	OPEN ETCS	

openETCS “CalculateTrainPositon” implementation
Test Scenario “3_linked_2_unlinkedBGs”

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1.1 REFERENCES

UNISIG Subset_026 version_3.3.0

Chapter 3.6 : Location Principles, Train Position and Train Orientation

1.2 INTENTION

This document illustrates the behaviour of the SCADE model “CalculateTrainPosition” https://github.com/openETCS/modeling/tree/master/model/Scade/System/ObuFunctions/ManageLocationRelatedInformation/TrainPosition/CalculateTrainPosition implementing the calculations according to https://github.com/openETCS/SRS-Analysis/blob/master/System%20Analysis/WorkingRepository/Group4/SUBSET_26_3-6/DetermineTrainLocationProcedures.docx .

As a showcase serves a train trip on a track equipped with 3 linked balise groups (BGs) and 2 unlinked BGs in between.

All visualized data have been produced by executing the SCADE model implementation, storing the results into an Excel sheet and generating diagrams from there.

2. TEST SCENARIO GENERATION

2.1 TEST MODEL

The CalculateTrainPosition function is stimulated by the test model environment at https://github.com/openETCS/modeling/tree/master/model/Scade/System/ObuFunctions/ManageLocationRelatedInformation/TrainPosition/CalculateTrainPosition/ctp_t.

It moves the train along the track by generating model inputs for

- Odometry
- Time
- Track description with balise groups
- Train properties, national and default values

The following paragraphs describe the details.

2.2 ODOMETRY

The odometry data generation is based upon the, exact and correct "true" train position pos_{true}. pos_{true} is not affected by any inaccuracies.

The test case increments the position by 100 cm with each clock.

$$pos_{true}(i+1) = pos_{true}(i) + 100\ cm$$

The simulated odometry of the test model converts pos_{true} into an inaccuracy afflicted value set via the following exemplary transfer function:

$$odometry = 1.02^{+0.03}_{-0.04} * pos_{true} = nominal^{max}_{min} * pos_{true}$$

The odometry induces a nominal value with +2% deviation from pos_{true}, an upper inaccuracy of + 5% and a lower inaccuracy of -2%. Practically, this odometry setting tends to overestimate.

Note:
The CalculateTrainPosition function itself receives the odometry inputs only, not os_{true} !

2.3 TRACK DESCRIPTION

The track generated by the test model is characterized by the following BGs:

BG 001:		
NID_BG	1	
pos_{true}	100000 cm	= 1.000 km
centerDetectionInaccuracies	0.0^{+10}_{-10}	± 10 cm
Q_LINK	Linked	
NoCoordinateSystemHasBeenAssigned	False	
Q_DIRLRBG	Nominal	
Q_DIRTRAIN	Nominal	

Linked BG 003:		Announced by BG 001
Q_DIR	Nominal	
Q_SCALE	10 cm	
D_LINK	20000	= 2.000 km
NID_BG	3	
Q_LINKORIENTATION	Nominal	
Q_LOCACC	2	
Linked BG 005:		Announced by BG 001
Q_DIR	Nominal	
Q_SCALE	10 cm	
D_LINK	20000	= 2.000 km
NID_BG	5	
Q_LINKORIENTATION	Nominal	
Q_LOCACC	2	

BG 102:		
NID_BG	102	
pos_{true}	200000 cm	= 2.000 km
centerDetectionInaccuracies	0.0^{+10}_{-10}	± 10 cm
Q_LINK	Unlinked	
NoCoordinateSystemHasBeenAssigned	False	
Q_DIRLRBG	Nominal	
Q_DIRTRAIN	Nominal	

BG 003:		
NID_BG	003	
pos_{true}	300000 cm	= 3.000 km
centerDetectionInaccuracies	0.0^{+10}_{-10}	± 10 cm
Q_LINK	Linked	
NoCoordinateSystemHasBeenAssigned	False	
Q_DIRLRBG	Nominal	
Q_DIRTRAIN	Nominal	

