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ETCS
Implementation Handbook

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1. Introduction

European **T**rain **C**ontrol **S**ystem (ETCS) is a unified European track-train transmission based train driving supervision system. It was elaborated in view of the rail transport liberalization to ensure rail transport competitiveness by using the same system in all European countries. This is expected to ensure cost reduction as a result of the scale of implementation and reduction of the development costs as well as seamless trans-border services as a result of European wide compatibility between on-board control command equipment and respective trackside installations.

Although ETCS implementation is required by EU law, time is needed before it is widely and commonly used on European railway lines by most of the traction units. It is because it is required for lines and traction units which are new or being upgraded.

As European railways are at the beginning of this period it is crucial to ensure common proper understanding of ETCS especially as many railways are working on implementation at the same time having different national, not only technical, constraints.

ETCS Implementation Handbook is therefore prepared for infrastructure managers' and railway undertakings' employees to support them in decisions related to ETCS implementation both trackside and on-board.

It has to be pointed that infrastructure managers and railway undertakings as end users, due to both technical and legal reasons, have to co-operate in respect to ETCS implementations not only with producers but also with **N**otified **B**odies (NB) and national safety authorities. Principal role of the NBs is to ensure real conformity between European widely used components to ensure especially proper conformity between on-board and trackside ETCS equipment. Principal role of the national safety authorities is to ensure safe ETCS operation under national technical and operational constraints. Moreover national safety authorities are deciding in questionable cases when a line of traction unit is being upgraded and when it is only a renewal influencing overall ETCS implementation time and indirectly reducing period and/or scale of using multiple control command systems.

European railway technique related legislation is subdivided into **H**igh **S**peed (HS) and **C**onventional **R**ailway (CR) legislation starting form the European Parliament Directives level. Consequently, there are two separate **T**echnical **S**pecifications for **I**nteroperability (TSI) for the **C**ontrol **C**ommand and **S**ignalling (CCS) for HS and CR railway. However in case of CCS sub-system of the trans-European railway system there is only one ETCS applicable in both cases specified by the technical documents pointed out in the annex A of the last CCS TSI applicable to both HS and CR railway regardless HS or CR nature of the TSI.

Although there is one ETCS regardless HS or CR nature of the lines and traction units it has to be noted that legal implementation constraints which are described in chapters seven of the respective EC Decisions establishing TSI HS CCS and TSI CR CCS are different. There are also some differences between articles seven of the HS and CR railway interoperability directives which define when and how Member States can apply and obtain derogations which might allow railways not to implement ETCS in some peculiar cases.

Based on those documents International Union of Railways believe in significant amount of ETCS implementations in the coming years and therefore offers ETCS Implementation Handbook covering questions to be answered by the railways prior to detail design of ETCS installations by industrial partners.

ETCS Handbook is not a manual as signalling rules differ from country to country. It is a set of recommendations, warnings and best practice examples handed over to support railways in ETCS implementation.

2. Legal background

This chapter describes the legal situation referring to main legally binding documents forcing railways in the EU countries to implement ETCS.

2.1 Basic EU Legislation Steps

The first European Commission decision which defines the **E**uropean **R**ailway **T**raffic **M**anagement **S**ystem (ERTMS) as the combination of the ETCS and the Global System for Mobile Communication – Rail (GSM-R) is the *2001/260/EC*: The Commission Decision of 21 March 2001 on the basic parameters of the CCS sub-system of the trans-European HS rail system referred to as "ERTMS characteristics" in *Annex II(3) to Directive 96/48/EC* (notified under document number C(2001) 746, *Official Journal L 093, 03/04/2001,p. 0053-0056).*

The next legislative step was taken in 2002, when the *2002/731/EC* Commission Decision of 30 May 2002 concerning the TSI relating to the CCS sub-system of the trans-European HS rail system referred to in *Article 6(1) of Council Directive 96/48/EC* (notified under document number C(2002) 1947, *Official Journal of the European Union, EN, L 245, 12/9/2002, p. 37–142*), with corrigendum *(Official Journal, EN, L 275/4 EN, 11.10.2002, p.3–4)* were published. This document includes the TSI of the CCS sub-system of the European HS rail system and it fully replaces the *2001/260/EC Decision*. This TSI CCS HS specification defines the target class A[1] system and the migration rules from the class B[2] ATP/ATC systems to this target solution. Being then in line with the work fulfilling CCM procedure status, the specification also updates the ETCS and GSM-R specifications. This document addressed the European HS railways, and from the legal point of view, it is not applicable to the CR system.

The basic parameters of the CCS sub-system of the European conventional system have been defined by the Commission Decision of 29 April 2004 modifying Annex A of the Commission Decision *2002/731/EC* of 30 May 2002 and establishing the main characteristics of Class A system of the CCS sub-system of the trans-European CR system referred to in *Directive 2001/16/EC* (notified under document number C(2004) 1559, *Official Journal, EN, L 155, p. 65–79*), updated by the corrigendum to this decision (*Official Journal, EN, L 193 1/6/2004, p. 53-63).* The document defines the target solution of a class A system independently of the maximal allowed speed on a particular TEN line and imposes the installation of both, the ETCS and GSM-R.

1 Class A: The unified, interoperable Control-Command system.

2 Class B: Control-Command systems and applications existing before entry into force of the relevant Directive, limited to those described in Annex B of the respective (HS or CR) TSI CCS.

The *Decision No 884/2004/EC* of the European Parliament and of the Council of 29 April 2004 amending *Decision No 1692/96/EC* on Community guidelines for the development of the trans-European transport network *(Official Journal, EN, L 167, 30/04/2004, p. 1-38)* with corrigendum *(Official Journal, EN, L 167, 7/6/2004, p. 1-55)* has established the rules for railways improvement.

The European Commission Decision introducing the TSI CCS CR is the first legal act concerning railways taken after the EU enlargement. In the annex to the document, the TSI of the CCS sub-system for the CR system is included. Chapter 7 of the TSI CCS CR defines the interoperability implementation rules on the European CR system regarding infrastructure and rolling stock. The general migration criteria and timing criteria are specified. The ERTMS consolidation phase and the baseline approach to the system deployment and future modifications are defined there. The requirements for Change Management Process and Configuration Management Plan are also described in this chapter. The decision determines the role of the **E**uropean **R**ailway **A**gency (ERA) established by the *EC Regulation 881/2004*. The responsibility for ETCS and GSM-R regarding specifications delivery, quality assurance, configuration management and change control, which is fragmented to a number of entities as UIC, UNISIG, ERTMS Users Group, EIRENE group, ERIG, GSM-R Industry Group and AEIF are now centralised in ERA to ensure the overall coherence of all processes. In its role of System Authority the ERA ensures the cooperation of a representative cross-section of the stakeholders in the process, such as infrastructure managers, railway undertakings, supply industry, NBs and safety authorities. The ERA is responsible for mastering the ETCS and GSM-R specifications change management process, including the delivery of the specifications, its quality assurance and configuration management.

The decision *2006/679/EC* of 28 March 2006 concerning the TSI relating to the CCS sub-system of the trans-European CR system has been amended by the decision *2006/680/EC* of 7 November 2006 concerning a TSI relating to the CCS sub-system of the trans-European HS rail system and modifying *Annex A*.

The commission decision of 6 March 2007 modifies *Annex A to Decision 2006/679/EC* concerning the TSI relating to the CCS sub-system of the trans-European CR system and *Annex A to Decision 2006/860/EC* concerning the TSI relating to the CCS sub-system of the trans-European HS rail system. This commission decision constitutes the legal reference today.

2.2 Overview of ERTMS Technical Documents

As stated in the introduction legally binding set of ETCS specifications is included in Annex A of the last CCS TSI from HS or CR and is applicable to HS and CR lines and traction units.

Basic technical documents pointed there and forming the set of the ETCS and GSM-R specifications are:

- **F**unctional **R**equirements **S**pecifications (FRS),
- **S**ystem **R**equirement **S**pecifications (SRS),
- Interface specification (FIS, FFFIS),
- Standards (EN).

Pointed documents are subdivided into mandatory and informative ones.

The ETCS FRS defines the system functionality. It was developed mainly by the railway representatives as the future system users and it included a very wide range of requirements. The FRS version in force for the ETCS equipment is FRS 4.29. For GSM-R, the reference document is EIREINE FRS 7.

The ETCS SRS describes the FRS clauses implementation details in the way necessary for the system development. The SRS version in force for the ETCS equipment is SRS 2.3.0. Concerning GSM-R, EIRENE SRS 15 is the mandatory document.

Among technical documents, one can find **F**unctional **I**nterface **S**pecifications (FIS), Form Fit Functional Specifications called (FFFIS) specifications, European Norms and others.

The full list of the ETCS related mandatory and informative documents is included in the *Chapter 9* of this handbook.

2.3 ETCS - Infrastructure and Rolling Stock Registers

The concept of infrastructure and rolling stock registers is introduced directly by the interoperability directives mentioned in *chapter 2.1*. The main objective: requirements and characteristics stated in the rolling stock register have to be cross-checked for interoperability with relevant requirements and characteristics stated in the infrastructure register as a pre-condition for operating a train on a given railway line. This is a general principle which is applicable not only to control command and especially ETCS but also to all other sub-systems of the trans-European railway system.

The TSI define the information to be covered by those registers in relation to given sub-systems. For ETCS relevant set of information is covered by Annex C of the TSI CR CCS describing line and train specific characteristics to be put in the registers

Cross check of infrastructure and rolling stock registers will allow infrastructure managers and railway undertakings to make different analyses to support decision processes. For instance it will be possible to check what kind of upgrading, if any, is required for certain rolling stock to ensure its possible use to offer transport on certain lines.

2.4 ETCS - Interoperability Constituents

As ETCS related **I**nteroperability **C**onstituents (IC) are defined in legal documents there is a need for short description with references as well as a short explanation regarding cross-acceptance principles.

ETCS System Modularity

The ETCS system, since the beginning of international works has been expected to offer to the users some modularity. The modularity of the system understood as a full subdivision into small modules with exactly defined functions and interfaces would be welcome by the users but at the same time would significantly reduce the competition between suppliers. Therefore, the discussion on so called “white box”, “grey box” and “black box” solutions was a quite intensive one.

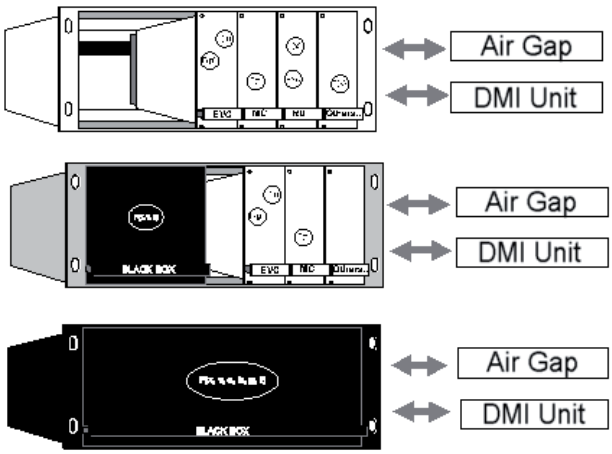


Fig. 1: Modularity of the ETCS system equipment

As a result of finding a compromise, the ETCS system comprises only a few modules adapting the “grey box” solution.

In parallel to searching the compromise mentioned above, the best ETCS implementation method has been looked for. The ETCS wide implementation is the key to achieve the significant railway transport competitiveness with other means of transport on the European market. The selected method of introducing the ETCS, as the basic part of the CCS sub-system of the trans-European railway system imposed the modules definition frame.

The European Commission's decisions mentioned in *Chapter 2.1* defining the CCS sub-system complete the *96/48/EC* and *2001/16/EC* directives belonging to the new legislation approach. As the result of this new approach, the TSIs define not only the relevant sub-system, but also selected complete sets, which are the subjects of the separate certification process as the integral parts of the sub-system. Inside the particular sub-systems of the trans-European HS railway system and CR system, such complete sets are called the **I**C.

Each TSI, including the one which defines the CCS sub-system, describes the sub-system division into the IC. For each interoperability constituent, its interfaces are shown on the list below.

Basic Interoperability Constituents of On-Board Assembly

The ETCS On-board is the main interoperability constituent. It comprises, with some exceptions, both the hardware and software objects of the ETCS on-board equipment.

ETCS On-board:

- Safety,
- On-board ETCS functionality,
- ETCS and EIRENE air gap interfaces,
- RBC (level 2/3),
- Radio in-fill unit (optional level 1),
- Eurobalise airgap,
- Euroloop airgap (optional level 1).

ETCS On-board Interfaces:

- STM (optional implementation of interface K),
- GSM-R on-board,
- Odometry,
- Key management system,
- ETCS ID Management,
- ETCS **D**river **M**achine **I**nterface (DMI),
- Key Management,

- Physical environmental conditions,
- Electromagnetic compatibility (EMC),
- Data interface including vigilance (optional) and train integrity,
- Safety Information recorder.

Due to the specific nature of fail-safe electronic equipment, the safety platform on-board is selected as a separate interoperability constituent.

Safety Platform On-board:

- Safety.

The odometry for distance and speed measurement, and the safety information recorder were selected separately as two following IC.

Odometry:

- Safety,
- On-board ETCS functionality (only odometry).

Odometry Interfaces:

- ERTMS ETCS on-board,
- Environmental conditions,
- EMC.

Safety Information Recorder:

- On-board ETCS functionality (only data recording).

Safety Information Recorder Interfaces:

- JRU downloading tool,
- ETCS on-board,
- Environmental conditions,
- EMC.

It should be mentioned that the basic interoperability constituent, the ETCS On-board, may include or not include the radio in-fill and Euroloop functions depending on the ETCS on-board equipment configuration.

The complete set of ETCS on-board control-command assembly IC comprises also the GSM-R on-board in relevant ETCS application level (2 or 3, or in level 1 with the radio in-fill), and the External **S**pecific **T**ransmission **M**odule (STM), if exists. There may be several different External STM constituents according to the amount of Class B systems required to co-operate with the ETCS on-board equipment.

GSM-R On-board:

- EIRENE functions (only data communication in level 2/3, or level 1 with radio in-fill).

GSM-R On-board Interfaces:

- ERTMS ETCS on-board (only in level 2/3 or level 1 with radio in-fill),
- GSM-R,
- EIRENE DMI,
- Environmental conditions,
- EMC.

External STM:

- Functions and safety,

External STM Interfaces:

- ERTMS ETCS on-board,
- Class B system air gap,
- Environmental conditions,
- EMC.

Basic Interoperability Constituents of Trackside Assembly

RBC:

- Safety,
- Track-side ETCS functionality (excluded communication via Eurobalises, radio in-fill & Euroloop),
- ETCS and EIRENE air gap interfaces (only radio communication with train).

RBC Interfaces:

- Neighbouring RBC,
- ERTMS GSM-R trackside,

- Key management system,
- ETCS-ID Management,
- Interlocking,
- Environmental conditions,
- EMC.

Radio In-fill Unit:

- Safety,
- Track-side ETCS functionality (excluded communication via Eurobalises, Euroloop and level 2/3 functionality),
- ETCS and EIRENE air gap interfaces (only radio communication with train).

Radio In-fill Unit Interfaces:

- ERTMS GSM-R trackside,
- Key management system,
- ETCS-ID Management,
- Interlocking and LEU,
- Environmental conditions,
- EMC.

Eurobalise:

- Safety,
- ETCS and EIRENE air gap interfaces (only Eurobalise communication with train).

Eurobalise Interfaces:

- LEU Eurobalise,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

Euroloop:

- Safety,
- ETCS and EIRENE air gap interfaces (only Euroloop communication with train).

Euroloop Interfaces:

- LEU Euroloop,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

LEU Eurobalise:

- Safety,
- Track-side ETCS functionality (excluded communication via radio in-fill, Euroloop and level 2/3 functionality).

LEU Eurobalise Interfaces:

- Track-side signalling,
- Eurobalise,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

LEU Euroloop:

- Safety,
- Track-side ETCS functionality (excluded communication via radio in-fill, Eurobalise and level 2/3 functionality).

LEU Euroloop Interfaces:

- Track-side signalling,
- Euroloop,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

Safety Platform track-side:

- Safety.

Grouping Interoperability Constituents of CCS Assembly

The TSI of CCS sub-system of both, HS and CR System allow defining groups of IC. It is possible to certify them jointly. The assessment of interfaces between particular constituents comprising the group is not included by such joint certification. This statement is important for the future system exploitation. One example of the on-board assembly and two examples of the trackside assembly interoperability, constituent groups as included in the TSI CCS CR, are shown below.

Interoperability Constituent Group of ETCS On-Board Assembly

Safety Platform On-board. ETCS On-board. Safety Information Recorder. Odometry:

- Safety,
- On-board ETCS functionality,
- ETCS and EIRENE air gap interfaces:
    - RBC (level 2/3),
    - Radio in-fill unit (optional level 1),
    - Eurobalise airgap,
    - Euroloop airgap (optional level 1).

Safety Platform On-board, ETCS On-board, Safety Information Recorder, Odometry – Interfaces:

- STM (implementation of interface K optional),
- ERTMS GSM-R on-board,
- Key management system,
- ETCS ID Management,
- ETCS DMI,
- Physical environmental conditions,
- EMC,
- JRU downloading tool,
- Data interface including vigilance (optional) and train integrity.

Interoperability Constituent Group of ETCS Trackside Assembly:

Safety Platform Trackside. Eurobalise. LEU Eurobalise:

- Safety,
- Track-side ETCS functionality (excluded communication via Euroloop and level 2/3 functionality),
- ETCS and EIRENE air gap interfaces (only Eurobalise communication with train).

