)



TURX00BEL: S6A for E26 @ 14/12/2020 (2020/349)




TURX00BEL: S6A for E28 @ 14/12/2020 (2020/349)
S6A [dBHz]
SINR [dB]
d(S6A)
TLE span
14:00:00
14:05:00
14:10:00
14:15:00
14:20:00
14:25:00
14:30:00