BG 104:		
NID_BG	104	
pos_{true}	400000 cm	= 4.000 km
centerDetectionInaccuracies	0.0^{+10}_{-10}	± 10 cm
Q_LINK	Unlinked	
NoCoordinateSystemHasBeenAssigned	False	
Q_DIRLRBG	Nominal	
Q_DIRTRAIN	Nominal	

BG 005:		
NID_BG	005	
pos_{true}	500000 cm	= 5.000 km
centerDetectionInaccuracies	0.0^{+10}_{-10}	± 10 cm
Q_LINK	Linked	
NoCoordinateSystemHasBeenAssigned	False	
Q_DIRLRBG	Nominal	
Q_DIRTRAIN	Nominal	

2.4 TRAIN PROPERTIES, NATIONAL AND DEFAULT VALUES

The following parameters are taken into account:

Distance Balise antenna – train front end distance	300^{+20}_{-10}	cm
Distance Balise antenna – train rear end distance	5000^{+220}_{-120}	cm
Q_NVLOCACC	3	m
Location Accuracy Default Value	0^{+30}_{-30}	cm
Center Detection Accuracy Default Value	0^{+20}_{-20}	cm

3. Test Results

The raw data results produced by the SCADE model are available in the tab “Input data of the SCADE model” of the Excel file https://github.com/openETCS/modeling/blob/master/model/Scade/System/ObuFunctions/ManageLocationRelatedInformation/TrainPosition/CalculateTrainPosition/outputs/Train_BGs_Location_3_linked_2_unlinkedBGs.xlsx.

The column names correspond to the outputs of the test model https://github.com/openETCS/modeling/tree/master/model/Scade/System/ObuFunctions/ManageLocationRelatedInformation/TrainPosition/CalculateTrainPosition/ctp_t.

The following characteristics apply for all diagrams shown the subsequent paragraphs:

- All distances are in cm
- The diagram x-axis represents the current true train position pos_{true} (s. chapt. 2.2).
- The CalculateTrainPosition model computes the train front end position. Since the offset between the antenna position and the train front end is an inaccuracies afflicted train specific constant, it is not included in the diagrams.
- In the following paragraphs the center detection inaccuracies and the BG location inaccuracies are not mentioned in every case in detail; but they are applied in the model anyway.

3.1 Train Position

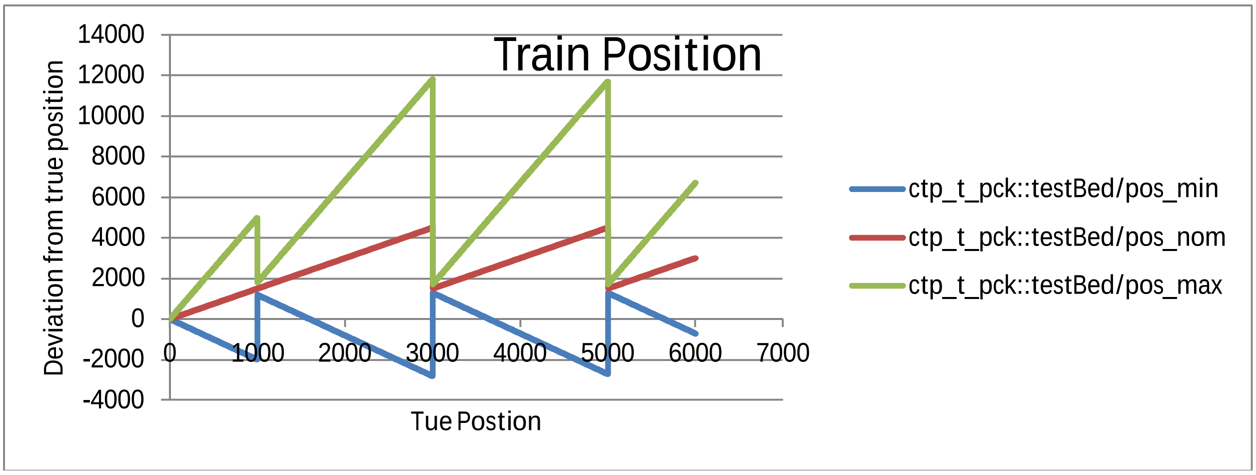

DIAGRAM 1: TRAIN POSITION DEVIATION

Diagram 1 presents the train position with nominal and min/max inaccuracies during the train trip from pos_{true} = km 0 until pos_{true} = km 6. Instead of the pure train position, the y-axis is calculated from