Safety Platform Trackside, Eurobalise, LEU Eurobalise – Interfaces:

- Track-side signalling,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

Safety Platform Trackside. Euroloop. LEU Euroloop:

- Safety,
- Track-side ETCS functionality (excluded communication via Eurobalise and level 2/3 functionality),
- ETCS and EIRENE air gap interfaces (only Euroloop communication with train).

Safety Platform Trackside, Euroloop, LEU Euroloop – Interfaces:

- Track-side signalling,
- ETCS-ID Management,
- Environmental conditions,
- EMC.

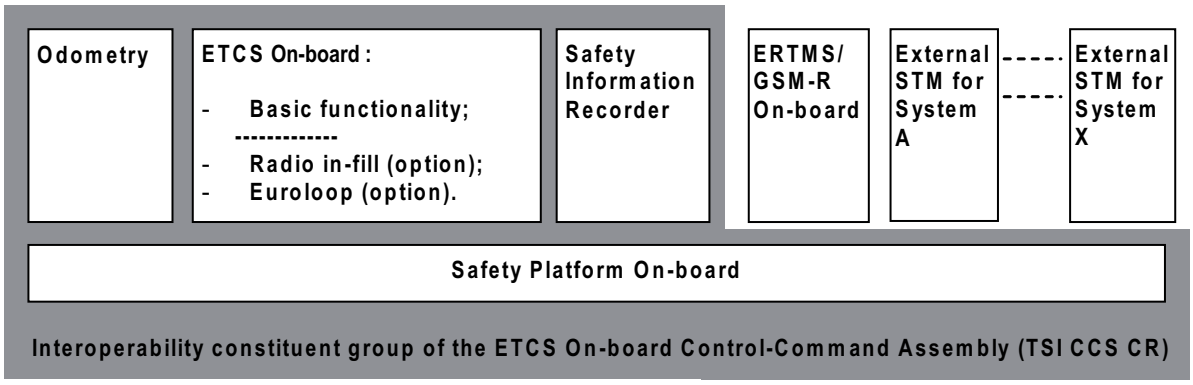


Fig. 2: Example of the ETCS On-board Assembly interoperability constituents' group

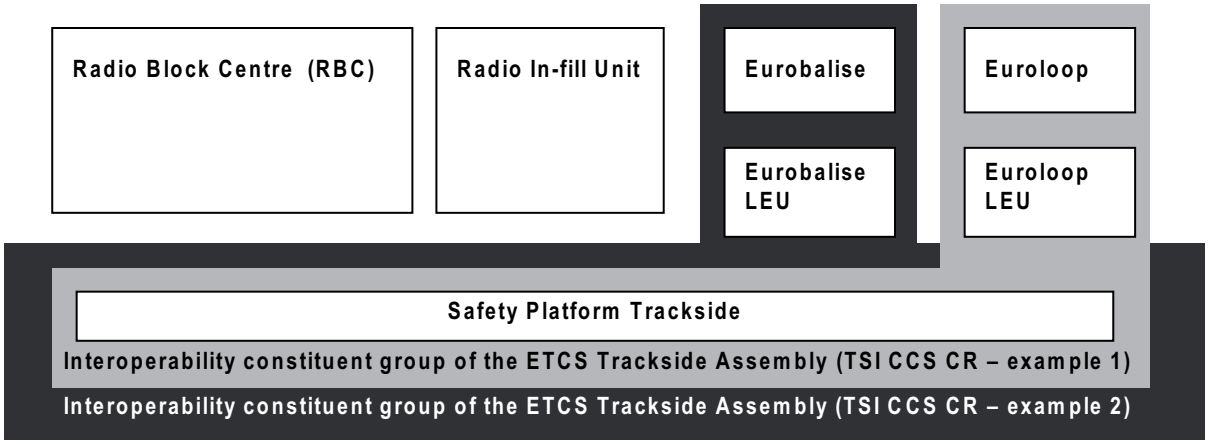


Fig.3: Examples of the ETCS Trackside Assembly interoperability constituent groups

The detailed description of ETCS On-board and Trackside Assembly IC and groups of them are included in the relevant *TSI CCS (HS or CR) document, tables: 5.1a and 5.1b (on-board), and 5.2a and 5.2b (trackside)*, respectively.

Assessment of Conformity of Constituents and Verification

ETCS as described in previous chapters is subdivided into IC, which are subject of independent conformity assessment by competent bodies notified by Community Member States to European Commission (called NoBos). On the level of ICs on the basis of "certificates of conformity" issued by a NB after passed assessments producers issue "EC Declarations of conformity", which are the basis for cross-acceptance through Community Member States. This is based on the "New Approach" and "Global Approach" community regulations.

The New Approach principles to technical harmonisation and standardisation are laid down by a Council resolution of 1985.

This resolution establishes the following principles:

- Legislative harmonisation is limited to essential requirements that products placed on the Community market must meet, if they are to benefit from free movement within the Community;
- The technical specifications of products to meet the essential requirements set out in the directives will be laid down in "harmonized" standards, the reference of which are published in the OJEC;
- Application of "harmonised" standards remains voluntary, and the manufacturer may always apply other technical specifications to meet the requirements;
- Products manufactured in compliance with "harmonized" standards, the reference of which are published in the OJEC, benefit from a presumption of conformity with the corresponding essential requirements;
- Product certification is required.

In addition to the New Approach principles, conditions for a uniform product conformity assessment are defined by the 1989 Council Resolution on the “Global Approach” to certification and testing, which states guiding principles for Community policy on conformity assessment. To that end, Community legislation, in particular, devises modules for the various phases of conformity assessment procedures, and lays down criteria for the use of these procedures and for the designation of bodies operating these procedures.

As general conformity modules have to be adjusted for conformity assessment of railway IC each TSI defining ICs is also defining applicable assessment procedures. They are described in chapters 6 and usually in dedicated annexes.

In case of ETCS system all defined IC are to be assessed using following modules:

- Module H2 (Full quality assurance with design examination) or
- Module B (Type examination) together with module D (Production quality assurance) or
- Module B together with module F (Product verification).

Principles of "Full quality assurance with design examination" (Module H2)

This module describes the procedure whereby a NB carries out an examination of the design of an Interoperability Constituent and the manufacturer ensures and declares that the Interoperability Constituent concerned satisfies the requirements of the TSI.

- The manufacturer must operate an approved quality system for design, manufacture and final product inspection and testing and it must lodge an application for assessment of his quality system with a NB. The quality system must ensure compliance of the Interoperability Constituent with the requirements of the TSI,
- The NB must assess the quality system to determine whether it satisfies the requirements. It shall presume compliance with these requirements in respect of quality systems that implement the relevant harmonized standard. This harmonized standard shall be *EN 9001- 2000,*
- The NB must examine the application and assess the results of the tests. Where the design meets the provisions of the TSI that apply to it, the NB must issue an EC design examination certificate to the applicant. The certificate shall contain the conclusions of the examination, conditions for its validity, the necessary data for identification of the approved design and, if relevant, a description of the product's functioning.

Principles of "Type examination" (Module B)

This module describes that part of the procedure by which a NB ascertains and attests that a type, representative of the production envisaged, meets the provisions of the TSI that apply to it.

- The applicant must place at the disposal of the NB of his choice, a specimen; representative of the production envisaged and hereinafter called 'type',
- A type may cover several versions of the Interoperability Constituent provided that the differences between the versions do not affect the provisions of the TSI,
- The NB must:
    - examine the technical documentation,
    - verify that any specimen(s) required for tests has (have) been manufactured in conformity with the technical documentation, and carry out or have carried out the type tests in accordance with the provisions of the TSI and/or the relevant European specifications,
    - where a design review is requested in the TSI, perform an examination of the design methods, the design tools and the design results to evaluate their capability to fulfil the requirements for conformity for the interoperability constituent at the completion of the design process,
    - where is requested in the TSI, perform an examination of the manufacturing process devised for manufacturing the interoperability constituent,

- identify the elements which have been designed in accordance with the relevant provisions of the TSI,
- perform the appropriate examinations and necessary tests,
- Agree with the applicant the location where the examinations and necessary tests will be carried out.

Principles of "Production quality assurance" (Module D)

This module describes the procedure whereby the manufacturer ensures and declares that the Interoperability Constituent is in conformity with the type as described in the type-examination certificate and satisfies the requirements of the TSI that apply to it.

- The manufacturer must operate an approved quality system for production, final product inspection and testing. The manufacturer must lodge an application for assessment of his quality system with a NB of his choice, for the IC concerned. The quality system must ensure compliance of the IC with the type as described in the type-examination certificate and with the requirements of the TSI that apply to them,
- The NB assesses the quality management system to determine whether it satisfies the requirements. It presumes compliance with these requirements if the manufacturer implements a quality system for production, final product inspection and testing in respect of the Standard *EN/ISO 9001- 2000*, which take into consideration the specificity of the interoperability constituent for which it is implemented,
- The manufacturer must draw up the EC declaration of Conformity of the Interoperability Constituent. The content of this declaration has to include at least the information, indicated in *Directive 01/16/EC.*

Principles of "Product verification" (Module F)

This module describes that part of the procedure whereby a manufacturer checks and attests that the Interoperability Constituent is in conformity with the type as described in the type examination certificate and satisfies the requirements of the TSI that apply to it.

- The manufacturer must take all measures necessary in order that the manufacturing process ensures conformity of the IC with the type as described in the type-examination certificate and with the requirements of the TSI,
- The NB must carry out the appropriate examinations and tests in order to check the conformity of the Interoperability Constituent with the type as described in the type examination certificate and with the requirements of the TSI either by examination and testing of every Interoperability Constituent or by examination and testing of IC on a statistical basis,
- The manufacturer must draw up the EC declaration of Conformity of the Interoperability Constituent,

- The content of this declaration has to include at least the information, indicated in *Directive 96/48/EC, Annex IV (3),*
- The manufacturer must keep a copy of the EC declaration of conformity for a period of 10 years after the last interoperability constituent has been manufactured. (Nota Bene: for all modules).

Control command sub-system as a whole is also a subject of conformity assessment using similar modules but adapted to suit sub-system requirements. These modules are respectively named SH2, SB, SD and SF and have to be used in similar way (SH2 or SB with SD or SB with SF).

It is important to know that in case of constituent NB is chosen by producer, but in case of a sub-system NB is to be chosen by the railway. Implementation projects have to involve from the beginning end user (railway), producer(s), NB(s) and national safety authority.

3. Overview of ETCS functionality

This chapter defines main ETCS features, referring to more detailed description in ETCS documents mainly FRS and SRS as well as ETCS application levels and configurations.

3.1 Main ETCS Features

The ETCS is a modern unified train control system worked out within international co-operation involving railway and industry, operational as well as CCS experts. As a result, ETCS is based on modern technology forming state of the art of railway track – train air gap transmission based signalling and may hereby, to a large extend, improve the safety and performance compare to existing systems.

Improved safety – precise running limits given by Movement Authorities

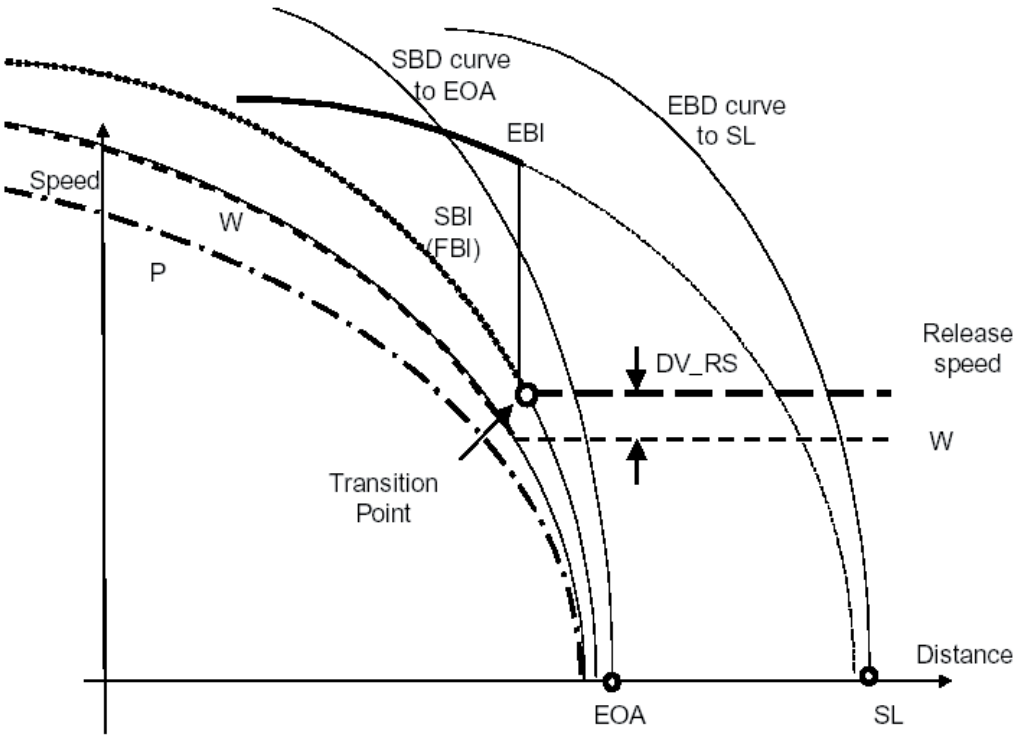
Traditional railway signalling is mainly based on interlocking and block systems excluding converging routes and ensuring train spacing. The vital messages elaborated by those systems are shown by trackside signals as colour aspects which are to be respected by drivers. Train control systems have been invented to ensure the reception of those messages and the driving compliant with the received distance and speed limitations.

Thus, the track – train transmission is used for transferring precise information about running limitations to the trains in the form of a Movement Authority. Such a Movement Authority exactly defines a place on a track which must not be passed by a train (**E**nd **o**f **A**uthority – EOA). In addition, other information, like speed profile, is transmitted to the on-board. For more information about ETCS **M**ovement **A**uthorities (MAs) please refer to *Subset-026 chapter 3*.

Improved safety – supervision of train driving

Received data are used by the on-board ETCS equipment to supervise the train drivers. For this purpose, the on-board equipment has to know not only the data related to the route, but also the data related to the train. These train data can therefore be entered by the train driver before starting the journey.

Based on the track data and on the data entered by the driver, the on-board equipment calculates a set of braking curves for train movement supervision. The braking curves and the way of using them are described in the SRS *Subset-026*. The respective basic principles are shown as an example for braking to a target.



P – permitted speed limit, W – warning limit, SBI – service brake intervention limit,
FBI – full braking intervention, EBI – emergency brake intervention limit,
SBD – service brake deceleration curve, EoA – end of authority,
EBD – emergency brake deceleration curve, SL – supervised location,
DV_RS – fixed speed difference between warning and release speed limits.

Fig. 4: Relationship between different braking curves (braking to target)

Higher performance – increasing speed and capacity

The track–train transmission based systems supervising train movements utilise precise information about running limits. Therefore, such systems can supervise a train continuously to avoid that the speed limits are exceeded.

The on-board equipment knowledge about train running limits is used to inform drivers through displays to ensure that drivers can see the limits independently from the weather conditions. In addition, this allows the railways to increase the running speeds without worrying about shortening the time period for trackside signal observation. The railways commonly use that kind of systems for HS trains taking into account the fact that the speed increase results also in the lengthening of braking distances.

The data transmission in more advanced systems is not only in the track-to-train direction, but also in opposite, train-to-track. This is used, for example, to inform trackside equipment about the train position. Different operational improvement possibilities are described in *Chapter 5.2*, while different technical improvement possibilities are described in *Chapter 5.3.*

Interoperability – capability to operate in different countries

Signalling systems based on trackside signals utilise different colour aspects depending on the national rules. Also the automatic train control systems based on the track – train data transmission have been developed separately for each country and sometimes even for given lines. Currently there are more then twenty different systems in use. The exact number cannot be given in some cases, as train driving supervision systems have different versions mainly for two reasons: improvements over years and customisation for different railway administrations.

The ETCS is the train control system worked out for the lines belonging to different railway administrations. As a result, ETCS offers a wide range of protection functions, different application levels and different configurations. National values ensure coherency between the system behaviour and the rules and regulations in different countries.

ETCS application levels and configurations are described in ETCS SRS *Subet-026, Chapter 4*. For information how the national values are defined, please refer to ETCS SRS *Subet-026, Chapter 7*.

3.2 ETCS Application Levels and Configurations

There are different possibilities to define operating relationships between track and train. In the ETCS system, such sets of relationships are called application levels.

It is necessary to see and understand the differences between:

- ETCS level of a line or track section in relation to ETCS trackside equipment,
- ETCS level of a traction unit in relation to ETCS on-board equipment,
- ETCS level of operation in relation to the operational use of both.

ETCS Levels for Traction Units

Traction units can be equipped with level 1, level 2 or level 3 ETCS on-board installation.

Level 1 ETCS on-board

The level 1 ETCS on-board equipment for a traction unit contains all necessary modules forming basic on-board ETCS set.

The level 1 on-board ETCS installation can be optionally equipped with: radio in-fill unit, Euroloop transmission module, and/or STM STM(s) for co-operation with class B systems.

Level 2 ETCS on-board

The level 2 ETCS on-board equipment for a traction unit contains basic on-board ETCS set of modules and GSM-R on-board module for data transmission. This module is essential for level 2 ETCS on-board due to the fact that such equipment must be capable of receiving MAs transmitted via GSM-R.

The level 2 ETCS on-board is capable to run on ETCS level 1 but can also be equipped with optional modules developed for level 1 ETCS on-board. As a result, also in this case within ETCS application level there are some possible configurations.

Level 3 ETCS on-board

Level 3 ETCS on-board equipment for a traction unit contains basic on-board ETCS set of modules and GSM-R on-board modules as for level 2, and in addition the train integrity module. The train integrity module is essential for level 3 ETCS on-board because according to moving block principle, the RBC must receive via GSM-R the vital information on train location and integrity for supervising train spacing.

