

## Complementary Tests: the key of the successful ERTMS deployment in Spain.

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**Summary:** This paper presents how the definition of specific tests to check the interoperability between different ERTMS suppliers, have been one of the key issues to solve the problems appeared during the first real implementations of this system. In fact, at the time being, Spain is one of the countries with a highest level of deployment of this system. Currently we have in operation in our country more than 1.500 Kms of double track with the system in commercial exploitation. All the existing ERTMS suppliers are present in the Spanish lines showing that the interoperability among all of them is a reality. This paper explains in detail this set of tests as well as the procedure used in Spain to get the final approval of the whole (track+on board) ETCS system in all the new Spanish High Speed lines. The paper shows how the definition, execution and evaluation of these tests has been one of the key issues for the successful ERTMS deployment.

**Index Terms:** ERTMS, Interoperability, Signaling.

### 1. INTRODUCTION

Spain is, at the time being, the European country where a highest level of ERTMS implementation has been reached. In fact four different trackside suppliers and five on board unit suppliers are commercially operating, clearly demonstrating that technical interoperability is a reality.

The key to achieve this level of ERTMS implementation is the definition, execution and technical evaluation of a set of tests which practically guarantee the interoperability among different suppliers. These tests have been defined jointly by Adif, Renfe, Cedex and Ministry of Public Works and Transportation (Fomento) in order to cover a lack in the European technical Specifications for Interoperability (TSI): Subset 076 of Unisig Specifications, "ETCS Tests Specifications" only covers the tests to be performed to an OBU (on Board Unit) to demonstrate its compliance with SRS (System Requirements Specifications, Subset 026), but at the present time there isn't any subset to test a specific track implementation nor a set of tests demonstrating the real train-track interaction.

For this reason the Spanish ETCS team before mentioned has developed the so called "Complementary Tests" which are a set of tests to check the real interaction between and OBU and a ERTMS track. These are a set of tests both for L1 (215 Test Cases) and L2 (225 Test Cases) to analyze the most important aspects of ERTMS functionality: Speed supervision and braking curves, Level transitions, Mode changes, Temporary Speed Restrictions Managing, MA timers managing, Odometry, Track conditions, ATO and preset speed, National Functions, degraded situations (lateral lamp signaling fusions, balise group lost, etc)...

From the first lines opened with ERTMS in Spain, we have seen the importance of performing the set of Complementary Tests for two main reasons: 1) Each time we have executed these tests we have found some inconsistencies and 2) Once all the problems detected with Complementary Tests have been

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solved no any major incidence related to ERTMS functionality has appeared during the commercial exploitation.

The most important inconsistencies detected while performing Complementary Tets have been the following: Components malfunctioning (EVC, balises...), Issues related with Specifications, Different specs interpretation, Migration problems /CRs, Errors in the implementation, Issues dealing with Operational Rules etc.... The number of inconsistencies has been progressively decreasing in parallel with an increasing level of common understanding of the SRS.

This paper will explain the Complementary Tests in detail as a vital contribution to ERTMS real deployment in Spain.

## 2. COMPLEMENTARY TESTS

The path taken to reach the current level of interoperability has not been simple. Overall when the European specifications of ERTMS were not sufficiently mature and the gaps within them have had to be filled with the experience of the pioneer countries in ERTMS, such as Italy, Switzerland, Holland and to a larger extent Spain due to its deployment of different suppliers. Indeed, as an example we can highlight that ERTMS test specifications, were only defined at a component level (Test Specs for the On Board Unit, Subset 076 or Test Specs for Euroballise Subset 085), but there were no test specifications for train-track integration. Subset-076 of Annex A of the TSI does not include any definition of tests relating to the engineering of the ERTMS track.

Nowadays, there is a collection of Subsets which contain the specification of tests for the complete system, taken as a whole (Subset 110, 111 and 112), but they are in an initial phase (edited in 2009 and 2010) and there are not yet a complete published test specification to verify the integration between track and train. That is the reason why the “Complementary Tests” were developed in Spain.

In this situation of lack of test specifications and with the presence of multiple suppliers as in Spain, it was logical that there were differences in interpretation of the specifications that resulted in the appearance of problems in the first implementations of the system. In fact, in 2003 and 2004 a first test campaign was already developed at CEDEX interoperability lab that was good as a first approach to limit differences between the on board units of the 5 suppliers of ERTMS. From this first campaign led by the Ministry of Public Works (through the Railways Infrastructures Directorate) a working group was created in which Adif, Renfe Operadora, CEDEX and Tifsa participated, with the aim of defining train-track compatibility testing that guarantee the correct behavior of the system. In figure 2 the adopted working scheme is shown.

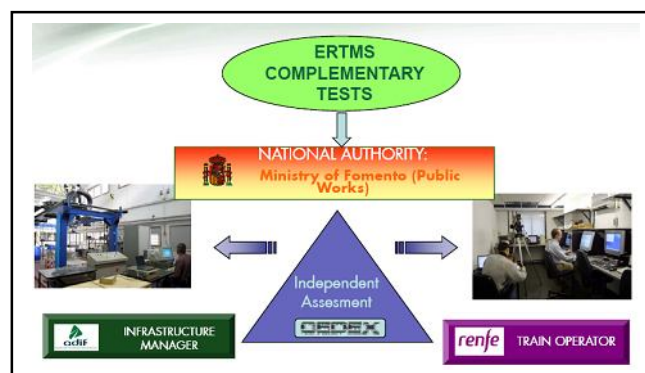


Figure 2. ERTMS System Authority

The aim of the complementary tests has been to prove the main functional qualities of each of the high speed lines by means of a group of test cases (215 in level 1 and 260 in level 2). While they do not try to carry out exhaustive tests on the installation, this should be assured by the validation dossier of the manufacturer, they test the more meaningful functional qualities on the more critical points on the line.