$$y = calculatedTrainPosition - pos_{true}$$

and therefore is the deviation of the calculated train position from pos_{true}. The subtraction flattens the diagram and discloses the effects; otherwise, the pure position would appear as a straight line with approximately 45° rising slope.

1. The train starts its trip at pos_{true} = 0 by using the odometry information.

2. The odometry tendency of overestimating caused by the transfer function in 2.2 lets the nominal deviation increase.

3. At pos_{true} = $100000\ cm = km$ 1.000 km 1.000 the train passes the linked BG 001. The calculated train position min/max range collapses from the odometry inaccuracies to the BG 001 location inaccuracies plus the BG center detection inaccuracies.

4. The linked BG 001 announces BG 003 (at km 3.000) and BG 005 (at km 5.000) in linking distances of 2 km each. The inaccuracies of both are derived from Q_LOCACC as part of the announcing linking information, the location of BG 001 and the center detection inaccuracies. As soon as the train passes one of these, the train position snaps onto the balise position, increased by the center detection inaccuracy of the passing BG.

5. Unlinked BGs are passed at track km 2.000 and 4.000 during the trip. They don't have any impact on the current train position, because their position is not known in advance.

6. The positioning curves in Diagram 1 mainly reside in the positive y-range, caused by the odometry overestimation tendency (s. 2.2).

7. The nominal train location returns to the same value on every passed linked BG. This demonstrates the effect of linking distances being exact without any inaccuracies.

3.2 LOCATION OF LINKED BG 001 AT KM 1.000

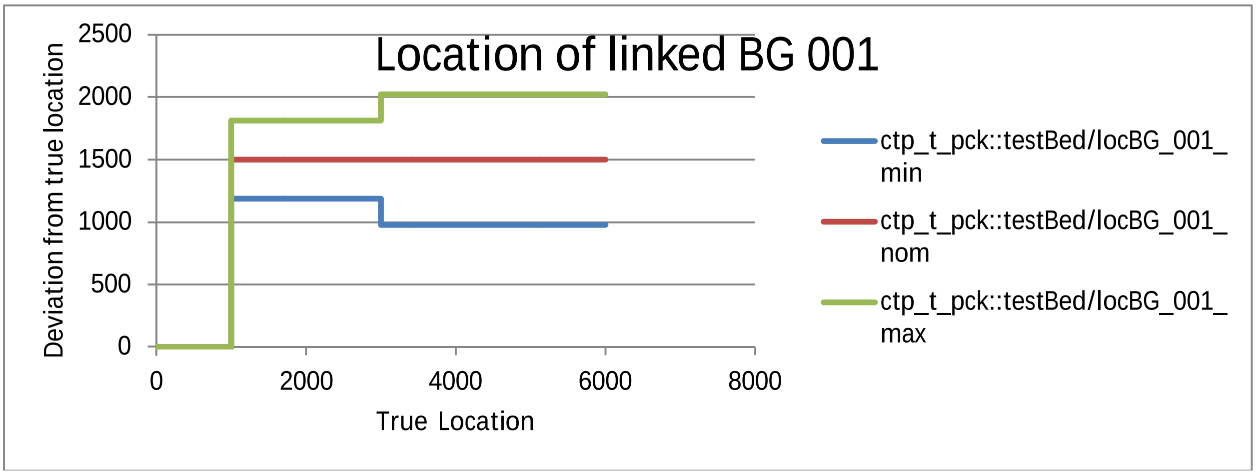

DIAGRAM 2: LOCATION DEVIATION OF LINKED BG 001

Diagram 2 visualized the calculated location of BG 001 with nominal values and min/max inaccuracies during the train trip from pos_{ideal} = km 0 until pos_{ideal} = km 6. Instead of the pure BG location, the y-axis is calculated from

$$y = calculatedBGLocation - loc_{true}(BG\ 001)$$

and therefore is the deviation of the calculated BG location from loc_{true} = 100000 cm = km 1.000 . The subtraction flattens the diagram and eases the comparison between different BGs. The diagram shows BG 001 from the train perspective during the trip.