The level 3 ETCS on-board is capable to run on ETCS level 1 but can also be equipped with optional modules used for level 1 ETCS on-board. As a result, also in this case there are some possible configurations within ETCS application level.

ETCS Levels for Lines

Different ETCS levels for lines and track sections allow each individual railway administration to select the appropriate ETCS application trackside, according to their strategies, to their trackside infrastructure and to the required performance. Furthermore, different application levels impose some constraints on the interfacing of individual signalling systems and class B train control systems to ETCS.

Level 0 ETCS line

Level 0 ETCS line is a line equipped neither with ETCS, nor with class B national system. It may mean the absence of ETCS and class B equipment or the presence of such equipment in commissioning, e.g. where trackside ETCS infrastructure exists but has to be ignored.

In Level 0, the line side optical signals or other means of signalling external to ETCS are to be respected by the drivers. The train detection and train integrity supervision are outside the scope of ETCS.

Level 0 uses no track-train transmission except Eurobalises to announce/command level transitions. Eurobalises therefore still have to be read. No balise data except certain special commands are interpreted.

Level STM ETCS line

The level STM ETCS line is a line equipped with class B national system. The line equipped with the national system for which no STM exists (e.g. not a class B system) has to be treated as level 0 ETCS line.

Level 1 ETCS line

The level 1 ETCS line is equipped with a spot transmission via Eurobalises which sends MAs to trains. The ETCS installation forms an overlay on the existing signalling system. The permitted speed of the train is continuously supervised. Balises transmitting MAs are switchable and connected to the signalling system e.g. by connecting them to signals via **L**ineside **E**lectronic **U**nits (LEU).

The train detection and train integrity supervision are outside the scope of ETCS.

Additional Eurobalises can be placed between distant and main signals to transmit in-fill information, so that the train will receive new information before reaching the signal. In-fill can also be provided using Euroloop or radio in-fill. In this case, new information is sent to the trains when available.

The possible level 1 ETCS line configurations are the following:

- Eurobalises near distant and main signals (level 1 with no in-fill),
- Level 1 with additional in-fill Eurobalises,
- Level 1 with Euroloop in-fill with lineside signals,
- Level 1 with Euroloop in-fill without lineside signals,
- Level 1 with radio in-fill with lineside signals,
- Level 1 with radio in-fill without lineside signals.

It has to be noted that lineside signals can be used in fall-back situations, especially when the on-board system cannot indicate MAs.

Level 2 ETCS line

The ETCS Level 2 line is a line prepared for radio based train control. The RBCs as main trackside equipment form an overlay on an underlying signalling system.

MAs are generated trackside and are transmitted to the train via GSM-R. The ETCS Level 2 provides a continuous speed supervision system, which also protects against overrunning the MA. The train detection and train integrity supervision are performed by the trackside equipment of the underlying signalling system (interlocking, track circuits etc.) and are outside the scope of ETCS.

The level 2 is based on GSM-R for communication (voice and data communication) and on Eurobalises as spot transmission devices mainly for location referencing. The trackside RBC which provides the information to the trains recognises each ETCS controlled train individually by the identity of its leading ETCS on-board equipment.

The possible level 2 ETCS line configurations are:

- Level 2 with lineside signals,
- Level 2 without lineside signals.

Lineside signals are required if a line is intended not only for the trains with traction units equipped with level 2 or level 3 ETCS on-board equipment or are provided as a fall back solution.

It has to be noted that the RBC consists of an interoperable part but has also got a National part. National part comprises two basic areas: collecting information for RBC, and using data available in RBC. Within first area it is necessary to prejudge how information has to be taken from interlocking and other signalling systems in a safe way, and how signal aspects have to be coded into ETCS language. Within second area it is necessary to prejudge how information gained from the interoperable part is used for National needs e.g. for displaying data to local dispatchers, automatic forwarding of data about emergency, automatic forwarding of diagnostic data. Railways shall be aware of the need to specify the National part.

Level 3 ETCS line

In comparison with level 2 ETCS line, the level 3 ETCS line has no additional hardware components – it uses GSM-R as for communication with the RBC and voice communication; and Eurobalises used as reference locations. However, the level 3 RBC is capable of supervising train spacing according to moving block principle using information on train location and integrity.

ETCS Level of Operation

A train equipped with ETCS on-board equipment always co-operates with the ETCS trackside equipment in a defined ETCS level. Such operation level which defines the operational relationships between track and train and the use of both equipment kinds is also called the ETCS Application Level. ETCS can be configured to operate in one of the following application levels:

- Level 0 - train equipped with ETCS operating on a line without ETCS or national system or with the ETCS systems in commissioning,
- Level STM - train equipped with ETCS operating on a line equipped with a national system to which it interfaces by use of an STM,
- Level 1 - train equipped with ETCS operating on a line equipped with Eurobalises and optionally Euroloop or Radio in-fill,

- Level 2 - train equipped with ETCS operating on a line controlled by a RBC and equipped with Eurobalises and GSM-R,
- Level 3 - in the interoperable part similar to level 2 but with train location and train integrity supervision based on information received from the train.

Levels 1, 2 and 3 are downwards compatible. It means that a level 3 equipped trains are able to operate in level 1 and 2, while level 2 equipped trains are able to operate in level 1. It should be noticed that the operation under STM is not a part of the downward compatibility chain. All transitions between levels are performed according to well-specified rules.

Level 0 - ETCS operation

Trackside equipment:

- No ETCS trackside equipment is used except for Eurobalises to announce level transitions and other specific commands,
- Main ETCS trackside functions – none.

On-board equipment:

- Onboard equipment with Eurobalise transmission,
- Main ETCS on-board functions:
    - Supervision of maximum train speed,
    - Supervision of maximum speed permitted in an unfitted area,
    - Reading of Eurobalises to detect level transitions and certain special commands. All other messages are rejected.

Operation:

- ETCS on-board equipment provides no supervision except for the maximum design speed of a train and maximum speed permitted in unfitted areas,
- No supervisory information is indicated on the DMI except for the train speed. The maximum permitted speed is only displayed temporarily and on the driver's request. Train data has to be entered.

Level STM - ETCS operation

Trackside equipment:

- Level STM uses the track-train transmission system from an underlying national system, which is not part of ERTMS/ETCS,
- For level transition purposes, Eurobalises are used,
- Main ETCS trackside functions – none.

On-board equipment:

- Onboard equipment with Eurobalise transmission,
- STM compatible with the respective national infrastructure,
- Main ETCS on-board function:
    - Depending on national system and on STM implementation,
    - Reading of Eurobalises to detect level transitions and certain special commands. All other messages are rejected,
    - Management of STM's,
    - Cab signalling to the driver (depending on national system).

Operation

- Level STM is used to run ETCS equipped trains on lines equipped with national train control and speed supervision systems. The device which allows the ETCS onboard equipment to utilise the transmission system of the national system is called STM,
- Train control information generated trackside by the national train control system is transmitted to the train via the communication channels of the underlying national system and can be transformed onboard into information interpretable by ETCS. The lineside optical signals might be necessary or not, depending on the expected traffic structure and on the performance and functionality of the underlying systems,
- The achievable level of supervision is similar to the one provided by the underlying national systems. The DMI information whilst running in national operation must also be considered when defining the STM. Train detection and train integrity supervision are performed by equipment external to ETCS,
- Level STM uses no ETCS track-train transmission except to announce/command level transitions and specific commands related to balise transmission. Eurobalises therefore still have to be read. No data except level transition commands and certain special commands are interpreted,
- The information displayed to the driver depends on the functionality of the underlying national system. The active STM is indicated to the driver as part of that information,
- Train data has to be entered,
- Each combination of national trackside systems shall be combined externally to the ETCS Onboard system and shall be regarded as one STM level,
- The reuse of ETCS Onboard functionality can be different depending on the configuration of a specific STM,
- Access to ETCS Onboard supervision functions is supported.

Level 1 - ETCS operation

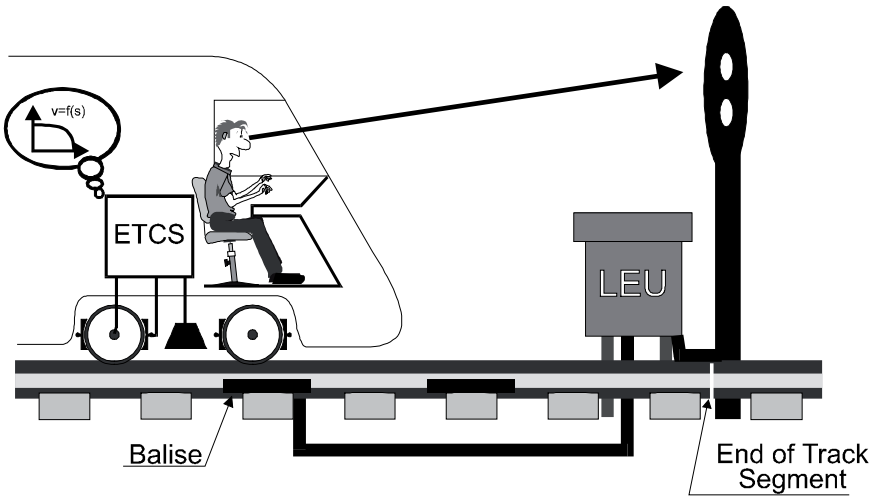


Fig. 5: ETCS Level 1 Operation

Trackside equipment:

- Eurobalises for spot transmission from track to train,
- Eurobalises must be able to transmit variable information,
- In-fill transmission by using Euroloop or radio in-fill is optional (but can be mandatory when no overlaps exist),
- Main ETCS trackside function:
  - Determine MAs according to the underlying signalling system,
  - Transmit MAs and track description data to the train.

On-board equipment:

- Onboard equipment with Eurobalise transmission,
- Euroloop transmission if in-fill by Euroloop is required,
- Radio in-fill transmission if in-fill by radio is required,
- Main ETCS on-board function:
  - Reception of MA and track description related to the transmitting balise,
  - Continuous speed supervision,
  - Selection of the most restrictive value of the different speeds permitted at each location ahead,
  - Calculation of a dynamic speed profile taking into account the train running/braking characteristics which are known on-board and the track description data,
  - Comparison of the actual train speed with the permitted speed and commanding of the brake application if necessary,
  - Cab signalling to the driver.

Operation:

- ETCS Level 1 provides a continuous speed supervision system, which also protects against overrunning the MA,
- If in level 1 without infill a lineside signal clears, an approaching train can not receive this information until it passes the Eurobalise group at that signal. Therefore, the driver has to observe the lineside signal to know when to proceed. The train has then to be permitted to approach the stopping location below a maximum permitted release speed.

Level 2 - ETCS operation

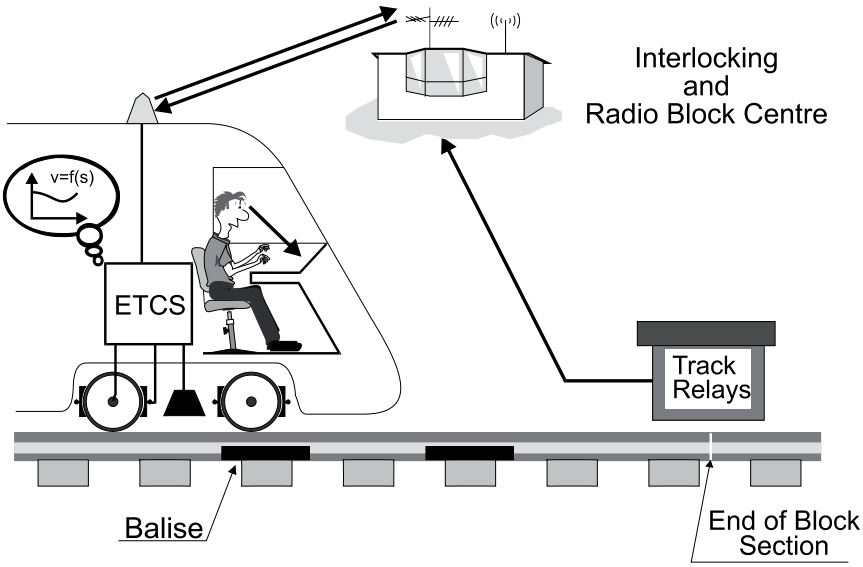


Fig. 6: ETCS Level 2 Operation

Trackside equipment:

- RBC,
- GSM-R for bi-directional track-train communication,
- Eurobalises mainly for location referencing,
- Main ETCS trackside functions:
    - Knowing each train equipped with and running under ETCS within an RBC area by its ETCS identity,
    - Following each ETCS controlled train's location within an RBC area,
    - Determining MAs according to the underlying signalling system for each train individually,
    - Transmitting MAs and track description to each train individually,
    - Handing over of train control between different RBC's at the RBC-RBC borders.

On-board equipment:

- Onboard equipment with Eurobalise and GSM-R transmissions,
- Main ETCS on-board functions:
    - The train reads Eurobalises and sends its position relative to the detected balises to the RBC,
    - The train receives a MA and the track description via GSM-R relating to a balise
    - Continuous speed supervision,
    - Selection of the most restrictive value of the different speeds permitted at each location ahead,
    - Calculation of a dynamic speed profile taking into account the train running/braking characteristics which are known on-board and the track description data,
    - Comparison of the actual train speed with the permitted speed and commanding of the brake application if necessary,
    - Cab signalling to the driver.

Operation:

- ETCS Level 2 provides a continuous speed supervision system, which also protects against overrunning the MA,
- Data transmission is achieved by continuous radio transmission (GSM-R). MAs are generated trackside and are transmitted to the train via GSM-R. For some functions, the radio transmission requires complementing by spot transmission (Eurobalise). The detection of trains is achieved by track-based equipment, usually track-circuits or axle counters. The trackside RBC which provides the information to the trains recognises each train individually by the ETCS identity of its relevant ETCS on-board equipment. Signalling information is communicated to the driver by equipment in the driving cab and, optionally, by the lineside signals. However, lineside signals may be removed if not required due to the mixed traffic on the line or for fall-back reasons.

Level 3 - ETCS operation

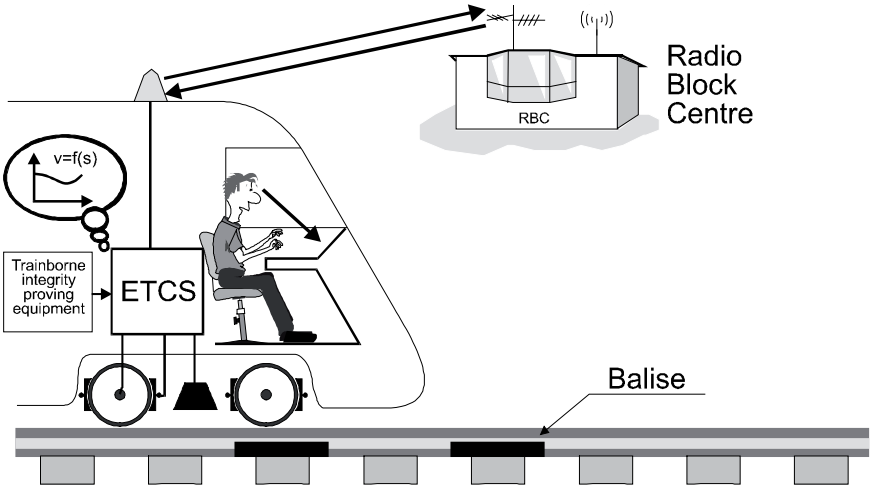


Fig. 7: ETCS Level 3 Operation

Trackside equipment:

- RBC,
- GSM-R for bi-directional track-train communication,
- Eurobalises for mainly location referencing,
- Main ETCS trackside functions:
  - Knowing each train within an RBC area by its ETCS identity,
  - Following each trains location within an RBC area,
  - Route locking and route releasing based on information received from the trains,
  - Determining MAs for each train individually,
  - Transmitting MAs and track description to each train individually,
  - Handing over of train control between different RBC's at the RBC-RBC borders.

On-board equipment:

- Onboard equipment with Eurobalise and GSM-R transmissions,
- Train integrity system,
- Main ETCS on-board functions:
  - The train reads Eurobalises and sends its position relative to the detected balises to the RBC,
  - The train monitors train integrity (external function, not part of ERTMS/ETCS) and sends this information to the RBC,
  - The train receives a MA and the track description via GSM-R relating to a balise,
  - Continuous speed supervision,

- Selection of the most restrictive value of the different speeds permitted at each location ahead,
- Calculation of a dynamic speed profile, taking into account the train running/braking characteristics which are known on-board and the track description data,
- Comparison of the actual train speed with the permitted speed and commanding of the brake application if necessary,
- Cab signalling to the driver.

Operation:

- ETCS Level 3 is a radio based train control system,
- MAs are generated trackside and are transmitted to the train via GSM-R. ETCS Level 3 provides a continuous speed supervision system, which also protects against overrunning the MA. Train location and train integrity supervision are performed by the trackside RBC in co-operation with the train (which sends position reports and train integrity information). Level 3 is based on GSM-R for track to train communication and on Eurobalises as spot transmission devices mainly for location referencing. The trackside RBC which provides the information to the trains knows each train individually by the ETCS identity of its leading ETCS on-board equipment. The lineside signals are not foreseen to be used when operating in Level 3.

Transitions between Levels

ETCS equipment which is not isolated always operates in one of the above described levels. All transitions between these levels are performed according to defined functions and procedures.

Additional national functions and rules which might be used by an individual railway to for example prevent not equipped trains from entering a level 2/3 area are not specified in ETCS specifications and have to be implemented outside ETCS.

Transitions between any levels are possible. The transition within the same level is not applicable for level 0 and 1. Transitions between level STM and level STM describe the switching from one STM to another STM. Transitions between level 2 and level 2, and, respectively, between level 3 and level 3, describe the handover between RBC's.

