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Correction of the wheel diameters in the ETCS OBU after a wheelset change

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SBB Martin Imhof
FOT Michael Riemenschnitter



- The speed / distance measurement of an ETCS OBU
- The issue with the wheel diameter
- Example: Event on 7th of March 2023
- Proprietary “solutions”
- Wheel diameter maintenance process
- Questions

- As a reminder, a ETCS OBU has usually following components to measure speed / distance:
 - Wheel sensor
 - Radar
 - Acceleration unit (not all)
 - ...

In order to measure the speed / distance correctly, the components have to be calibrated respectively be recalibrated from time to time.



- The wheel sensor is the crucial element of the train speed / distance measurement.
- Current odometry solutions seem to trust the wheel sensor data most (over radar and accelerometer information).
- The wheel diameter known by the ETCS OBU directly influences the quality of the measurement.
- For a vehicle in operation, the wheel diameter needs to be corrected periodically:
 - After a certain distance when the diameter of the wheel is reduced due to wear (usage).
 - After a wheel set has been replaced.



If the wheel diameters known by the ETCS OBU differ from the physical wheel diameters

- the ETCS OBU is over- / under-estimating the distance travelled.
- If the difference reaches a certain value, correct radar information is not considered anymore (“invalidated” due to the priority of the sensors) and the physical position of the vehicle may no longer be inside the calculated confidence interval.
- Balise groups announced by linking and then detected outside the expectation window (defined by the confidence interval) are rejected by the ETCS OBU
 - As a result, the position of the vehicle is not reset (LRBG)
 - Linking reaction is performed (no reaction/service brake/TRIP)

Apart from the linking reaction, the ETCS specifications do not define any reactions, if the ETCS OBU detects that its confidence interval is not correct.

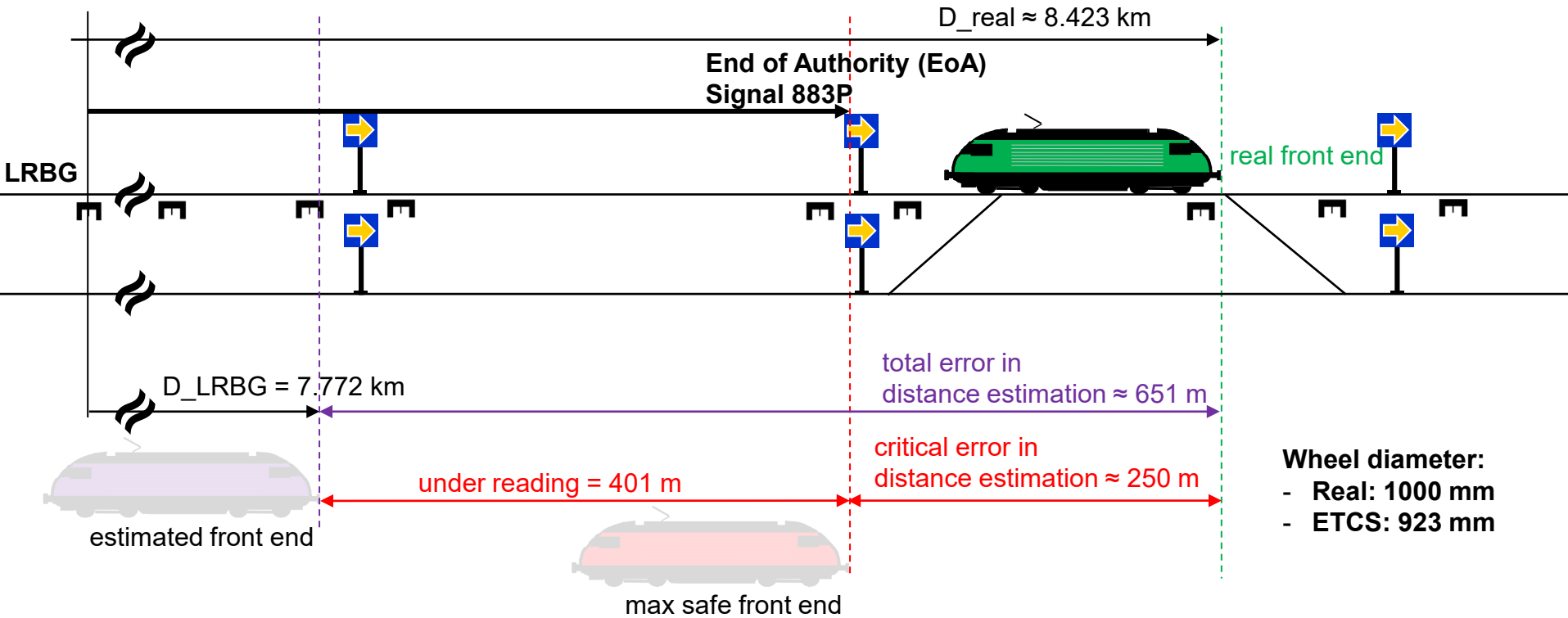


If the correction of the wheel diameter is not performed

- to compensate wear:
The ETCS OBU is considering a distance / speed that is too large
(physical position is in rear of the position estimated by the ETCS OBU)
=> Minor impact on safety and performance
- after a wheel set has been replaced:
The ETCS OBU is considering a distance / speed that is too small
(physical position is in advance of the position estimated by the ETCS OBU)
=> **Critical safety issue**



Example: Event on 7th of March 2023



Wheel diameter:
 - Real: 1000 mm
 - ETCS: 923 mm

Not true to scale, illustration only



Some ETCS OBU react by enlarging the confidence interval when a balise group announced by linking is read outside the expectation window.

- The next balise group is subsequently read within the (enlarged) expectation window and is taken into consideration by the ETCS OBU.
(safety alerts by FOT on 01.05.2020 and 02.09.2020)

Other ETCS OBU do not enlarge the confidence interval in such condition.

- As the following balise groups are not taken into consideration (detected outside the expectation window) the error increases with distance.
- In the safety critical scenario (correction not performed after a wheel set change), the distance between confidence interval and real train front end increases +/- linearly.
- The risk of a collision of two trains increases substantially since trackside design measures for risk mitigation (overlap, placing of balise groups,...) are much less effective for vehicles significantly outside their confidence interval.

Total tolerable hazard rate for ETCS onboard as defined in SUBSET-091:
ca. $10^{-9}/h$ (SIL 4); hazardous event ODO-4: *“The confidence interval for distance measurement does not include the real position of the train.”*

- Fulfilling the requirement would roughly allow **1 event every 1000 years** on current L2 lines in CH
- Observations/Monitoring: **3-5 events per year** caused by wrong wheel diameters

A „SIL 4“-compliant maintenance process (human error!) for measuring and entering the wheel diameters is required by SRAC, implemented and certified (ECM):

- 2 independent measurements
 - Enter the values of first measurement (1 person)
 - Check the entered values with 2nd measurement (2nd person)

Key question: How can maintenance rules that purely rely on the correct execution of manual processes guarantee “SIL 4”-compliance?



Questions