1. The train starts its trip at pos_{true} = 0 without any knowledge of BG 001.

2. At pos_{true} = 100000 cm = km 1.000 the train passes the linked BG 001.
   The balise specific location inaccuracy is not known for BG 001; the national value Q_NVLOCACC is applied instead. Directly above BG 001, the BG location must be within the range given by the odometry and the BG 001 location inaccuracy. Although the train does not know where within the BG 001 location inaccuracy range BG 001 is found really, it is arranged arbitrarily symmetrically around the current nominal odometry position. This is feasible as long as all distances derived from BG 001 are calculated correctly.
   In sum, the calculated BG location min/max range collapses from the odometry inaccuracies to the BG 001 location inaccuracies.

3. At pos_{true} = 300000 cm = km 3.000 the train passes the linked BG 003. There the train position snaps onto the BG 003 location. For BG 001 this means, that the location inaccuracies of the linked BG 001 and BG 003 have to be applied, which increases the inaccuracy of BG 001 as seen by the train from there on.

4. At pos_{true} = 500000 cm = km 5.000 the train passes the linked BG 005. There the train position snaps onto the BG 005 location. For BG 001 this has no impact, since linking distances are exact without tolerances and only the location inaccuracies of the first and last BG in a linking chain have an effect. Because the location inaccuracies of BG 3 and BG 5 are equal, the BG 001 location does not change.

3.3 LOCATION OF LINKED BG 003 AT KM 3.000

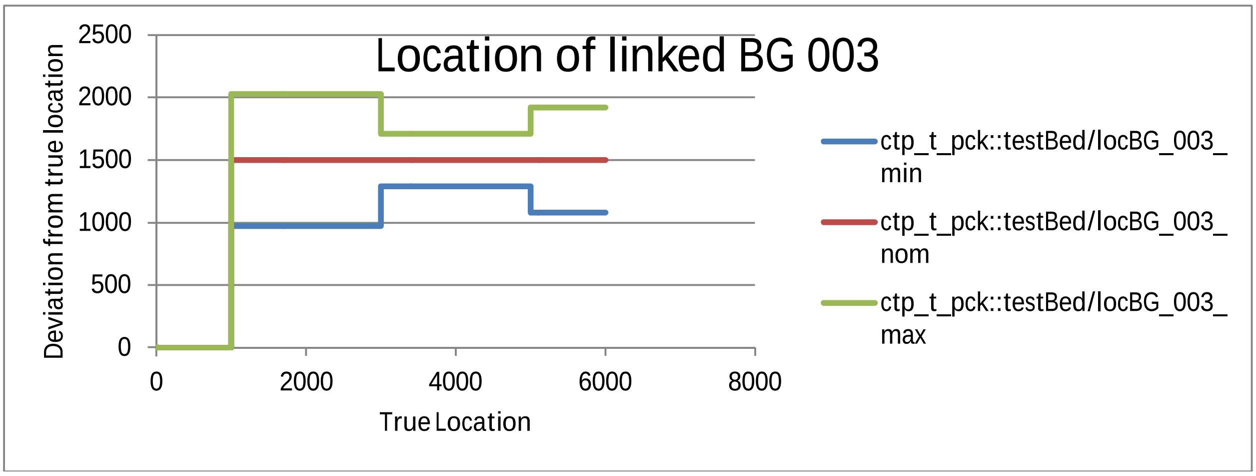

DIAGRAM 3: LOCATION DEVIATION OF LINKED BG 003

Diagram 3 visualized the calculated location of BG 003 with nominal values and min/max inaccuracies during the train trip from pos_{true} = km 0 until pos_{true} = km 6. Instead of the pure BG location, the y-axis is calculated from

$$y = calculatedBGLocation - loc_{true}(BG\ 003)$$

and therefore is the deviation of the calculated BG location from loc_{true} = 300000 cm = km 3.000 . The subtraction flattens the diagram and eases the comparison between different BGs. The diagram shows BG 003 from the train perspective during the trip.