Superposition of ETCS Applications on a Single Line.

The purpose of this function is to superimpose different ETCS application levels on a single line. A train must not attempt a level transition to another level if it is not equipped appropriately. Instead, it must continue to operate in the current level. The protection against entering an area for which a train is not equipped must therefore be provided in that level.

It might be required in some places to operate trains in different application levels over the same line. A junction station where a level 1 line crosses a level 2 line can be such an example. Therefore, it must be possible to operate trains not equipped with radio through the station in level 1 and, at the same time, keep level 2 trains operating in level 2.

Potentially dangerous or uncontrollable situations could arise if a train interprets conflicting information for different levels received via the radio and via the balises. Therefore, clear rules are required to ensure that a train only interprets the relevant information. It must also be ensured that a train only equipped with level 1 will not attempt to enter a level 2 area even if it is being told to do so.

It is possible even to superimpose several application levels in parallel on the same track, for example to run trains without train integrity device in level 2 and in parallel trains equipped with train integrity device in level 3. Other examples might be a station which is shared by trains arriving over level 1 and level 2 lines (junctions) or parallel operation of a national system with ETCS. Mixed levels are supported.

Technical and Operational Interoperability

Different ETCS applications levels and configurations are capable of ensuring interoperability. However the level of unification is not always the same. These led to a discussion about technical and operational interoperability based on a relationship between ETCS levels and drivers' obligation to observe, understand and obey trackside signals. Further discussions on railway interoperability, which were taking into account wide technical context, not narrowed only to command control defined technical, operational and legal interoperability as unification steps for the trans-European railway system.

Technical Interoperability means that trains and drivers can cross the borders between different railway administrations however drivers are obliged to observe, understand and obey trackside signals and indicators as well as apply operational rules and regulations being in force on the tracks of a given railway administration.

Operational Interoperability requires all information available trackside to be included in a unified way on-board in cab-signalling as well as requires unification of operational rules and regulations. Such unification of operational rules and regulations requires not only common documents but also unification of day by day practice in relation to personnel influencing safe railway operation. However, operational interoperability is presently achieved by ETCS rules and in all other cases by the driver's knowledge of rules as well as his ability to speak the language of the infrastructure owner.

Legal Interoperability is an ambiguous expression. On one side it is used for a far future situation when all technical, operational and legal barriers for through Europe railway operation will be removed. On the other side this expression is also used to emphasize conformity between technical solutions and legal requirements. In this context lines equipped with national ATP/ATC systems included in *Annex B of the CCS TSI* are “legally interoperable”.

Interoperability versus ETCS

Lack of consensus on unified ETCS cab display practically means that ETCS is only capable to ensure technical interoperability.

3.3 ETCS - Modes of Operation

Principally there are three modes of operation of an ETCS train: full supervision, partial supervision and shunting. Full supervision takes place when all necessary data about train characteristic and about train route are available for train running supervision. Shunting takes place when train data are accepted to vary over time. Partial supervision takes place when train data are known and stable but train route data are known partially. Partial Supervision is further subdivided into operational modes appropriate for different operational situations. All the different modes of operation and transitions between them are described in SRS *Subset-026, Chapter 4.*

4. Criteria for equipping a railway with ETCS

This chapter contains basic considerations to be undertaken before ETCS implementation on a specific line as well as description of national values being an important tool to ensure coherency between ETCS and national rules and regulations.

4.1 ETCS - Implementation Strategies

The national strategy selection for ETCS implementation means in practice the necessity of taking two important decisions:

- Selection of the sequence, in which particular lines will be equipped with ETCS,
- Selection of ETCS level for particular lines or, at least, selection the criteria for it.

The present status of control command systems varies from country to country. There are huge differences in technical systems and in the level of safety and reliability offered by the systems. These differences also influence capacity of lines. Taking them into account, the ERTMS specifications do not precise the way, how the common standards can be achieved in particular countries. Other important reasons, why the specifications are rather general, seem to be the diversity of legal requirements and various life expectancies of existing systems. When first priorities for ETCS are to be set, the preferred options seem to be the following:

- Installation of ETCS on international corridors (TEN lines), preferably to provide ETCS equipment throughout,
- Installation of ETCS on other TEN lines,
- Installation of ETCS on other lines.

A pure ETCS system can only be installed on new lines or on lines where there has been no train control system before.

In all other cases the migration of the ETCS has to be considered. The existing national system will exist in parallel with the new system until all national traction units are equipped with ETCS. For this implementation the STM is needed, and it is important that the STM is not integrated in the on board. The STM should be capable to be removed when the trackside equipment of the national system can be removed.

4.2 Operational Assessment of ETCS Options

It is important to asses ETCS configuration in view of the functionalities, which are expected to be ensured. As examples we can point: covering LX protection functionality, and revocation of an already given authority.

On a majority of conventional lines, the LXs exist and it is not possible to replace all of them with viaducts or tunnels due to huge costs of such investments. The ETCS configurations offer different functionalities, which can be used for reflecting LX protection in data transmitted from track to train. If there is a wish to ensure covering LX protection functionality it is important to decide how and answer whether this is possible for all or only for some ETCS configurations.

In emergency situations, there is a need to contact the train as quickly as possible to reduce the speed or to stop the train. There is a significant difference between spoken information given to the driver and instructions or orders given by data transmission to ETCS on-board equipment. Transmission of spoken information takes more time and does not assure the level of safety that is achievable when the information is transmitted by data. However, depending on configuration, data could be transmitted at any time or only in certain situations. This is important for all emergency messages.

Below please find basic considerations for different possible ETCS levels and configurations.

ETCS Level 1

In level 1 the following configurations are possible:

- without in-fill,
- with in-fill:
    - by additional balises,
    - by Euroloop,
    - by Euroradio.

Level 1 without in-fill

In case of implementation of ETCS level 1 without in-fill line capacity can be reduced in comparison to the state without ERTMS. This reduction only takes place when the train has passed the last balise group before a signal showing danger and the signal aspect changes to a proceed aspect afterwards. Without ETCS drivers can speed up when the signal changes into less restrictive aspect while with ETCS level 1 without in-fill, on-board system will prevent speed up until balise group near the signal to be passed. The reduction of capacity depends on the release speed. The lower the release speed is, the bigger the delay of the train can be before it is able to accelerate. At traditional optical signalling the distance, from which trackside signals have to be visible for the driver is defined in rules. This distance is in practice equivalent to the length of a section in front of signal “equipped” with “in-fill by driver’s eyes”.

As far as co-operation with signalling systems, the influence on these systems is relatively small. The main issue in level 1 is installation of LEUs and balises. The LEUs take information for switchable balises directly from signals or from the interlocking system. In some cases, the information coming directly from the signal may require to be supplemented with switch position information. If the information is taken directly from optical signals, the signalling equipment type is generally not important. In this case it is possible to interface to existing electronic, relay and electric installations. Co-operation of ETCS level 1 with mechanical installations with optical systems is also theoretically imaginable. However, if the information is taken from the interlocking, it is recommended to use electronic or relay signalling equipment only.

If ETCS on-board equipment or the balise transmission module is not working, it is possible to continue running based on trackside signals. Similar or even equal capacity can be achieved, but level of safety is lower, as the driver is not supervised by the system. Fall back situations require knowledge of local signalling, operational rules and regulations by the relevant staff.

LX occupation time optimisation for trains running with different speeds is not part of ETCS level 1.

Level 1 with in-fill

For Level 1 with in-fill the co-operation with existing signalling systems is in principle the same, as for level 1 without in-fill. The only difference is the need to install in-fill devices in addition to LEUs and balises. Such in-fill devices can be, as mentioned before, additional balises, Euroloops or Euroradio (GSM-R).

The fallback strategy for level 1 with in-fill is the same as for level 1 without in-fill. All relevant staff shall know local signalling, operational rules and regulations. They continue running using trackside signal information.

GSM-R can be used also for updating of MAs as in-fill medium. Such configuration does not require centralisation of data and MA processing by RBC but requires fixed radio infrastructure.

LX occupation time optimisation for trains running with different speeds is not part of ETCS level 1.

ETCS Level 2

In level 2, the following configurations are possible:

- with trackside signals,
- without trackside signals.

Implementation of ETCS level 2, train separation will still be based on trackside train detection systems. However, all the information will be available in RBCs. MAs can be based on track occupancy information from longer sections in front of the train (more block sections) than the line block signalling aspects. This allows RBC to give to the longer MAs (e.g. based on 4-5 block sections) to the trains. The consequence can be higher speed of the trains. Therefore, the influence of ETCS level 2 on line capacity has to be determined precisely.

LX occupation time optimisation for trains running with different speeds is possible to be executed in ETCS level 2.

4.3 Defining National Values

Some of the ETCS functions are dependent on national regulations. The ETCS is not the only signalling system in a particular country where several national rules are valid. Today it is even possible to have different regulations valid in a certain area and/or on the railway network belonging to a certain infrastructure owner.

Therefore ETCS system:

- covers wide functionality,
- allows customisation by a set of variables called “national values”.

When the train equipped with the on-board ETCS system enters a new country, obviously equipped with a trackside ETCS system, a proper data packet, which includes a set of national values, is transmitted throughout the track-to-train communication channel. All of these variables have pre-defined values so called default values which are not transmitted from track to train but stored on board. National values are always transmitted as a complete set, neither sub-set or individual values are used. Default values are used every time when a corresponding national value is not available or if it is unknown which set of national values is to be used. The currently used set of national values is retained when the on-board equipment is switched off or isolated.

The track-to-train data transmission packet containing national values is the first one described in the SRS document. It is a track-to-train transmission “Packet Number 3: National Values”. This packet downloads a set of national values to the train, to the on-board ETCS system. It can be transmitted using any ETCS system track-to-train transmission media.

Table 1. Structure of the Packet Number 3: National Values

Group		Variable	Bit Length	Comment
General header	All track-to-train transmission packets	NID_PACKET	8	
		Q_DIR	2	
		L_PACKET	13	
	Particular packets	Q_SCALE	2	
National Value Packet header		D_VALIDNV	15	
		N_ITER	5	
		NID_C(k)	10	Identification of national area(s) to which the set applies
National value track-to-train transmission variables		V_NVSHUNT	7	
		V_NVSTFF	7	
		V_NVONSIGHT	7	
		V_NVUNFIT	7	
		V_NVREL	7	
		D_NVROLL	15	
		Q_NVSRBKTRG	1	
		Q_NVEMRRLS	1	
		V_NVALLOWOVTRP	7	
		V_NVSUPOVTRP	7	
		D_NVOVTRP	15	
		T_NVOVTRP	8	
		D_NVPOTRP	15	
		M_NVCONTACT	2	
		T_NVCONTACT	8	
		M_NVDERUN	1	
		D_NVSTFF	15	
		Q_NVDRIVER_ADHES	1	

The Packet Number 3 consists of three main parts. The first one is a general packet header and includes four fields with variables.

The first three variables are the same as in all the other packets and they are as follows:

- Packet Identifier (NID_PACKET), which informs that it is a National Values' Packet
- Validity direction of transmitted data (Q_DIR)
- Packet Length (L_PACKET)

The fourth variable (Q_SCALE) of a header is a qualifier for the distance scale and it indicates the same scale used for values describing distances, defined in all variables intended for this purpose inside this packet.

The second part may also be called a header of this particular packet and it includes three variables:

- Definition of the distance on which the national values are valid (D_VALIDNV),
- Number of iterations (N_ITER),
- Identifier of country(s) or region(s) to which the following set of national values applies (NID_C(k)).

Please note, that this packet may contain more than one NID_C values making the set of national variables applicable to more then one area identified by one NID_C code. As a result the length of the national values packet is variable.

The described above components of the Packet Number 3 header are making the first of two main parts of the packet. A header has rather a technical purpose, while the second main part of the packet consists of the essential national value variables set.

The main part of Packet Number 3 consists of the eighteen variables set for national values, as shown in Table 1.

For better understanding of the purpose of these variables in the following description they are divided into four functional groups presented in a different order than they are placed inside the packet structure.

The simplest group of variables inside track-to-train transmission Packet Number 3 consists of national values of seven speed limits permitted in specific situations.

The V_NVONSIGHT, V_NVSHUNT, V_NVSTFF and V_NVUNFIT variables give national values of permitted speed limits when the ETCS system is running respectively in On Sight (OS), Shunting (SH), Staff Responsible (SR) or Unfitted (UN) ETCS on-board system operation modes. The V_NVSTFF variable corresponds with the D_NVSTFF variable, which will be described further.

Note that for the OS and SH modes the speed limit can also be given from the trackside. While an available national value overrides the default value of the speed limit, the speed limit given from the trackside takes priority over the national value. Relevant track-to-train transmission packets used to define local speed limits different from national values may also contain a special, reserved value of the certain variable which orders to use the national speed value of the required mode.

The next variable in this group, V_NVREL, defines national value of the permitted speed limit of Release Speed, which is maximal allowed speed for the train to continue the movement close to the EOA.

The V_NVALLOWOVTRP and V_NVSUPOVTRP variables define certain speed limits related to the “Override EOA” function. The first one, V_NVALLOWOVTRP, gives maximum speed limit

allowing the driver to select this function. The second one, V_NVSUPOVTRP, is the national value of permitted speed limit to be supervised when the “Override EOA” function is active.

All of the speed limiting values may be defined from 0 up to 600 km/h, with resolution of 5 km/h. The variable value is a resolution multiplying factor, which is an integer number with the range from 0 up to 120. Values from 121 to 127 are not used and defined as spare.

The default values for the national speed limiting variables group are shown in Table 2.

Table 2. Default values for national speed limiting variables

Variable	Default value
V_NVONSIGHT	30 km/h
V_NVSHUNT	25 km/h
V_NVSTFF	40 km/h
V_NVUNFIT	100 km/h
V_NVREL	40 km/h
V_NVALLOWOVTRP	0 km/h
V_NVSUPOVTRP	30 km/h

The second group of track-to-train transmission Packet Number 3 consists of three variables used to define national values of distances and time related to passing the EOA.

The D_NVPOTRP defines a national value of the maximal distance for the train movement in the reverse direction in a Post Trip (PT) mode after an emergency braking caused by passing the EOA.

The D_NVOVTRP and T_NVOVTRP variables are related to the “Override EOA” function. They correspond with V_NVALLOWOVTRP and V_NVSUPOVTRP as all of them are used for the same function.

The D_NVOVTRP and T_NVOVTRP values give respectively a maximum distance and maximum time for overriding the train trip, which should be executed due to passing the EOA.

Table 3. Default values for the EoA passing related national value variables

Variable	Default value
D_NVPOTRP	200 m
D_NVOVTRP	200 m
T_NVOVTRP	60 s
V_NVREL	40 km/h
V_NVALLOWOVTRP	0 km/h
V_NVSUPOVTRP	30 km/h

The T_NVOVTRP may be defined with the resolution of 1 s by an integer number of seconds in the range from 0 to 255 s. The range of distance definition variables will be discussed further.

The next group consists of two variables defining maximal time without receiving a new “safe” message from the track and the reaction, which will be proceeded when this time elapses.

The main purpose for introduction of these variables is to allow the train to run without an emergency brake when a GSM-R radio transmission temporarily is not covering the whole train route while the ETCS level 2 or 3 is used.

The M_NVCONTACT variable values allow forcing one of three following possible system reactions defined due to the national (regional) preferences:

- train trip (variable value = 0),
- apply service brake (value = 1),
- no reaction (value = 2).

Two bits used for this value give possibility of defining fourth reaction, which in the current system functionality, described in a valid SRS document version, is not predicted. Variable value equal to 3 is left as spare.

The second variable in this group, T_NVCONTACT, gives a national value of the time, during which a “safe” message must be received from the trackside. When this time elapses and no “safe” message has been received, the ETCS on-board system introduces an appropriate action defined by a national value of the M_NVCONTACT variable.

The T_NVCONTACT may be defined with the resolution of 1 by an integer number of seconds in the range from 0 to 255.

The default values of these two variables are shown in the table 4.

Table 4. Default values for no “safe” message reaction variables

Variable	Default value
M_NVCONTACT	No reaction
T_NVCONTACT	∞ (no limit)

The last group of six national values defining variables is in fact a set of miscellaneous variables not belonging to any of three functional groups described above.

The first one described below corresponds to the V_NVSTFF variable, which gives the maximum permitted speed in the Staff Responsibility (SR) system operation mode. It is the D_NVSTFF variable, which defines maximum distance for running in the SR mode.

The D_NVROLL variable, as it can be recognised by a D_ prefix, also defines distance. It is used for Roll Away Protection and Reverse Movement Protection functions. The D_NVROLL gives the national value of a roll away distance limit.

The M_NVDERUN variable national value decides if it is permitted to enter a new driver ID to the ETCS on-board system while running.

The last three variables are qualifiers for permission of certain driver actions.

The Q_NVDRIVER_ADHES variable value allows or not the driver to modify the trackside adhesion factor.

The Q_NVEMRRLS variable value gives a national decision if it is permitted to release an emergency brake (triggered by speed exceeding the system intervention limit with lack of driver reaction) immediately when such a condition does not last any more, or only when standstill. Note that the brakes release action (e.g. pressing the button) depends on the braking system and is a different issue. A Boolean value of a variable equal to 0 means that the brake release is permitted only at standstill while value 1 permits an immediate brake release.

The last, Q_NVSBKTRG variable value defines a national permission to use the service brake when braking to a target is supervised.

The value of a single bit length variable (M_NVDERUN, Q_NVDRIVER_ADHES and Q_NVSRBKTRG) means respectively: when equal to 0 – action is not permitted, and while equal to 1 – action permitted.

