Rail Traffic Management and Signaling

Train control systems poses high demands on positioning with respect to availability, reliability and integrity. These requirements can only be fulfilled by means of integrated positioning systems, which combine GNSS with other sensors.

The use of GNSS in railway systems presents many advantages, in particular the monitoring of train's exact location, logistic information management, enhanced train signaling (which improves safety, but also enables e.g. reduced distances between trains and therefore increased train frequencies), and the possibility to map the transport infrastructure.[1]

Thus, while the number of applications based on GNSS is considerably behind the number of those used in other domains, such as road transport, incorporating GNSS receivers into modern signaling, train control and other railway systems has become common.

Application Architecture

Train control, signaling, passenger traffic or transportation of dangerous goods are safety-critical applications, which show very demanding requirements in terms of availability, continuity and integrity. In order to fulfill these high performance demands complementary positioning sensors such as accelerometers or digital track maps and alternative communication components (e.g. GSM-R, UMTS, satcom) have to be grouped around the receiver/communication core.

In railway applications like train control and train supervision a GNSS receiver usually serves as a basic sensor which is enhanced by other navigation sensors and by an integrated fault tolerant sensor fusion software.[2]

Traffic Management and Signaling systems include the Signaling Block systems which encompasses collision avoiding systems. Both the ETCS (European Train Control System) in Europe and the PTC (Positive Train Control) in U.S., deal with train control and signalling systems standardization in order to improve interoperability.

The GNSS receivers for Traffic Management and Signaling are considered safety critical applications.

European Train Control System

The European Rail Traffic Management System (ERTMS) is the European cross-border interoperable standard for train control, signaling and traffic management. This standard includes two layers that can rely on GNSS information:

1. **European Train Control System** (ETCS): Is the signaling element of the system which includes the control of movement authorities, automatic train protection and the interface to interlockings.[3]

    - It allows the stepwise reduction of complexity for train drivers (automation of control activities),
    - It brings track side signaling into the driver cabin,
    - It provides information to the onboard display,
    - It allows for permanent train control,
    - Train driver concentrates on core tasks.

    1. **European Traffic Management Layer** (ETML): Is the operation management level intended to optimize train movements by the interpretation of timetables and train running data, involving the improvement of:[3]

    - Real-time train management and route planning,
    - Rail node fluidity,
    - Customer and operating staff information.

    The European Train Control System (ETCS) shall replace the national train control systems in the future to ensure cross-border interoperability and improve railway safety and efficient management.

    The ETCS deals with control and signaling systems used in remote electronic braking, train diagnostics and train/wagon location monitoring, all of which are functions whose safety and accuracy could especially be improved through application of GNSS. For example, combining GNSS position data with traditional train

sensor readings, such as odometry, can improve the ETCS location performance and therefore allow a safe discrimination between parallel tracks and track change at switches.[2]

The availability of satellite signals as well as the geometry of available satellites can be affected by obstacles (e.g. hills, buildings, vegetation, tunnels). Since the GNSS positioning performance also depends on the environmental conditions and the required performance level, positioning availability can not always be achieved due to unavoidable shadowing of GNSS signals under typical train operation environment. Therefore, GNSS location shall not be used as sole means in a train control system. The hybridization with aiding sensors is mandatory and a terrestrial augmentation of SBAS systems may be needed.[2]

Positive Train Control

Nowadays, modern railways in many countries are adopting Positive Train Control (PTC) systems to prevent collisions, derailments, work zone incursions, and passage through switches in the wrong position.

The PTC systems are integrated command, control, communications, and information systems for controlling train movements with safety, security, precision, and efficiency. PTC systems will improve railroad safety by significantly reducing the probability of collisions between trains, casualties to roadway workers and damage to their equipment, and over speed accidents.

A PTC system can automatically vary train speeds, re-route traffic, and safely direct maintenance crews onto and off tracks. In addition to enhancing safety, PTC increases track capacity by maintaining a constantly updated operating plan that optimizes rail use and flow.[4]

The PTC systems are the most common usage of GNSS technology within Rail applications and is the result of combining real-time position information with sophisticated command and control systems to monitor and control train movements.