1. The train starts its trip at pos_{true} = 0 without any knowledge of BG 001.
2. At pos_{true} = 100000 cm = km 1.000 the train passes the linked BG 001 and announces BG 003.
   Since linking distances are exact without tolerances and only the location inaccuracies of the first and last BG in a linking chain have to be taken into account, the location of BG 003 above BG 001 is calculated from the location inaccuracies of BG 001 and BG 003.
3. At pos_{true} = 300000 cm = km 3.000 the train passes the linked BG 003; its position snaps onto BG 003. Here, only the location inaccuracies of BG 003 have to be considered. The inaccuracy of BG 003 decreases.
4. At pos_{true} = 500000 cm = km 5.000 the train passes the linked BG 005; its position snaps onto BG 005.
   Since linking distances are exact without tolerances and only the location inaccuracies of the first and last BG in a linking chain have to be taken into account, the location of BG 003 above BG 005 is calculated from the location inaccuracies of BG 003 and BG 005, which increases the inaccuracies of BG 005 again.

3.4 LOCATION OF LINKED BG 005 AT KM 5.000

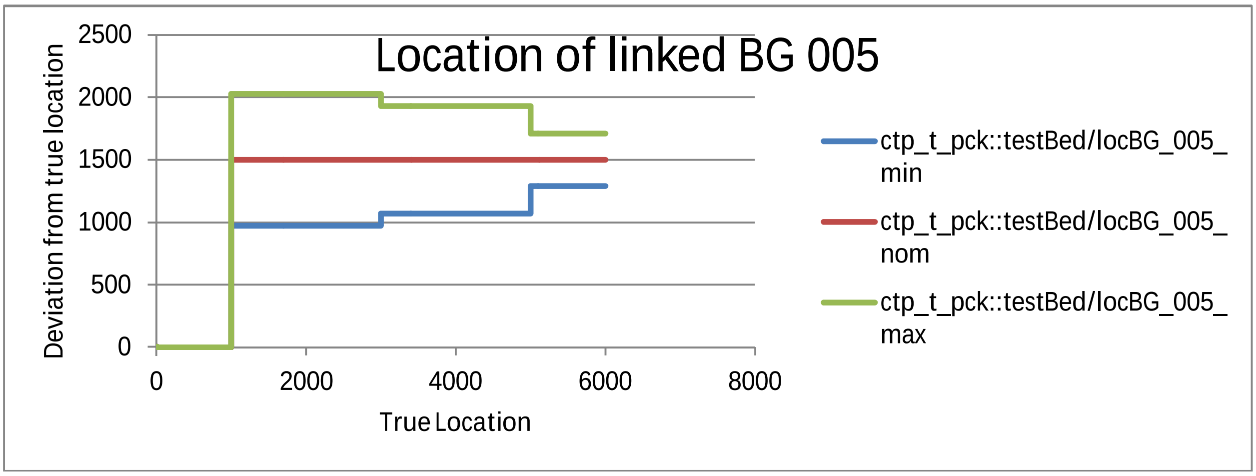

DIAGRAM 4: LOCATION DEVIATION OF LINKED BG 005

Diagram 4 visualized the calculated location of BG 005 with nominal values and min/max inaccuracies during the train trip from pos_{true} = km 0 until pos_{true} = km 6. Instead of the pure BG location, the y-axis is calculated from

$$y = calculatedBGLocation - loc_{true}(BG\ 005)$$

and therefore is the deviation of the calculated BG location from loc_{true} = 500000 cm = km 5.000 . The subtraction flattens the diagram and eases the comparison between different BGs. The diagram shows BG 005 from the train perspective during the trip.