Table 5. Default values for the EoA passing related national value variables

Variable	Default value	Meaning
D_NVSTFF	32767	∞ (no limit)
D_NVROLL	2 m	
M_NVDERUN	1	Permitted
Q_NVDRIVER_ADHES	0	Not permitted
Q_NVEMRRLS	0	On standstill
Q_NVSBKTRG	1	Permitted

As it was mentioned in the National Value Packet header description, the Q_SCALE variable is a qualifier for the distance scale and it indicates the same scale used for values describing distances, defined in all variables intended for this purpose inside this packet. As a result, all variables for the national value distance definition have the same scale factor. A value of Q_SCALE is also a resolution of each particular distance value. Therefore it is possible to define one of three possible resolutions: 10 cm, 1 m or 10 m, for the distance value giving variables. Note that D_NVOVTRP and D_NVPOTRP values may be defined in a full range of possible

values while maximal possible values of D_NVROLL and D_NVSTFF variables are reserved and have a special meaning. They are interpreted by the system as an infinite value. The possible range of the distance definition versus the value of Q_SCALE variable is shown in the table 6.

Table 6. Default values for the distance defining national value variables

Variable	Minimum Value	Maximum Value				Q_SCALE: Value Meaning (Resolution)
		0 10 cm	1 1 m	2 10 m	3 Spare	
D_NVOVTRP	0	3276,6 m	32.766 km	327.66 km	N.A.	N.A. – Not Applicable
D_NVPOTRP	0	3276,6 m	32.766 km	327.66 km	N.A.	
D_NVSTFF	0	327,67 m	32.767 km	327.67 km	N.A.	
D_NVROLL	0	3276,7 m	32.767 km	327.67 km	N.A.	

4.4 Defining ETCS Movement Authorities

MA as a permission for a train to run to a specific location within the constraints of the infrastructure belongs to basic ETCS principles. As such MAs are described in *ETCS SRS subet 026, chapter 3*. This chapter describes ETCS MA purpose and structure. The structure in details is given in *SRS chapters 7.4.2.3 – 7.4.2.4* defining packets to be used to transmit ETCS MAs from trackside to on-board ETCS assemblies.

As MAs are one of the main basis for supervision of the way the driver is driving the train (the other is e.g. current position measurement) it is extremely important to define them in the best possible way. As MAs are replacing colour aspects of the trackside signals it is important to consider relationship between old solution (trackside signals) and new solution (MAs displayed in driving cab for assisting drivers).

Colour aspects of trackside signals inform drivers about: maximum train speed when passing signal showing the aspect, maximum speed in front of next signal, number of unoccupied track sections behind signal or a mixture of them. Changing that into MA giving precise speed and distance limits requires some rules which have to be defined on a national level. In addition to speed and distance limitations in some cases old system includes time constraints defined sometimes in separate rules which are to be included in MAs as timeouts of MA and timeouts of overlaps.

Following considerations are subdivided into ETCS level 1, ETCS level 2 and STMs relevant considerations as in ETCS level 1 applications MAs are defined by LEUs, in ETCS level 2 (3) applications MAs are defined by RBC and in case of STMs MAs are defined on the basis of national system data processed on-board.

Questions related to Movement Authorities in ETCS level 1 application

In case of ETCS level 1 applications MAs are given by switchable balises. Data transmitted by such balises are defined by LEUs connected to those balises via so called interface “C”. The link between LEUs and basic layer signalling systems is crucial for collecting basic data and is not defined by ETCS specifications. However this link must ensure proper collection of basic vital data taking into account both safety and minimal costs.

Reducing length of cables connecting LEUs with interlocking

ETCS specifications suggest direct link between LEU and interlocking. This means taking vital data from their source but at the same time it means in many cases long cables. To reduce the length of cables it is possible to connect LEUs with lineside signals. As a result in each case there is a need to check if from signal data can be acquired in a safe way. Secondly, because interlocking offers us all data giving an opportunity to define speed and distance constraints for the MA while lineside signals offer extracting data from shown aspects. The same aspect may be shown by a signal in different operational situations e.g. for different routes set for the train passing such signal. As a result distance constraints may vary in relation to the setting of the points behind the signal. To solve that LEU may be supplementary connected to point machine. The other possibility is to use shortest distance to define MA and to use infill balises to correct distances when appropriate. The use of shortest distance is crucial for safe operation in case of problems with receiving infill balise.

Connecting LEUs with line block signals

Modern line block systems are frequently integrated with interlockings on the neighbouring stations however autonomous line block systems are in use and will be in use in the future. In both cases connecting LEUs with block system logic may require long cables. Reducing the length of cables by connecting LEUs to signals require an answer for the first question but not for the second. The distance constraints due to no points are different for different signals but stable for signal aspects shown by signal. Distance constraints can be then pre-programmed for a certain LEU.

How precisely ETCS have to reflect present signalling rules

The easy and safe side way to define MAs and associated data on the basis of signal aspects is to reflect precisely that, what is stated in present signalling rules. This however may impose on new technology old constraints reflecting old technology lacks.

Two examples:

- **PKP S2 signal (LoA instead of EoA according to the rules)**

The S2 (green) signal aspect according to the rules means maximum speed up (160 km/h) to the next signal. Rules do not say anything about speed or distance beyond next signal. As a result if we decide to reflect rules precisely MA has to be defined as a **L**imit **of** **A**uthority (LoA) – maximum speed for given distance and no further information.

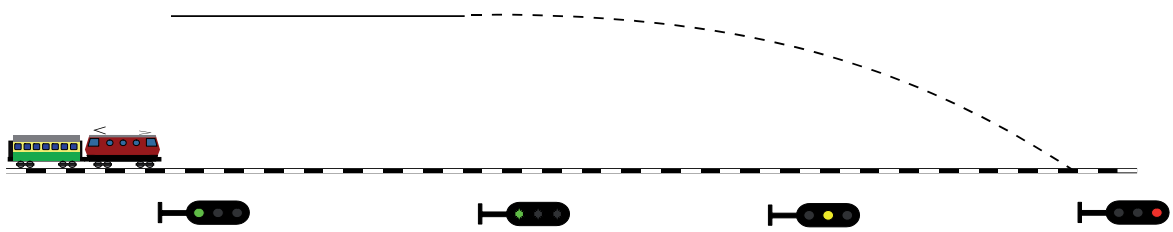


Fig. 8: LoA

This would lead to emergency braking especially when balise group associated to next signal is not finding within limits. Therefore a possibility to define respective MA as an EoA has to be considered.

EoA needs distance to the EoA (0 speed restriction), however shortest value for the certain location, line or network (on the basis of signalling rules) can be used. Distance would be then updated by information in the next balise group.

- **PKP S3 signal (speed restrictions imposed at next signal according to the rules)**

The S3 (flashing green) signal aspect according to the rules means: two block sections free, maximum speed (160 km/h) allowed at the signal, maximum speed at the next signal 100 km/h. As a result speed restriction to 100 km/h is imposed in a certain location to ensure stopping before S1 (red) signal. In ETCS one should consider whether such speed restriction is still necessary. Speed restriction resignation can only be accepted if a certain speed restriction was imposed to ensure appropriate distance for braking in front of more restrictive speed restriction e.g. to ensure stop in front of a next signal. Such resignation will smooth train running, decrease energy consumption and increase line capacity. However decision about resignation has to be taken carefully as the same signal aspects might be used in case of speed restrictions imposed.

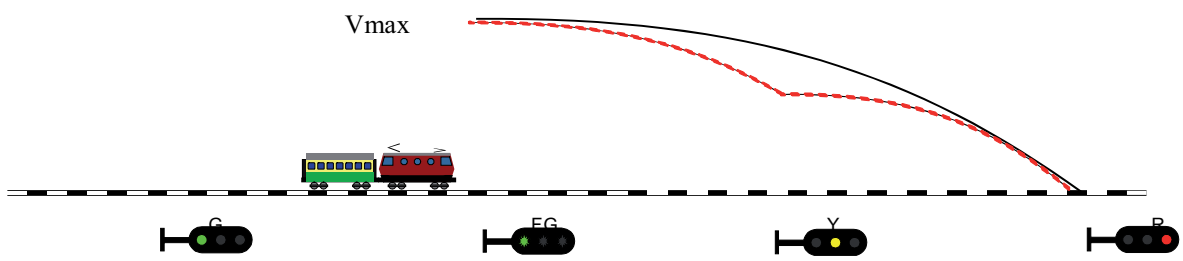


Fig. 9: Speed restriction imposed by flashing green signal aspect

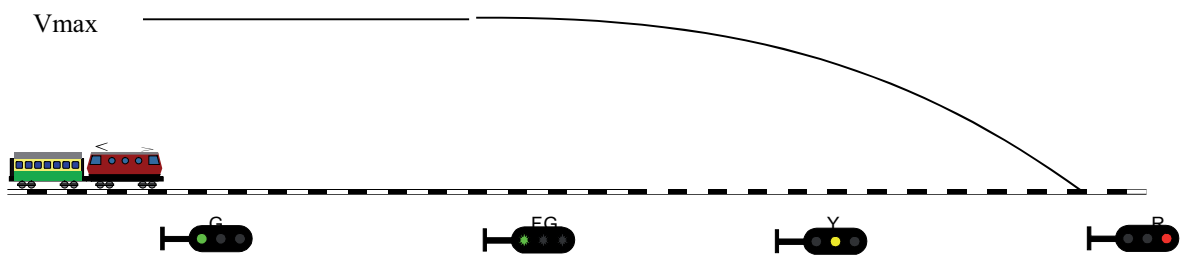


Fig. 10: EoA

Long MAs and their revocation

In case of ETCS level 1 applications MAs will be in principle as long as signal aspects allow them to be. Data about farther sections of track are not easily available. Theoretically one can collect additional required data using e.g. dedicated fibre optic cable, but as a consequence this would require MAs revocation possibilities which are limited in cases of level 1 application.

Taking into consideration level crossings protection systems' constraints

Level **C**rossing (LX) protection systems impose constraints on trains. Precise rules differ from country to country and depend on LX category. Moreover LX protection systems are frequently autonomous and that means that constraints imposed by them are not covered by main signal aspects. Additionally some railways for certain LX categories use trackside signals which inform train drivers about status of the respective LX protection systems. Decision whether include LX protection systems' constraints in ETCS or not can be taken by an Infrastructure Manager separately for each LX. Moreover permanent speed restrictions due to LXs and speed restrictions imposed by defective LX protection can be considered separately.

The ETCS SRS baseline 2.3.0 does not include unified way to inform on-board ETCS equipment about constraints imposed by LX protection systems. Existing ETCS functions allow the railways to pass relevant information to the ETCS on-board equipment in several ways. Unified solution is expected to be included in ETCS SRS baseline 3.0.0.

Movement Authorities in ETCS level 2 (3) applications

In case of ETCS level 2 (3) applications MAs are given by RBC using radio transmission. RBC is preparing MAs using data collected from interlocking and block systems. In this case to minimise fibre optic cable cuts and to minimise the length of cables data is taken from interlocking and not from signals and points. RBC will then have all data about operational situation including the way the points are set. This allows preparation of MAs for defined trains and defined route without constraints imposed by trackside signalling. All speed restrictions have to be assessed if they are required (limitations due to points, bridges, etc.) or not (imposed to ensure braking distance in front of other speed restriction).

Long MAs and their revocation

As a result long MAs comfortable for drivers and, in exceptional cases, allowing also increase of speed over trackside signalling limits are possible. For safety reasons they have to be based on already set and proven routes, but in case of traffic disturbances due to continuous transmission revocation of an MA already given is possible and parts of route far in front of the train can be released (when revocation is confirmed) and used for different train.

Taking into consideration LXs protection systems' constraints

Constraints imposed by LX protection system may be included in the ETCS data transmission from RBCs to trains. This however requires relevant information to be available in the RBC. That is not so problematic in case of speed restrictions which apply permanently due to LXs. Taking into consideration constraints imposed by faulty LX protection requires data transmission between LX protection system and RBC. Requirements in that respect are not unified and have to be precisely defined by infrastructure manager.

STM profiles defined on-board in case of using STMs

In case of a line equipped with national system and ETCS on-board receiving running constraints from national system via STM data precision is mainly limited by national system in use. This data can be supplemented by more precise information available on-board only in some cases. As many national systems are not including enough data to define for ETCS an STM profile which is replacing MA and allowing the train to run in "STM European mode", ETCS specification defines also "STM National mode" which allows STM to supervise driving according to national system principles using ETCS on-board components.

The STM technology allows less problematic migration from national systems to ETCS. Since the transition time to pure ETCS is, due to economic constraints, expected to be used for at least 20 years, STM technology is certainly worth to be studied in detail how STM profiles can replace MAs in case of running in an STM mode.

4.5 Braking Curves Calculation

Drivers have to apply the braking force in the way that allows stopping the train in front of the signal showing danger or appropriate slowing down in front of a speed restriction. The moment drivers actually start braking depends on the real conditions. The drivers take gradients and adhesion conditions between wheel and rail into account. Therefore it can be said, that safe braking depends first of all on drivers' experience.

In addition it is important to notice, that deceleration which is assumed to be up to 1.5 m/s^2 under normal circumstances is not stable in time. It is known from tests that even small amounts of wet leaves, for instance, reduce this value even three times. Therefore ETCS implementation requires careful train braking curve calculation.

Braking Curves in ERTMS

The purpose of braking curves is to assure that the train remains within the given distance and speed limits defined by the MA. The speed limit may vary along track and is defined by the **M**ost **R**estrictive **S**peed **P**rofile (MRSP) taking into account all speed imposed restrictions.

Main braking curves used by ETCS are following:

- Emergency brake deceleration (EBD),
- Emergency brake intervention (EBI),
- Service brake intervention (SBI),
- Warning (W),
- Permitted speed (P).

The dynamic speed monitoring is described in *Subset-056 chapter 3.* The purpose of the emergency brake deceleration curve is to assure that the train will remain within the limits of the MRSP and will not pass the EOA. The purpose of all other curves and indications is to assist the driver in preventing an emergency brake intervention by maintaining the speed of the train within the appropriate limits. The requirements for the braking curves are different for the following three regions:

- Ceiling speed monitoring,
- Target speed monitoring,
- Release speed monitoring.

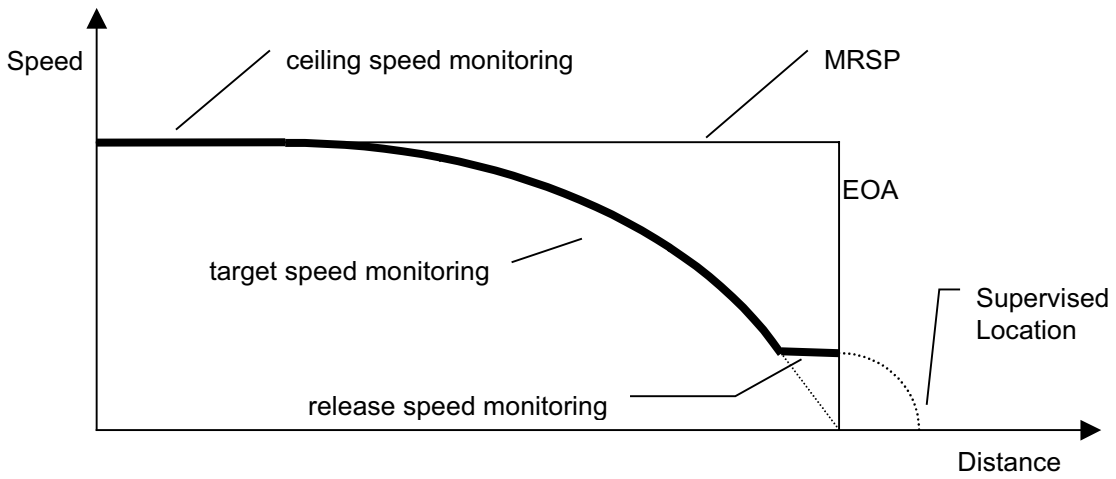


Fig. 11: Different types of speed monitoring

Ceiling speed monitoring is the area where the MRSP remains constant and where the train can run with the speed as defined by the MRSP without the need to break to a target. Target speed monitoring is the area where the train brakes to a target. Release speed monitoring is the area close to the EoA where the train is allowed to run with release speed to approach the EOA.

There are three specified speed margins for exceeding of the MRSP. ETCS shall give an audible warning to the driver if the measured speed is more than a margin dV_warning higher than the MRSP. Optionally ETCS may command the service brake if the measured speed is more than a margin dV_sbi higher than the MRSP. ETCS shall command the emergency brake if the measured speed is more than a margin dV_ebi higher than the speed according to the MRSP. To optimise the performance at low speed the values of the speed margins are speed dependent. They increase linearly from the minimum value for V = 0 km/h to the maximum value for V = 200 m/h. The minimum and maximum values of speed margins are given in the table 7.

Table 7: The maximum value is also valid for the speeds higher than 200 km/h.

Braking curve	Speed margin	V = 0 km/h	V = 200 km/h	Remarks
Audible warning	dV_warning	2.0 km/h	8.0 km/h	
Service braking	dV_sbi	2.5 km/h	12.5 km/h	Optional
Emergency braking	dV_ebi	2.5 km/h	12.5 km/h	Service braking not implemented
Emergency braking	dV_ebi	3.0 km/h	15.0 km/h	Service braking implemented

An audible warning shall be given by ERTMS at time interval T_warning before the calculated SBI will be passed. This interval is a reaction time for the driver to operate the full service brake, T_react. The value for reaction time depends on train speed and the minimum value, dT_react_min = 1 s and the maximum value dT_react_max = 2 s.

To calculate the exact location where the warning has to be given, a prediction of the speed during the interval T_warning is necessary. For this prediction one of the following two options shall be used:

- current speed, which means that the speed is assumed not to change from the currently measured value,
- expected deceleration.

