High Integrity Navigation Overlay Services For Railway Applications: a selected example of Italian GNSS perspective

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Italy is one of the four major contributors to the European GNSS

Italian national strategy based on use on EU systems Galileo and EGNOS and on interoperability with other GNSSs; Italy hosts one of the Galileo Control Centre

Italy recognises the potentiality of GNSS to be a pillar for innovation of the society and for SME development

Italy recognises the potentiality of the integration among Navigation, Telecommunication and Earth Observation disciplines

The Italian Space Agency have undertaken initiative to develop pre-operational project for several applicative sectors.
Selected Sectors and Priorities

Mainly the following sectors have been addressed:

Maritime
Civil Aviation
Road (including hazardous transportation)
Infomobility
Rail

Among other programmes undertaken:

- PRESAGO project to define procedural methods and procedures required for PRS (Public Regulated Service - the Galileo classified service)
- SENECA project to promote the GNSS based innovation on Civil Aviation
- Several SME initiatives supporting development of selected applications (e.g. UAV, interport management) and technology developments (e.g. innovative antennas, atomic clocks)

ASI, recognising the importance of the rail sector and the potentiality for satellite based innovation (particularly for regional rail safety and efficiency enhancement), is fostering the role of the Satellite Navigation and Telecommunication for rail
ERTMS-ETCS (European Rail Traffic Management System – European Train Control System) developed in Europe for high speed lines is *de facto* the railways standard train control system being adopted in most new lines and major upgrades.

By fact, major limitation to its extensive adoption (i.e. local and regional lines, freight lines) is the cost associated with its implementation and maintenance.
Why satellite technology?

Main advantages

• Reduction of operational and maintenance cost
• Increasing of line capacity

Market perspective:

• Cost-effective solution to increase safety on low traffic lines
• Increase traffic on many lines

Main challenge:

• Fulfill the **Safety Integrity Level SIL-4** requirements in terms of THR (Tolerable Hazard Rate) imposed for railways

  \[ \text{THR} \leq 10^{-9}/\text{h} \]
• In ERTMS/ETCS Train location is determined by means of **Balises** and **Odometry**
• The Balises are transponders deployed at georeferenced points
• The odometer provides the relative positioning w.r.t. the last balise
• When the Balise Reader energizes a balise, it receives a message with the balise Id
• The on board computer (EVC) sends a position report to the Radio Block Center
The GNSS Location Determination System generates the same signals produced by a Balise Reader detecting a physical Balise, through the same logical and physical interface, then emulating the Balise reader behavior with respect to the train equipment.

In this way the On Board ERTMS/ETCS location determination functions do not need to be changed.
GNSS-based services for Train Control

- GNSS based train location determination can be considered a disruptive technology.
- It will succeed in replacing the current technologies based on balises and track circuits if and only if it will be **cost-effective**.

THR ≤ 10⁻⁹/h

<table>
<thead>
<tr>
<th>Functionality</th>
<th>Current Technology</th>
<th>SIS Integrity Monitoring</th>
<th>Augmetation</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Train Location Determination</td>
<td>Based on Balise</td>
<td>X</td>
<td>X</td>
<td>Medium</td>
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<tr>
<td>• Single track</td>
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<tr>
<td>Train Location Determination</td>
<td>Based on Balise, Track Circuit</td>
<td>X</td>
<td>X</td>
<td>Medium, High</td>
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<tr>
<td>• Multiple tracks</td>
<td></td>
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<tr>
<td>Train Integrity</td>
<td>Track Circuit + On Board Circuitry</td>
<td>X</td>
<td></td>
<td>High</td>
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The ERSAT–EAV project (GSA)

ERTMS ON SATELLITE – Enabling Application Validation

Enhanced Railway Signalling Application

- IP Network
- 4G (Public versus Dedicated)
- Multiconstellation
- Local Area Trusted Augmentation Services
- Localization in GNSS denied Areas
- Satellite-based enhanced localisation
- EGNSS-based Localisation
- GPS
- GALILEO
- EGNOS
3InSAT Test Bed (ESA Artes 20)

Reference Station

RBC

TALS

Train antennas

50 km
Assessing the performance of a Safety of Life system is a rather challenging task due to the fact that very small probabilities are involved.

Approach: virtualized testbed, with
- rich sets of data collected in a real railway environment (e.g., 3InSat & ERSAT EAV Test Bed),
- historical time series related to rare GNSS SIS fault events (satellite malfunctions and atmosphere anomalous behaviors)
- simulated faults for the new-coming constellations
Conclusions

- Multi-constellation architectures offer higher degree of flexibility to reach the SIL-4 level (recommended for high demanding accuracy in the railways applications).

- Nevertheless, the availability of an augmentation network is of paramount importance in reducing the Protection Level.

- Sharing as much as possible of the supporting (i.e., augmentation) infrastructure and on board processing, including new developments such as Advanced Receiver Autonomous Integrity Monitoring (ARAIM), with the avionics field is a key factor for cost effectiveness.

- Definition of a standard for the Railway High Integrity Navigation Overlay System is a key success factor for spreading the GNSS application into the rail.

- Definition of a strategic roadmap for the adoption of an international standard is of primary concern.
THANKS FOR YOUR ATTENTION
References

• A. Neri, F. Rispoli, P. Salvatori, "The perspective of adopting the GNSS for the evolution of the european train control system (ERTMS): a roadmap for standardized and certifiable platform", ION GNSS+ 2015, Tampa, FL, U.S.A;
• A. Neri, S. Sabina, U. Mascia, "GNSS and odometry fusion for high integrity and high available train control systems.", ION GNSS+ 2015, Tampa, FL, U.S.A;
• Rispoli F., Neri A., Senesi F., "Innovative train control systems based on ERTMS and satellite-public TLC networks", WIT Transactions on the Built Environment, Volume 135, 2014, Pages 51-61, 14th International Conference on Railway Engineering Design and Optimization, COMPRAIL 2014; Rome; Italy; 24 June 2014 through 26 June 2014;
• Neri, F. Rispoli, and P. Salvatori, "An analytical assessment of a GNSS based train integrity solution in typical ERTMS level 3 scenario", ENC 2015, Bordeaux, France;
• P. Salvatori, A. Neri, C. Stallo, and F. Rispoli, "Ionospheric Incremental Delay Models in Railway Applications", IEEE International Workshop on Metrology for AeroSpace, 2015, Benevento, Italy;
• A. Neri, F. Rispoli, P. Salvatori, and A.M. Vegni, “A Train Integrity Solution Based on GNSS Double-Difference Approach,” in Proc. of ION GNSS+ 2014, September 8-12, 2014, Tampa, FL, USA.