1. The train starts its trip at pos_{true} = 0 without any knowledge of BG 001.

2. At pos_{true} = 100000 cm = km 1.000 the train passes the linked BG 001 and announces BG 005.
   Since linking distances are exact without tolerances and only the location inaccuracies of the first and last BG in a linking chain have to be taken into account, the location of BG 005 above BG 001 is calculated from the location inaccuracies of BG 001 and BG 005.

3. At pos_{true} = 300000 cm = km 3.000 the train passes the linked BG 003.
   Since linking distances are exact without tolerances and only the location inaccuracies of the first and last BG in a linking chain have to be taken into account, the location of BG 005 above BG 003 is calculated from the location inaccuracies of BG 003 and BG 005. The location inaccuracies differences of BG 001 and BG 003 cause a change of the BG 005 location inaccuracies here.

4. At pos_{true} = 500000 cm = km 5.000 the train passes the linked BG 005; its position snaps onto BG 005. Here, only the location inaccuracies of BG 005 have to be considered. The inaccuracy of BG 005 decreases.

3.5 Location of Unlinked BG 102 at km 2.000

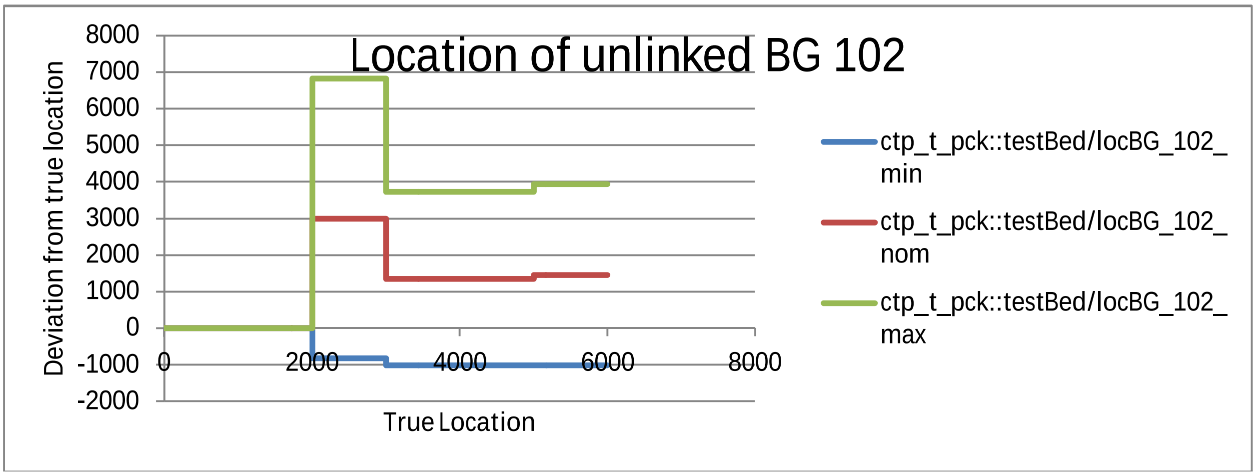

DIAGRAM 5: LOCATION DEVIATION OF UNLINKED BG 102

Diagram 5 visualizes the calculated location of BG 102 with nominal values and min/max inaccuracies during the train trip from pos_{true} = km 0 until pos_{true} = km 6. Instead of the pure BG location, the y-axis is calculated from

$$y = calculatedBGLocation - loc_{true}(BG\ 102)$$

and therefore is the deviation of the calculated BG location from loc_{true} = 200000 cm = km 2.000 . The subtraction flattens the diagram and eases the comparison between different BGs. The diagram shows BG 102 from the train perspective during the trip.