In addition to audible warning, a visual warning shall be given to the driver to indicate that the train is approaching the moment that an audible warning will be given. The visual warning shall increase in size from the minimum value at the starting point until the maximum value at moment when the train passes the audible warning curve. The starting point for the increase of the visual warning shall be a time interval T_visual before reaching the audible warning curve. To optimise the performance at low speed T_visual shall follow the same convention as defined for T_react. The value of T_visual has provisionally been proposed to be between minimum value of 2 s and maximum value of 3 s.

Slippery Tracks

In order to maintain a sufficient level of safety on excessively slippery tracks there may be a need to take reduced adhesion conditions into account in the speed dependent deceleration. The adhesion information shall be expressed as a one bit parameter with values “normal adhesion” and “reduced adhesion”. The default reaction of the speed supervision function in ERTMS to reduced adhesion conditions shall be to reduce the speed dependent deceleration when calculating the guaranteed or expected deceleration.

The onboard system may be equipped with a button to switch the adhesion factor between normal and reduced adhesion. Reduced adhesion shall be taken into account when the driver operates the relevant button and when the button operation is permitted by national value. Reduced adhesion shall be taken into account when a message with start and end of the relevant section of track is given from trackside.

ETCS Braking Curves versus Line Capacity

The parameters for braking curve calculation are set to achieve the high level of safety. They take numerous factors into account. The disadvantage of using these parameters could be, dependent on the line configuration (with or without lineside signals), a reduction of line capacity. This will result from the fact that the train will have to start deceleration a bit earlier than at the run without ERTMS (according to trackside signals). A typical example is approaching the EOA. In that case, if programmed, the train will have to proceed with release speed, which will usually be lower than in non-ERTMS environment, especially when the train is driven by experienced driver with perfect route knowledge.

Service braking supervision is optional

For some trains it is important that service braking supervision is optional. It is because for some existing trains emergency braking is characterised by lower deceleration rate then service braking changing the sequence they appear on a speed / distance diagram. Additionally some trains are not equipped with two different braking systems.

5. How to design an ETCS installation

This chapter includes information about balise placement, improvement possibilities, and managing interfaces.

5.1 Balise Positionning

Balise placement on the track is not as easy as it looks like at the first glance. The basic principles are described in SRS *Subset-026, Chapter 3*. Detailed obligatory rules applying for determination of balises' positions on the track are described in Dimensioning and Engineering Rules (*Subset-040*). Precise requirements regarding mounting are described in FFFIS for Eurobalise (*Subset-036*). Moreover Performance Requirements for Interoperability (*Subset-041*) defines on-board required minimum accuracy for ETCS odometers in terms of distance, speed and time and requires Infrastructure Managers to place balises considering those limitations.

ETCS balises are put on track in balise groups containing between one and eight balises. Balise groups have they directionality. In relation to each balise group we define nominal and reverse direction. In a group composed of at least two balises directionality is known from the balise numbers in the group. For single balise groups it is determined from linking data from previous balise group.

Engineering Rules define for instance: minimum and maximum distances between balises in the same balise group, number of balises that can be processed per unit of time. For level 1 application Engineering Rules define for instance minimum distance between first balise in a group and position where the train has to stop, minimum distance between balise group and EoA, as well as minimum distance between last switchable balise and limit of train detection section. The same document defines also ETCS on-board balise antenna mounting constraints. FFFIS for Eurobalise defines for instance height, lateral and angular balise mounting tolerances. All those together give ETCS trackside equipment designers number of constraints and still several balise placement possibilities.

Balise Positioning Possibilities in Level 1

The balise placement possibilities for level 1 application are limited due to level 1 balise placement constraints imposed by Engineering Rules. Moreover in level 1 switchable balises are used and therefore power supply cables lengths and data cables lengths have to be considered. For economic reasons length of all cables have to be possibly short including data cables from LEUs to switchable balises and data cables from safe data sources to LEUs. As safe data sources we can accept interlockings, signals and point machines (which are sometimes necessary for supplementing data taken from signals). As a result in ETCS level 1 application the way the balise chain is put on the track is, to a large extend, predefined by the signalling system on which ETCS superstructure is build.

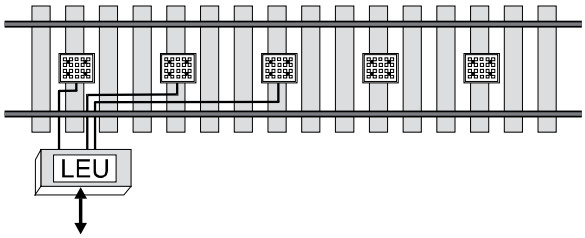


Fig. 12: Balise Positioning Possibilities in Level 1

Balise Positioning Possibilities in Level 2

In case of ETCS level 2 applications balises could be put on the track according to different principles. One possibility is to apply the principle adopted for level 1. However this requires balises for each signal and the tracks are in many cases bi-directional. In this case the distances between balises differ and the absolute distance errors differ too. Second possibility is to put balises in well-defined distances. This way seems to be quite effective for instance for the tracks used bi-directionally as all balises are equally well placed for both directions.

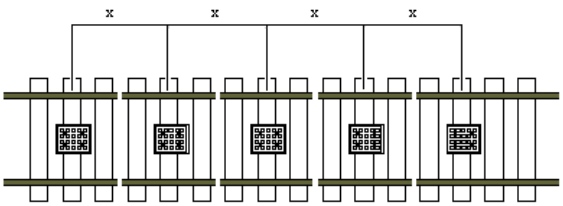


Fig. 13: Balise Positioning Possibilities in Level 2

Third possibility is to put balises in the middle of track sections. This concept is also good for bi-directional tracks, but in case of long track sections two balise groups may be required to keep the distance between balises (as location reference points) and ends of sections (as preferred EoA / stopping location) within acceptable absolute error limits.

Use of Single Balise

A balise group may contain one balise. In this case passing such group as a first one the ETCS train will not be able to define directionality of the track. But if it is a group within the balise chain the linking information within ETCS allows quick and safe determination of directionality of the track. As a result Infrastructure Managers can decide to use single balise groups on the lines and groups containing at least two balises at entrances where trains enter equipped lines.

Use of Triple Balises

If exploitation will show that balises are likely to malfunction a railway may decide to use three balises in each group programmed in such a way, that all the information is stored twice but divided between balises in such a way that lack of one balise doesn't mean lack of any information.

Odometer Accuracy and Balise Linking

The minimum ETCS on-board odometer accuracy presently required for distance measurement (see *Subset-041*) is defined as 5 meters plus 5% of distance travelled from the last reference point. This allows prediction of maximum absolute errors in expected stopping positions and make sure that all interoperable trains would be able to run fluently. As a result required odometer accuracy together with operational stopping positions can be used to prejudge balise chain thickness.

5.2 Operational Improvement Possibilities

ETCS - Configurations and Operational Improvements

Operational improvement during ETCS implementation largely depends on decision related to ETCS level and configuration. As described in *Chapter 3.2* level and configuration will prejudge about centralisation and infill. This will directly influence operational possibilities in relation to solving disturbances. We can distinguish three major types of installations looking from the point of view of operational flexibility:

- spot transmission without infill – MA can be changed/revoked only when passing switchable balise group and only in a way that is predefined by underlying signalling system,
- spot transmission with infill – as previous type but MA change can be received by trains over infill section,
- centralised signalling with RBC - MA can be changed/revoked at any moment as there is a continuous transmission possibility and can be changed in a flexible way as far as it is assured by the vital operational functions used by section/line dispatcher.

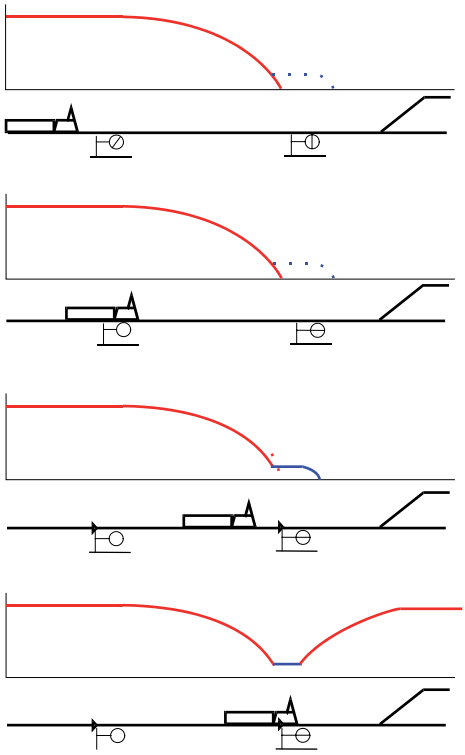


Fig. 14: Spot transmission without infill

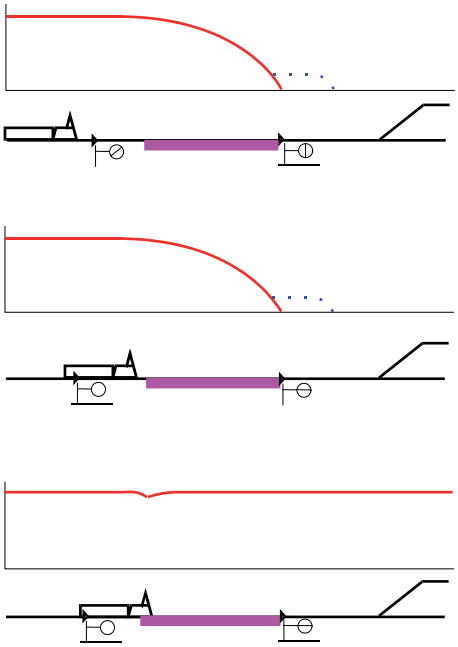


Fig. 15: Spot transmission with infill

Differences between those options are shown on a picture taking an example of signal aspect being cleared after train passed previous signal. This is a typical situation during operational disturbances and it precisely shows the difference between quoted spot transmission options.

Left side (spot transmission without infill) from top shows:

- train approaching a stop signal,
- train passes signal and then signal ahead clears,
- train passes next signal with speed lower than release speed,
- train receives balise at the next signal and calculates new speed profile and may accelerate.

Right side (spot transmission with infill) from top shows:

- train approaching a stop signal,
- train passes signal and then signal ahead clears,
- train enters infill section and calculates new speed profile and may continue.

Third option (MAs given by RBC) is not shown on the picture as speed profile known to the train in this case does not depend on the place on track where the train is as continues RBC-train communication is available.

ETCS - Movement Authorities

Operational improvement depends also very much on a way how during engineering phase MAs are predefined. On one side all restrictions and limitations imposed on trains by trackside signalling may be transferred to the electronic MAs to fulfil the rules and regulations. On the other side there is a possibility to define more appropriate limitations taking into account not only precise locations of speed restrictions and applicability of the restrictions to different train categories but also ensured braking to speed limits.

Some speed restrictions imposed by trackside signalling which are related for instance to switch position have to be observed. Description of the questions related to the definition of MAs is included in *Chapter 4.4.*

ETCS - Implementation at Stations

For operational result it is extremely important to answer the question how far stations are to be equipped with ETCS. It is of course possible to implement ETCS on main tracks only, but then each train leaving main tracks on the station enters unequipped area. This means that on-board equipment switches to UNFITTED mode and coming back to Full Supervision requires space and time.

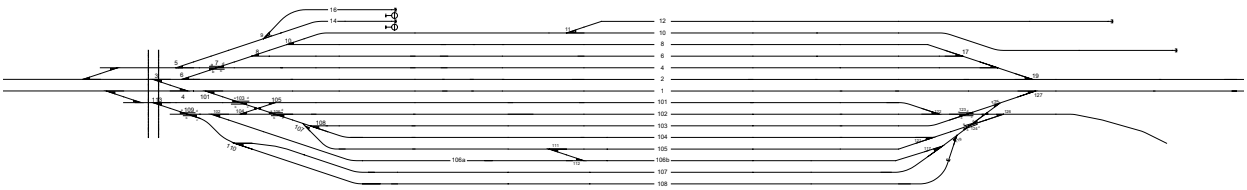


Fig. 16: Example station layout

Example station layout shows that equipping main tracks only will affect in many case most of the trains passing certain stations.

Equipping more tracks at stations requires in case of level 1 more balises, LEUs and cables. In case of level 2 it requires first of all more data in the RBC and some additional non-switchable balises. In both cases detail consideration is necessary to find a balance between unequipped tracks and operational constraints imposed by equipped trains using them.

ETCS - Fallback Strategies

For railway operation it is crucial to answer how the trains will be run in case of failures affecting normal way of running. For that purpose during preparation of the ETCS installation it is necessary to define fallback. In case of level 2 applications it is possible to superimpose on the same line level 1 installation as a fallback, however this is an expensive solution. The other solution is to

keep lineside signals and treat them as a fallback. This is a natural choice in case of using the same line to run trains not equipped with ETCS. It is also possible to use class B system as a fallback, but such solution would require all trains to have class B on-board equipment or STM which is not a way to trans-European solutions. It is also possible to define for fallback purpose appropriate rules and regulations which have to be observed in fallback situations. On one side this last solution is not ensuring flexible and smooth operation in fallback situations but on the other taking into account high availability of ETCS it is not to be used so frequently.

It has to be stated that ETCS uses underlying signalling which influences the availability of a whole CCS on a given section or line and therefore fallback strategies require always careful considerations.

5.3 Technical Improvement Possibilities

In the present development stage, ETCS is a complete train control system with advanced functionality as it has been decided by industrial and railway partners involved in the functional and system requirements definition. This current development stage is called the consolidation phase. The prototype trackside and on-board equipment passed necessary tests and some pilot installation projects are being conducted. However, this is still a living system, i.e. a number of technical improvements seem to be possible and some of them are expected to be introduced in the next system version. The current ETCS equipment is based on the baseline 2.3.0. It is planned to migrate to a new baseline 3.0.0. There are efforts being made to include some of the possible technical improvements mentioned below in this new ETCS version, which may be frozen for several years due to the EC intentions taking into account the economical reasonability.

Redefinition of Overlaps

Most of railways use overlaps as a part of their safety philosophy. The overlap is defined as a part of an entrance route located after the end of the route. The overlap must not be released until the train has stopped. Overlap implementation on the station tracks layout needs a certain space, shorten possible track lengths and increase the time needed for a train in opposite direction to pass the station. The ETCS functionality allows reduction of the overlaps and building the safety philosophy on certain odometer accuracy and/or using of the infill function. Such decisions however need to be validated by proper cost-benefit analysis.

Redefinition of Speed Restrictions

Speed restrictions are in many cases presently given by signals and apply to whole sections between signals. This is due to limitations of the colour light trackside signalling. ETCS implementation allows Infrastructure Managers to redefine speed restrictions precisely taking into account actual limitations imposed e.g. by points. An example is shown below.

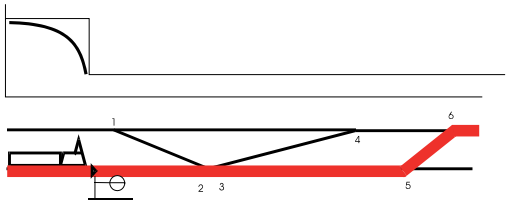


Fig. 17: Speed restriction imposed by colour light signalling system (point 5/6)

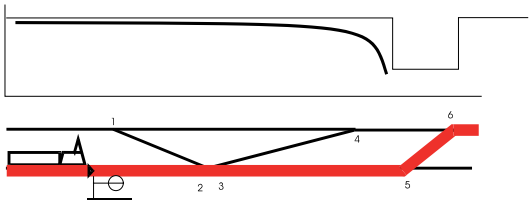


Fig. 18: speed restriction imposed by ETCS (point 5/6)

Different Ways to Introduce TSR

Temporary **S**peed **R**estrictions (TSR) can be imposed on trains by including them in speed profiles taken into account when calculating most restrictive static speed profile. There are in principle two ways to deal with TSRs. One is to add respective packets to existing trackside data storage – to balises in case of level 1 or to an RBC database in case of levels 2 and 3. This may be convenient in case of RBC but may be difficult in case of level 1. Therefore infrastructure manager may decide to have a procedure to add on a track TSR balises when necessary. Such balises will not be included in the balise linking and therefore special precautions have to be undertaken to ensure that such balises are not missed. The minimum is to put such balises on the track in pairs.

Use of STM Modules

Before the ETCS system development, most of railways used different national ATP/ATC systems in most cases not compatible one with another. During the migration phase from these national class B systems to the target class A system it is possible to use class B trackside equipment and translate its track-to-train communication using relevant **S**TM for a certain class B system. The idea of using STMs has been developed before first ETCS prototype installations seem to be not effective, particularly for trains expected to pass a number of borders between areas equipped with different class B systems. A limited space for a number of class B antennas on a traction vehicle and a complicated interface between ETCS on-board equipment and class B STMs was a reason of scepticism for this way of class B to class A migration. Some efforts have been done to combine several partially compatible class B systems into one STM.

The interface K combining the ETCS interfaces for three class B systems: French KVB, Swedish and Portuguese Ebicab and Italian RSDD, called together the KER, is an example of possible solutions.

The current EC policy based on economical evaluations and ETCS deployment estimations prefers pure class A implementation on selected lines rather than migration from class B systems with STM to the target class A system on a certain area. Such approach is expected to be a faster ETCS deployment strategy.

Level Crossing Protection in ETCS

The efforts of some European railway infrastructure managers brought the consensus of a LX functions implementation for the nearest ETCS SRS version. The Functional Scenarios have been prepared for it. The following basic scenarios have been determined:

- Passing a LX in normal situation,
  (no impact on actual train speed and DMI indications due to LX),
- Passing a LX that is protected after LX indication started on DMI,
- Passing a not protected LX requiring stop,
- Passing a not protected LX not requiring stop.

If the LX is located on the line with mixed traffic, where the time between the LX equipment activation and the train approach the LX is importantly various due to the maximum allowed speed for different train types, it is possible to install more than one activation point and also more than one balise transmitting the LX protection status. In such case, the first LX activation point should be speed dependent. The first LX protection status transmitting balise should be located in such distance from the LX, that a train with the speed lower than the first activation point threshold should pass this balise with the speed lower than limited by the braking curve to stop this train in front of the LX.