The use of GNSS technology it will produce the following benefits:

- Give dispatchers and passengers more accurate information on train arrivals.
- Enable the automation of track surveying and mapping operations.
- Allow the automation of track inspection systems that work much faster and detect more defects than human crews, saving time and money while improving safety.
- Synchronizes the timing of railroad communication systems, including data transmissions for PTC, voice contact between locomotive engineers and dispatchers, and intermodal communications among trains, rail stations, ports, and airports.

In U.S., the PTC systems may use the nationwide Differential Global Positioning System that is accurate enough to tell whether a train changed tracks after going through a switch.

Application Characterization

In general, a GNSS-based train control system will be superior to other train control systems due to:[2]

- Lower cost,
- Better interoperability (no need of infrastructure equipment),
- Performance improvement with respect to the existing odometry.

ETCS Characterization

The European Train Control System fulfills two main objectives: Define a communication based train control system, which is useful for both high and low speed railway services. Define a standard for a uniform signaling system on an MMI (Man-Machine Interface), so neither locomotives nor drivers have to be replaced when crossing borders. The textual display on the MMI can be made to comply with the driver's language.

The ETCS equipment consists of two main subsystems:

- **On-board system**, which performs speed supervision and brake intervention.

- **Radio Block Centre trackside system**, which gives permission to run within a movement authority (MA). The task of this system is to ensure that all trains in the related area are keeping the safety distance to the neighboring trains. Also the supervision of special operational procedures like joining or splitting of trains is a task of this system.

For lines with different capacities three application levels with different types of trackside and on-board equipment are possible.[5]

PTC Characterization

The PTC systems are comprised of:

- Digital data link communications networks,
- Continuous and accurate positioning systems such as Nationwide Differential Global Positioning System (NDGPS),
- On-board computers with digitized maps on locomotives and maintenance-of-way equipment,
- Throttle-brake interfaces on locomotives,
- Wayside interface units at switches and Wayside detectors and
- Control center computers and Displays.

PTC systems may also interface with tactical and strategic traffic planners, work order reporting systems, and locomotive health reporting systems.

These systems also issue movement authorities to train and maintenance-of-way crews, track the location of the trains and maintenance-of-way vehicles, have the ability to automatically enforce movement authorities, and continually update operating data systems with information on the location of trains, locomotives, cars, and crews.

In addition to providing a greater level of safety and security, PTC systems also enable a railroad to run scheduled operations and provide improved running time, greater running time reliability, higher asset utilization, and greater track capacity. They will assist railroads in measuring and managing costs and in improving energy efficiency.[6]

In the future, GNSS will be integrated in vehicle-to-vehicle communication systems in order to warn trains and cars of potential collisions at railroad crossings. [4]

Application Examples

In Europe, projects such as GADEROS (Galileo Demonstrator for Railway Operation System), RUNE (Railway User Navigation Equipment), INTEGRAIL and most recently GRAIL were each aimed at supporting the introduction of GNSS in the railway sector (particularly in rail safety applications).[1]

- **INTEGRAIL** system: The aim of INTEGRAIL system in Europe is to open the way for profitable use of the EGNOS signal in safety-critical railway traffic management and control, achieving significant improvements for the rail traffic operator with respect to cost, redundancy and reliability of the present train speed measurement systems, by adding satellite navigation information and the integrity information offered by EGNOS. The INTEGRAIL system is able to provide reliable position and integrity information under varying operational conditions.[7]

- **ECORAIL** system: The aim is to design and test a positioning system that is based on satellite navigation in a safety critical railway application.[8]

- **GRAIL** system: The objective is to support the introduction of GNSS in the Rail market, with a special emphasis on ERTMS/ETCS.[9]

Concerning PTC System Development and Deployments, there are currently 11 different PTC projects in varying stages development and implementation, involving 9 different railroads in at least 16 different States, and consisting of over 4,000 track miles in U.S.