1. The train starts its trip at pos_{true} = 0 without any knowledge of BG 102.

2. At pos_{true} = 100000 cm = km 1.000 the train passes the linked BG 001 and determines its location.

3. At pos_{true} = 200000 cm = km 2.000 the train passes the unlinked BG 102. Its location is derived from the location of the linked BG 001 and the distance between BG 001 and BG 102 measured by odometry.

4. At pos_{true} = 300000 cm = km 3.000 the train passes the linked BG 003. The BG 102 location is derived from the location of the linked BG 001 and the distance between BG 001 and BG 102 measured by odometry and, in addition, from the location of the linked BG 003 and the distance between BG 003 and BG 102 measured by odometry. The location determined via a cross bearing to BG 001 and BG 003 leads to significantly reduced inaccuracies of BG 102.

5. At pos_{true} = 500000 cm = km 5.000 the train passes the linked BG 005. The BG 102 location is derived from the location of the linked BG 001 and the distance between BG 001 and BG 102 measured by odometry and from the location of the linked BG 003 and the distance between BG 003 and BG 102 measured by odometry. BG 003 and BG 005 are coupled via linking distance and make up a linking chain of 2 BGs, causing a location inaccuracy step-up.

3.6 Location of Unlinked BG 104 at km 4.000

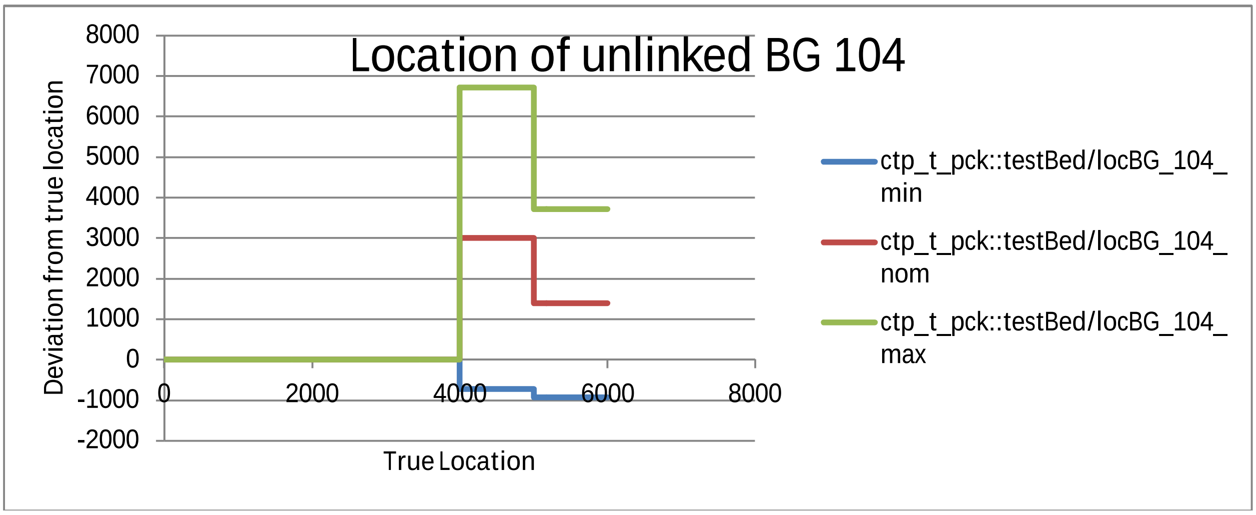

DIAGRAM 6: LOCATION DEVIATION OF UNLINKED BG 104

Diagram 6 visualizes the calculated location of BG 104 with nominal values and min/max inaccuracies during the train trip from pos_{true} = km 0 until pos_{true} = km 6. Instead of the pure BG location, the y-axis is calculated from

$$y = calculatedBGLocation - loc_{true}(BG\ 104)$$

and therefore is the deviation of the calculated BG location from loc_{true} = 400000 cm = km 4.000 . The subtraction flattens the diagram and eases the comparison between different BGs. The diagram shows BG 104 from the train perspective during the trip.

The effects are the same as characterized in 3.5.