Most of specific LX functionality needs may be fulfilled by the combination of the proposed LX scenarios, other ETCS functions and certain balise placement.

For example, the functionality requested by German railways to introduce a special LX status called “not enough protected” when the train did not reach the LX after its activation during certain, predicted time may be achieved by one of proposed LX scenarios and the ETCS “section time-out” function.

Level 1 Limited Supervision

Following additional requirements for ETCS were proposed:

- It shall be possible to provide full supervision at certain locations only, and limited supervision at others,
- It shall also be possible to provide warning and train trip functions similar to the ones provided by existing systems (AWS, Crocodile, Signum etc.), retaining the simplicity of implementation and reducing cost for interfacing to lineside signals and data preparation,
- It shall also be possible to implement ETCS 1 without full cab signalling and possibly with a reduced safety level for speed monitoring functions.

L1LS is a proposed cheaper way to equip secondary lines with ETCS level 1 components.

L1LS will allow Infrastructure Managers to equip chosen signals instead of all and offer reduced functionality similar to class B systems. It is expected, that all ETCS traction units will be prepared to run on ETCS L1LS lines.

5.4 ETCS external interfaces

ETCS Trackside - External Interfaces

Basic layer signalling <> LEUs / RBC

ETCS trackside assembly does not provide all signalling functions and therefore have to co-operate with basic layer signalling systems namely interlocking, line block systems and LX protection systems and their components to gain information about current operational situation. This is crucial for the preparation of the ETCS MAs, which have to be based on safe data acquired in a safe way from safe places to guarantee their correctness as they are vital for train driving supervision.

In case of level 1 signalling data acquisition is distributed along the line and can be seen as gaining information from basic layer signalling components like lineside signals, point machines, track circuits, etc. or as gaining information from interlocking. This data is supplemented on LEU level with some permanent data like distances, gradients, speed restrictions, etc. not depending on points position.

In case of level 2 all signalling data are collected by the RBC. Also in that case operational data are supplemented with permanent data describing infrastructure like distances, gradients, speed restrictions, etc. In that case all that data is accumulated in RBC database.

This interface is national or local and largely depends on basic layer signalling systems in use. Requirements in respect to this interface can be defined by infrastructure manager or left to industrial partner responsible for ETCS implementation.

RBC <> GSM-R

On the other side in case of ETCS level 2 or 3 RBCs are interfacing GSM-R. As GSM-R is a radio cell network composed of Base Stations, Base Stations Controllers, Network Management Sub-system and Network Switching Sub-system comprising Mobile Switching Centre and registers it is treated as transmission medium external to ETCS and not as internal ETCS component.

As a result ETCS SRS is only defining radio messages and their content on an application layer while all the other requirements are defined by a number of GSM-R related documents.

Subset-037 is applicable to radio communication systems providing communication services for safety-related application processes using open networks. It specifies for ETCS Class 1 the Radio System Interoperability for message exchange between on-board and trackside equipment in respect to safety-related application processes, like Automatic Train Control of ETCS level 2/3. Additionally, it specifies for ETCS level 1 the optional message exchange between on-board equipment and radio in-fill unit.

ETCS on board - External Interfaces

Train <> ETCS on-board

ETCS on-board assembly is supervising the way the driver drives the train. For this purpose it needs some additional information about status of certain rolling stock functions and devices. For that ETCS specifications define Train Interface Unit (TIU) supporting data acquisition on train side in six groups of variables as shown in table 8.

Letters I and O in the second column show if the variable purpose is to input and/or to output data transmitted via TIU. This interface is described in *FIS for the Train Interface – Subset -034*. However it has to be stated that in reality all the details of this interface depend on rolling stock type and have to be designed according to quoted document for each type of locomotive and each type of fixed composition train separately. The cost of this interface is therefore largely dependent on a number of locomotives / train units to be equipped.

Table 8: Data acquired by Train Interface Unit

Control of Train / Engine		**Mode control functions**	
Change of traction power	O	ETCS onboard sleeping	I
Pantograph	O	ETCS onboard isolation	I
Air tightness / Flap control (Air condition)	O	LZB STM isolation	I
Door control	I / O	Indusi STM isolation	I
Tilting	I	**Control of brakes**	
Main switch / Circuit breaker	O	Service Brake	I / O
Traction cut off	O	Emergency Brake	I / O
Automatic Train Driving	O	Regenerative brake	O
Coupling Status	I	Magnetic shoes	O
Cold Movement Detector	I	Eddy current brake	O
Cab Status information		Brake pressure	I
Direction controller position	I	Brake handle	I
Cab Status (Desk status)	I	Inhibit passenger emergency brake	I / O
Vigilance action	I	**EIRENE-Radio related functions**	
Vigilance Disable	O	Train running number	I / O
Vigilance Reset	O	Juridical recording data	I
Train integrity		Emergency button/ Radio Alert	I
Train integrity	I		

Driver <> ETCS on-board

This interface between the on-board equipment and the driver is defined in the document *Subset-033.*

GSM-R on-board <> ETCS on-board

This interface is defined by (MORANE) Radio Transmission FFFIS for EuroRadio – *A11T600112.*

National System <> ETCS on-board

STMs are very important for migration from national control command systems to European ETCS standard. For first applications industrial partners offered to the railways ETCS on-board assemblies with integrated STMs. Such solution called "internal STM" is not so good for companies operating trains because of two important reasons:

First internal STMs are offered by single companies (usually those which were producing national system in the past) and that means no competition.

Second required internal STMs would have to be defined when ETCS on-board assembly is ordered as adding an internal STM later on would be very difficult if not impossible. For those reasons it was decided to define an interface for external STMs enabling each on-board assembly to be equipped with as many as needed STMs in whatever moment of their lifecycle. As national systems differ significantly this interface and STMs have to comply with several documents namely: *STM FFFIS – Subset-035*; *STM FFFIS Safe Time Layer – Subset-056*; *STM FFFIS Safe Link Layer – Subset-057* and *FFFIS STM Application Layer – Subset-058 and Subset-059 Performance Requirements for STM.*

The interfaces "K" and "AK"

As some national systems are using balises similar to the ETCS Eurobalises it was necessary to define common interface for airgap "A_K" and common interface for connecting KER STMs to on-board ETCS assembly "K". Otherwise operators would have to decide for compliance with only one of those systems, as it will be not effective and in most cases even not possible to put more then one antenna on single locomotive. As the main differences between Eurobalise and KER balises air-gap definition are related to signal modulation/demodulation and the bit rate, it is even possible to combine both system antennas to single unit.

Interface "A_K": The air-gap interface between ETCS onboard Eurobalise antenna and Eurobalise is called "A" interface. Respectively, such interface for Euroloop is called "A_L" interface. Similarly, the air-gap interface between the KER balises and the ETCS onboard antenna is signed as the "A_K" interface.

Interface "K": The module combining the ETCS and KER air-gap transmission – Eurobalise and KER Balise Module is connected to the ETCS using the "K" interface and the KER STM.

5.5 ETCS Internal Interfaces

ETCS internal interfaces can be subdivided into communication over air gap and interfaces between IC of trackside assembly and between IC of on-board assembly. Full list of interfaces of the IC is listed in *Chapter 2.5* dealing with IC. Comments regarding most important interfaces are collected below.

In relation to IC and interfaces between them it has to be underlined that it is allowed by EU legislation to offer to the users groups of IC without certifying separate IC namely without testing interfaces between IC forming the group. Examples of the groups are shown in *Chapter 2.4*, but new groups can be proposed by industry without any need to change legislation. This process must be watched by end users as more groups and more complex groups mean lower exchangeability and higher dependability on the supplier.

It has to be underlined that temporarily EU legislation accepts certification of ETCS on-board assemblies and ETCS trackside assemblies containing non-certified IC. This is however a temporary situation. EC declares that even if certification of IC and their groups will not be driven by the market it will be required by law.

ETCS Trackside - Internal Interfaces

Eurobalise <> LEU

Eurobalise interface "C" for communication between switchable eurobalises and LEUs is defined in *FFFIS for Eurobalise – Subset-036*. This is however an internal interface in a group.

Euroloop <> LEU

Euroloop interface "C_L" for communication between euroloop and LEUs is defined the document *FFFIS for Euroloop sub-system – Subset-044*.

Radio in-fill <> LEU/Interlocking

As radio can be used for infill purpose trackside radio in-fill equipment has to communicate with LEU or with interlocking. Interface for such communication is described in *Radio in-fill FIS with LEU/Interlocking – Subset-049*.

RBC <> RBC

Communication between neighbouring RBCs may be seen as internal or external from the point of view of implementation projects. As a result it is important to prejudge who is responsible not only for handing over of the trains in compliance with *FIS for RBC/RBC Handover – Subset-039* but also for communication between RBCs for other purpose.

ETCS on board - Internal Interfaces

These interfaces are practically not public at the moment. Looking on group proposed in TSI for CCS for on-board assembly we find that only on-board GSM-R and external STMs are outside which means that they can be supplied by different supplier and should work over interface without problems. This two are treated as external for ETCS although not external for ERTMS and are described in previous chapter.

There are some exceptions like interface for connecting DMI to on-board kernel which is defined in *FIS for Man Machine Interface – Subset-033*.

Track-train communication interfaces

Eurobalise <> Antenna (interface "A")

Eurobalise interface "A" for communication between Eurobalises (switchable and non-switchable) and Eurobalise on-board antenna is defined on lower layers in *FFFIS for Eurobalise – Subset-036* and on application layer in *ETCS SRS – Subset -026*.

Euroloop <> Antenna (interface "AL")

Euroloop interface "A_L" for communication between euroloop and Eurobalise on-board antenna is defined in *FFFIS* "A_L" *Euroloop sub-system – Subset-044*, which has to be read together with *FFFIS for Euroloop sub-system – Subset-043*.

Interface "AK"

See *Chapter 3.4.*

Radio infill interface

Radio in-fill interface is defined on lower layers by Trackside-trainborne FIS for Radio in-fill – *Subset-047* and by Radio in-fill *FFFIS – Subset-048* and on application layer by ETCS SRS – *Subset-026.*

GSM-R

GSM-R as an ETCS transmission medium is defined by (MORANE) Radio Transmission FFFIS for EuroRadio – *A11T600112*, GSM-R SRS – EIRENE SRS, EuroRadio FIS – *Subset-037* and Key Management FIS – Subset-*038.*

Additionally radio messages and their content are defined in ETCS SRS – *Subset-026* and the requirements for GSM-R are stated in European Standard *EN 310 515* Requirements for GSM operation in railways.

5.6 Responsibility for Interfaces

External and internal interfaces are described respectively in *Chapters 3.4 and 3.5*. This chapter is a separate one to show to the railways the importance of the contractual statements related to responsibility for creating and managing the interfaces. This statement is not only applicable to external interfaces but also to internal ones especially if system components are supplied by different industrial partners.

ETCS specifications belong to public domain and are in use by different signalling companies. This creates for the common control command system (ETCS) a market on which railways can gain on competition between suppliers. Those suppliers in certain cases will install ETCS on neighbouring lines or stations and in other cases will supply components to be used within one control command installation. In both cases all those components have to co-operate.

It is very important for the end users to be sure that responsibility for all interfaces is precisely defined in Terms of Reference for the projects. This is the only way to ensure inclusion of associated works in the offers and consequently in the contracts.

6. Preparation for the Call for offer

6.1 Preparation of documentation for ETCS installation

There is no single way according to which the documents for ETCS installations are to be prepared. However it is possible to point out a number of data to be included in such documentation.

ETCS level 1 installation documentation should define:

- places where balise groups will be mounted on track,
- which balises are permanent, which are switchable,
- places where LEUs will be mounted trackside,
- permanent data to be transmitted by those balise groups including full balise group identity number,
- list of packets to be transmitted as permanent data like national variables packet, linking packet, gradient profile, …, as well as content of those packets,
- list of packets to be transmitted as variable data like MAs, …, linking, gradient,
- connections between LEUs on one side and interlocking, line block systems, LX protection systems, lineside signals, point machines on the other side (covering all vital data to be acquired from basic layer signalling systems),
- documentation for each LEU defining relationship between data acquired from basic layer signalling systems and content of the variable data packets to be transmitted by connected balises,
- infill devices and infill packets to be transmitted.

ETCS level 2/3 installation documentation should define:

- places where permanent balise groups will be mounted on track,
- permanent data to be transmitted by those balise groups including full balise group identity number,
- list of packets to be transmitted as permanent data per balise group like national variables, …, as well as content of those packets,
- autonomous balises and their LEUs connected to LX protection systems,
- connections between RBC on one side and interlocking, line block systems, LX protection systems on the other side,
- RBC databases e.g. describing possible train routes,

- Rules for creating MAs on the basis of data in RBC databases and data acquired from basic layer signalling systems,
- GSM-R installation documentation.

As data for RBC databases are crucial for safe and reliable future operation of ETCS level 2 installations as well as LEUs databases are crucial for safe and reliable future operation of ETCS level 1 it is suggested to define precisely where these data are coming from and how these data are verified. RBCs' and LEUs' databases can be filled in with data by industrial partners or by railway workers. In both situations railway infrastructure manager must define both – source of data and verification procedure pointing verification method and source of data for verification.

Installed ETCS components have to be put into service according to the rules applicable to interoperable sub-systems. Because of that it is suggested to agree as early as possible with national safety authority involvement of a NB which will be involved in the preparation of the documents for putting into service.

7. ETCS installation and staff training

ETCS installation is performed by industrial partners; however railway staff has to be involved from a very beginning to ensure:

- access to area restricted for railway staff only,
- proper management of operational disturbances,
- railway staff involvement in putting into service.

Dedicated common groups comprising industrial and railway staff are suggested as being able to solve most of the installation and putting into service questions.

It has to be stated that putting into service involves also a NB and a national safety authority. The role of the NB is described in the TSI CCS. It is responsible for conformity assessment which has to be done according to the conformity modules chosen by awarding authority in compliance with the CCS TSI in force. The national safety authority must ensure proper checking of technical and operational interconnections with components which are not unified on a European level as well as verification of completeness of conformity assessment performed by NB.

Extensive railway staff training has to take place before putting ETCS into service. Training has to cover operational and maintenance staff as well as deeply trained system specialists.

8. Extract of ETCS / GSM-R worldwide implementations

ETCS

ETCS is being deployed nationally on specific routes, as a first step to aligning with other national plans along specific international corridors, in accordance with the European MoU six-corridor strategy.

From the infrastructure point of view, - in 2007 – about 2,000 km of lines are in commercial operation in ETCS lev.1 and lev.2 configuration and about 28,000 km are contracted or planned in the next 10 years.

From the rolling stock point of view, about 850 units are in commercial operation on the ETCS network, about 280 are going to be purchased and 480 retrofitted.

If we refer to a European railway network of about 221,000 km (29 countries), we have today about 1% of network with ETCS in commercial operation and about 13% of network contracted or planned in the next 10 years.

If we refer to the ETCS-Net of about 38,000 km we have today about 5% of network with ETCS in commercial operation and about 74% of network contracted or planned in the next 10 years.

GSM-R

GSM-R has been generally deployed on a national basis, in many cases, to replace the old analogue systems and it will also be used to bear the ETCS data in the level 2 and 3 applications, when ETCS is deployed.

2007 is an important year for GSM-R in Europe, with the first case of full migration by a railway administration: ProRail (The Netherlands). 1st January 2007 is the starting date for switching off TELERAIL, the old analogue network.

By the end of 2007 four more administrations will have migrated, or taken the first step towards migration: Italy, Germany, Norway and Sweden.

In Europe, where the total railway network taken into account is about 221,000 km, GSM-R coverage is planned on about 150,000 km – about 68%.

On 1st Sept. 2007, the network comprised about 60,500 km equipped with GSM-R infrastructure, of which about 41,000 is operational.

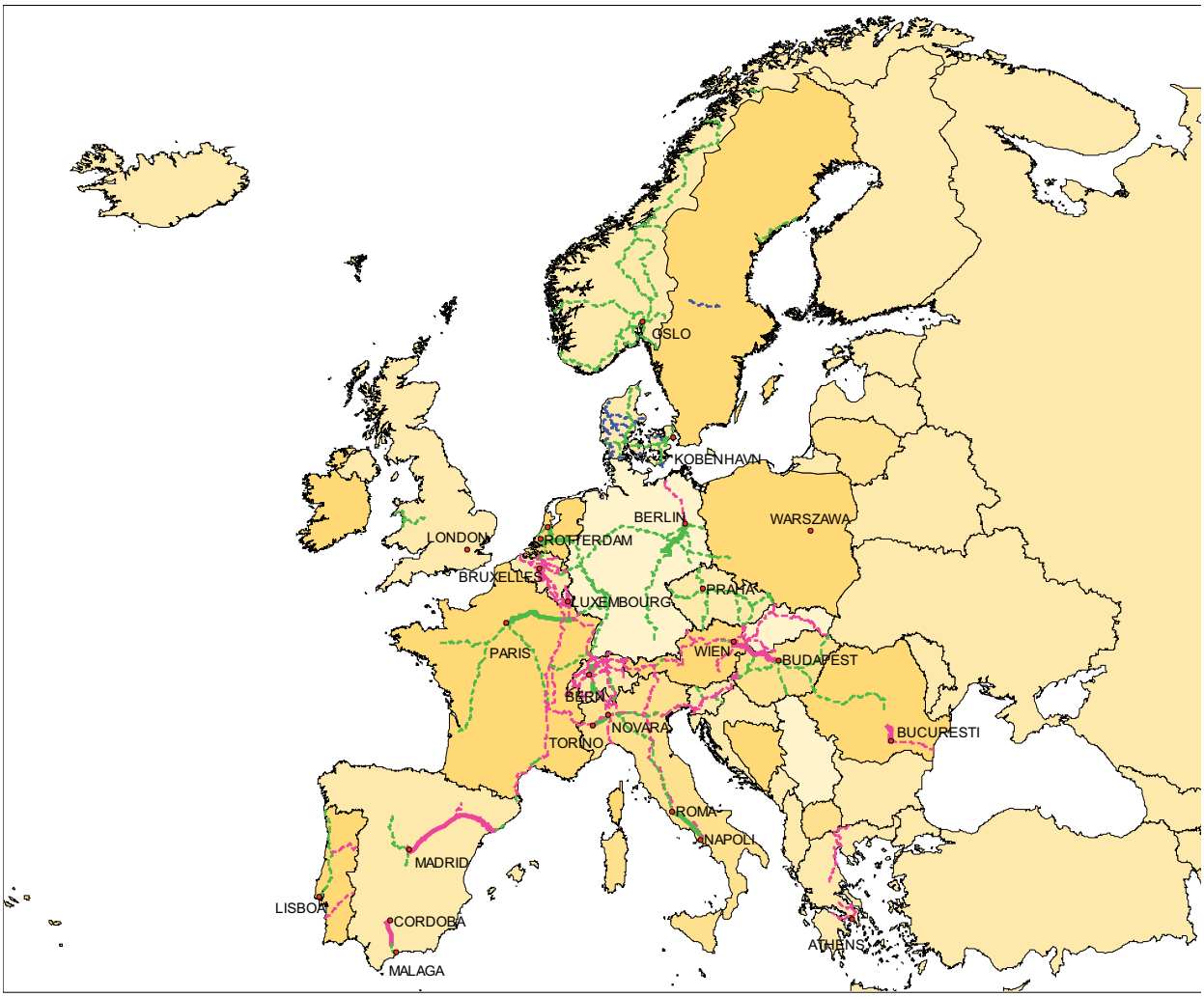


Fig. 19: ETCS commercial operation in EUROPE

Table 9: ETCS European implementations

Country name	Line	Section length (km)	ETCS Level
Austria	Wien to Hungarian border section Hegyesschalom	67	1
France	Paris - Strasbourg HSL	300	2
Germany	Berlin - Halle/Leipzig	135	2
Hungary	Hodos - Zalacséb-S.	23	1
Hungary	(Vienna -) Hegyeshalom - Budapest	190	1
Italy	Torino-Novara	90	2
Italy	Roma-Napoli	200	2
Luxembourg	Luxembourg – Bettembourg (Luxembourg - Bettembourg - Berchem)	11	1
Luxembourg	Ettelbruck - Luxembourg (Luxembourg - Dommeldange, Lorentzweiler, Mersch, Cruchten Ettelbruck)	40	1
Romania	Bucharest - Campina	92	1
Spain	Madrid Lérida	480	1
Spain	Almdóvar del Rio (west of Córdoba) - Antequera/Santa Ana	100	1
Spain	Lérida - Roda de Barà (near Tarragona)	91	1
Switzerland	Löstchberg base tunnel between Frutigen - Visp (Bern - Brig)	35	2
Switzerland	Mattstetten Rothrist (Olten - Berne)	45	2
The Netherlands	Betuwe Line Rotterdam - Zevenaar	110	2

9. Full list of ETCS documents

In reference to the commission decision of 6 March 2007 modifying *Annex A to Decision 2006/679/EC* concerning the TSI relating to the CCS sub-system of the trans-European CR system and *Annex A to Decision 2006/860/EC* concerning the TSI relating to the CCS sub-system of the trans-European HS rail system, the list of reference documents is the following

All reference documents can be found via ERA website.

9.1 List of mandatory specifications in Annex A of the CCS TSI

Index Number	Reference	Document Name	Version
1	UIC ETCS FRS	ERTMS/ETCS FRS	4.29
2	99E 5362	ERTMS/ETCS Functional Statements	2.0.0
3	UNISIG SUBSET-023	Glossary of Terms and Abbreviations	2.0.0
4	UNISIG SUBSET-026	SRS	2.3.0
5	UNISIG SUBSET-027	FFFIS Juridical Recorder-Downloading Tool	2.2.9
6	UNISIG SUBSET-033	FIS for Man-Machine Interface	2.0.0
7	UNISIG SUBSET-034	FIS for the Train Interface	2.0.0
8	UNISIG SUBSET-035	STM FFFIS02	2.1.1
9	UNISIG SUBSET-036	FFFIS for Eurobalise	2.3.0
10	UNISIG SUBSET-037	Euroradio FIS	2.3.0
11	Reserved 05E537	Off line key management FIS	
12	UNISIG SUBSET-039	FIS for the RBC/RBC Handover	2.1.2
13	UNISIG SUBSET-040	Dimensioning and Engineering rules	2.0.0
14	UNISIG SUBSET-041	Performance Requirements for Interoperability	2.1.0
15	UNISIG SUBSET-108	Interoperability-related consolidation on TSI annex A documents (mainly SUBSET-026 v2.2.2)	1.1.0
16	UNISIG SUBSET-044	FFFIS for Euroloop sub-system	2.2.0*
17	Intentionally Deleted		
18	UNISIG SUBSET-046	Radio In-fill FFFS	2.0.0
19	UNISIG SUBSET-047	Track-side-Trainborne FIS for Radio In-Fill	2.0.0
20	UNISIG SUBSET-048	Trainborne FFFIS for Radio In-Fill	2.0.0
21	UNISIG SUBSET-049	Radio In-fill FIS with LEU/Interlocking	2.0.0
22	Intentionally deleted		
23	UNISIG SUBSET-054	Assignment of Values to ETCS variables	2.0.0
24	Intentionally deleted		
25	UNISIG SUBSET-056	STM FFFIS Safe Time Layer	2.2.0
26	UNISIG SUBSET-057	STM FFFIS Safe Link Layer	2.2.0

Index Number	Reference	Document Name	Version
27	UNISIG SUBSET-091	Safety Requirements for the Technical Interoperability of ETCS in Levels 1 & 2	2.2.11
28	Reserved	Reliability – Availability Requirements	
29	UNISIG SUBSET-102	Test specification for Interface “k”	1.0.0
30	Intentionally deleted		
31	UNISIG SUBSET-094	Functional Requirements for an On-board Reference Test Facility	2.0.0
32	EIRENE FRS	GSM-R FRS	7
33	EIRENE SRS	GSM-R SRS	15
34	A11T6001 12	(MORANE) Radio Transmission FFFIS for EuroRadio	12
35	ECC/DC(02)05	ECC Decision of 5 July 2002 on the designation and availability of frequency bands for railway purposes in the 876-880 and 921-925 MHz bands.	
36a	Intentionally deleted		
36b	Intentionally deleted		
36c	UNISIG SUBSET-074-2	FFFIS STM Test cases document	1.0.0
37a	Intentionally deleted		
37b	UNISIG SUBSET-076-5-2	Test cases related to features	2.2.2
37c	UNISIG SUBSET-076-6-3	Test sequences	2.0.0
37d	UNISIG SUBSET-076-7	Scope of the test specifications	1.0.0
37e	Intentionally deleted		
38	06E068	ETCS Marker boards definition	1.0
39	UNISIG SUBSET-092-1	ERTMS EuroRadio Conformance Requirements	2.2.5
40	UNISIG SUBSET-092-2	ERTMS EuroRadio Test cases Safety Layer	2.2.5
41	Reserved	UNISIG SUBSET 028	JRU Test Specification
42	Intentionally deleted		
43	UNISIG SUBSET 085	Test Specification for Eurobalise FFFIS	2.1.2
44	Reserved	Odometry FIS	
45	UNISIG SUBSET-101	Interface “K” Specification	1.0.0
46	UNISIG SUBSET-100	Interface “G” specification	1.0.1
47	Intentionally deleted		
48	Reserved	Test specification for mobile equipment GSM-R	
49	UNISIG SUBSET-059	Performance requirements for STM	2.1.1
50	Reserved	Test specification for EUROLOOP	
51	Reserved	UNISIG	Ergonomic aspects of the DMI
52	UNISIG SUBSET-058	FFFIS STM Application Layer	2.1.1

Index Number	Reference	Document Name	Version
53	Reserved	AEIF-ETCS-Variables-Manual	AEIF-ETCS-Variables-Manual
54	Intentionally deleted		
55	Reserved	Juridical recorder baseline requirements	
56	Reserved	05E538	ERTMS Key Management Conformance Requirements
57	Reserved	UNISIG SUBSET-107	Requirements on pre-fitting of ERTMS on-board equipment
58	Reserved	UNISIG SUBSET-097	Requirements for RBC-RBC Safe Communication Interface
59	Reserved	UNISIG SUBSET-105	Requirements on pre-fitting of ERTMS track side equipment
60	Reserved	UNISIG SUBSET-104	ETCS version management
61	Reserved	GSM-R version management	
62	Reserved	UNISIG SUBSET-099	RBC-RBC Test specification for Safe Communication Interface
63	Reserved	UNISIG SUBSET-098	RBC-RBC Safe Communication Interface

9.2 List of mandatory EN standards in Annex A of the CCS TSI

Index Number	Reference	Document Name	Version
A1	EN 50126	Railway applications – The specification and demonstration of reliability, availability, maintainability and safety (RAMS)	1999
A2	EN 50128	Railway applications – Communication, signalling and processing systems – Software for railway control and protection systems	2001
A3	EN 50129	Railway applications – Communication, signalling and processing systems – Safety related electronic systems for signalling	2003
A4	EN 50125-1	Railway applications – Environmental conditions for equipment – Part 1: equipment on board rolling stock	1999

A5	EN 50125-3	Railway applications – Environmental conditions for equipment – Part 3: equipment for signalling and telecommunications	2003
A6	EN 50121-3-2	Railway applications – Electromagnetic compatibility - Part 3-2: Rolling stock – Apparatus	2000
A7	EN 50121-4	Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the signalling and telecommunications apparatus	2000
A8	EN 50238	Railway applications – Compatibility between rolling stock and train detection systems	2003

9.3 List of informative specifications in Annex A of the CCS TSI

Index Number	Reference	Document Name	Version	Type
B1	EEIG 02S126	RAM requirements (chapter 2 only)	6	2 (index 28)
B2	EEIG 97S066	Environmental conditions	5	2 (index A5)
B3	UNISIG SUBSET-074-1	Methodology for testing FFFIS STM	1.0.0	2 (index 36)
B4	EEIG 97E267	ODOMETER FFFIS	5	1 (index 44)
B5	O_2475	ERTMS GSM-R QoS Test Specification	1.0.0	2
B6	UNISIG SUBSET-038	Off-line Key Management FIS	2.1.9	1 (index 11)
B7	Reserved UNISIG SUBSET-074-3	FFFIS STM test specification traceability of test cases with STM FFFIS	1.0.0	2 (index 36)
B8	UNISIG SUBSET-074-4	FFFIS STM Test Specification Traceability of testing the packets specified in the FFFIS STM Application Layer	1.0.0	2 (index 36)
B9	UNISIG SUBSET-076-0	ERTMS/ETCS Class 1, Test plan	2.2.3	2 (index 37)
B10	UNISIG SUBSET-076-2	Methodology to prepare features	2.2.1	2 (index 37)
B11	UNISIG SUBSET-076-3	Methodology of testing	2.2.1	2 (index 37)
B12	UNISIG SUBSET-076-4-1	Test sequence generation: Methodology and Rules	1.0.0	2 (index 37)
B13	UNISIG SUBSET-076-4-2	ERTMS ETCS Class 1 States for Test Sequences	1.0.0	2 (index 37)
B14	UNISIG SUBSET-076-5-3	On-Board Data Dictionary	2.2.0	2 (index 37)
B15	UNISIG SUBSET-076-5-4	SRS v.2.2.2 Traceability	2.2.2	2 (index 37)

Index Number	Reference	Document Name	Version	Type
B16	UNISIG SUBSET-076-6-1	UNISIG test data base	2.2.2	2 (index 37)
B17	UNISIG SUBSET-076-6-4	Test Cases Coverage	2.0.0	2 (index 37)
B18	Intentionally deleted			
B19	UNISIG SUBSET-077	UNISIG Causal Analysis Process	2.2.2	2 (index 27)
B20	UNISIG SUBSET-078	RBC interface: Failure modes and effects analysis	2.2.2	2 (index 27)
B21	UNISIG SUBSET-079	MMI: Failure Modes and Effects Analysis	2.2.2	2 (index 27)
B22	UNISIG SUBSET-080	TIU: Failure Modes and Effects Analysis	2.2.2	2 (index 27)
B23	UNISIG SUBSET-081	Transmission system: Failure Modes and Effects Analysis	2.2.2	2 (index 27)
B24	UNISIG SUBSET-088	ETCS Application Levels 1&2 -Safety Analysis	2.2.10	2 (index 27)
B25	TS50459-1	Railway applications -European Rail Traffic Management System - DMI part 1 - Ergonomic principles of ERTMS/ETCS/ GSM-R Information	2005	2 (index 51)
B26	TS50459-2	Railway applications -European Rail Traffic Management System - DMI part 2 - Ergonomic arrangements of ERTMS/ETCS Information	2005	2 (index 51)
B27	TS50459-3	Railway applications -European Rail Traffic Management System - DMI part 3 - Ergonomic arrangements of ERTMS/GSM-R Information	2005	2 (index 51)
B28	TS50459-4	Railway applications -European Rail Traffic Management System - DMI part 4 - Data Entry Procedure	2005	2 (index 51)
B29	TS50459-5	Railway applications -European Rail Traffic Management System - DMI part 5 – Symbols	2005	2 (index 51)
B30	TS50459-6	Railway applications -European Rail Traffic Management System - DMI part 6 - Audible Information	2005	2 (index 51)
B31	EN-50XXX	Railway applications -European Rail Traffic Management System - DMI part 7 - STMs	2005	2 (index 51)
B32	Reserved	Guideline for references		None
B33	EN 310515	Global System for Mobile communication (GSM); Requirements for GSM operation in railways	2.1.0	
B34	05E466	Operational DMI information	1	1 (index 51)
B35	Reserved UNISIG SUBSET-069	ERTMS Key Management Conformance Requirements		1 (index 56)

Index Number	Reference	Document Name	Version	Type
B36	04E117	ETCS/GSM-R Quality of Service user requirements - Operational Analysis	1	None (index B37)
B37	UNISIG SUBSET-093	GSM-R Interfaces – Class 1 requirements	2.3.0	1 (index 32, 33)
B38	UNISIG SUBSET-107A	Requirements on pre-fitting of ERTMS on-board equipment	1.0.0	2 (index 57)
B39	UNISIG SUBSET-076-5-1	ERTMS ETCS Class 1 Feature List	2.2.2	2 (index 37)
B40	UNISIG SUBSET-076-6-7	Test Sequences Evaluation and Validation	1.0.0	2 (index 37)
B41	UNISIG SUBSET-076-6-8	Generic train data for test Sequences	1.0.0	2 (index 37)
B42	UNISIG SUBSET-076-6-10	Test Sequence Viewer (TSV)	2.10	2 (index 37)
B43	04E083	Safety Requirements and Requirements to Safety Analysis for Interoperability for the CCS Sub-System	1.0	1
B44	04E084	Justification Report for the Safety Requirements and Requirements to Safety Analysis for Interoperability for the CCS Sub-System.	1.0	2 (index B43)

Note:

- *Type "1" specifications represent the current state of the work for the preparation of a mandatory specification still "reserved"*
- *Type "2" specifications give additional information, justifying the requirements in mandatory specifications and providing help for their application.*

Index B32 is intended to ensure unique references in the Annex A documents. As this is used for editorial purposes and to support future changes of documents referred only, it is not classified as a "Type" and not linked to a mandatory Annex A document.

10. Abbreviations

This chapter contains only limited number of abbreviations which are helpful to understand ETCS system and especially ETCS Handbook. There is no intention to create new or additional glossary of terms and abbreviations especially as readers can find description of abbreviations and terms already in two mandatory documents.

For the terms and abbreviations used in SRS and other documents supporting SRS please look into *Subset-023 Glossary of terms and abbreviations.*

Table 10: Chosen abbreviations Supplemented with a links to ETCS SRS

ASP	Axle Load speed Profile	SRS chapter 3.11.4
CS	Ceiling Speer	SRS chapter 3.13.5
EBI	Emergency Brake Intervention limit	SRS chapter 3.13.4.7
EOA	End of Movement Authority	SRS chapter 3.8.1.1
LOA	Limit of Movement Authority	SRS chapter 3.8.1.1
MA	Movement Authority	SRS chapter 3.8
MRSP	Most Restrictive Speed Profile	SRS chapter 3.11.9
RAP	Roll Away Protection	SRS chapter 3.14.2
RMP	Reverse Movement Protection	SRS chapter 3.14.3
RS	Release Speed	SRS chapter 3.13.7
SBI	Service Brake Intervention limit	SRS chapter 3.13.4.6
SSP	Static Speed Profile	SRS chapter 3.11.3
TSR	Temporary Speed Restriction	SRS chapter 3.11.5

CCS	Control Command and Signalling
CR	Conventional Railway
DMI	Driver Machine Interface
ERA	European Railway Agency
ERTMS	European Railway Traffic Management System
ETCS	European Train Control System
FFFIS	Form Fit Functional Specifications
FIS	Functional Interface Specifications
FRS	Functional Requirements Specifications
GSM-R	Global System for Mobile communication - Rail
HS	High Speed

IC	Interoperability Constituents
LEU	Lineside Electronic Units
LX	Level Crossing
NB	Notified Body
RBC	Radio Block Centre
SRS	System Requirement Specifications
STM	Specific Transmission Module
TSI	Technical Specification for Interoperability
UIC	International Union of Railways

ETF

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