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For more than 5 years the execution of the complementary tests has resulted in detecting errors as well as different interpretations of the ERTMS specifications (SRS), which have been solved through the participation of expert teams from Adif, Renfe, CEDEX and Tifsa. Equally, these bugs were reported to the ERTMS User Group and the European Railway Agency for the corresponding clarification of the specifications.

As a conclusion we can state that, through the implementation of complementary tests, it has been proven that once corrected the detected problems in these tests, no relevant functional problem has appeared during the later commercial exploitation. This is the best indication of the usefulness of these aforementioned complementary tests in the deployment of the ERTMS in Spain.



Figure 3. Complementary Tests Execution.

### 3.1 Complementary tests technical description

The Complementary Tests are composed by a complete catalogue of test cases (215 for Level 1 and 260 for Level 2). These test cases have been designed to test the main functionality of the complete system focusing in its normal operation. Some examples of what is tested are:

- Speed supervision and braking curves
- Level transitions
- Mode changes
- TSR Managing
- Managing of MA timers
- Odometry
- Track conditions
- ATO and preset speed
- DMI
- National Functions
- Signal balise group reading in PT mode
- Maximum Speed for exploitation with free route ahead
- Degraded situations (lateral lamp signaling fusions, balise group lost, etc)

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Each test case contains a Code, a Name, an Objective, a Description, and Conditions for Execution, Expected Result and Observations. The Code of the test case is a series of numbers and letters, important to trace each test case. The test cases are grouped and categorized by their functionality and the code is related with this. An example of a test case is shown in Figure 4.

With this Spain has a complete catalogue of test cases to test the train-track integration. This catalogue is alive and it is constantly growing and being completed, optimized and debugged.

Test case Nº	2.1.1 g) 1
Test case Name	Speed Supervision. Supervision of Temporary Speed Restrictions (TSR) in Level 0
Test case Objective	To verify that when the system is in Level 0 and it receives a TSR, the system supervises correctly the maximum permitted speed.
Description	The train advances running in Level 0 and UN mode, and it receives via balise, in a packet 65, one (or more) TSR.
Conditions for test case execution	The train runs in UN mode. In the route that the train is following there is one (or more) TSRs applied.
Expected Result	When the train reaches the zone defined in the TSR received, it supervises the speed according to the value included in the corresponding packet 65. It shall be checked :  JRJ log of the packet (or packets) 65 received from Eurobalise Permitted speed indications in the DMI (at drivers request)
Observations	

Figure 4: An example of a test case

There are five different situations for an ERTMS implementation:

1. A new line and new train.
2. A line already validated and a new train.
3. A new line and an already validated train
4. A line already validated and an already validated train in another line.
5. A line already validated and a new train with a software already validated in another train.

For the first situation all the tests cases need to be executed, as it means that a totally new system is being implemented. This happens only once in a railway administration. For example, in Spain the first need was to open the High Speed Line (HSL) Madrid-Zaragoza-Lleida with Ansaldo ERTMS track system and S/102 Talgo-Bombardier train with Siemens onboard EVC in Level 1.

The second situation is the next to happen when a new train is being introduced in the system. In Spain this was the case of the S/120, CAF train, with Ansaldo onboard equipment in the same HSL.

The third situation happens when a new line is being opened. The case was the continuation to Tarragona of the opened HSL Madrid-Lleida, The track system of this Lleida-Tarragona section was supplied by Thales.

The fourth situation is the result of the combinations of the previous ones. An example of the fifth situation is the S/103 (Velaro), Siemens train, with also Siemens onboard equipment with the same software that the S/102, already tested. After following this process since 2004, no interoperability problems have been found during the commercial service

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Each test case has been analyzed and evaluated its need for each situation. Also this is being done with the category of “test in laboratory” or “test in field”. Therefore there is a complete table of test cases categorized and preselected for each situation.

These tests are executed when the system is already finished, train and track. This means, that both systems have completed their verification and validation processes independently.

A deep analysis of each particular situation to be tested is made. The set of tests cases that apply to each specific situation are chosen: an expert group makes a previous analysis of what test cases apply or not because of the train and track characteristics and the functionality of the systems. For example, transitions will apply when different signaling systems are involved. Physical characteristics of the line are analyzed, slopes, commercial stations, slab track, etc. The selected test cases are positioned in real scenarios according to what it is tested.

The scenarios where the test cases are fitted together are carefully designed and mounted to success in the objective of the test and to optimize testing time.

At the beginning, the Complementary Tests have been executed in field, in real conditions, with the train and the track. Now in Spain we are in a transition process between the field and the laboratory while this last is totally validated. Tests on track were a good solution at the beginning but they are now unsustainable. There is a need of testing in simulation labs performing most of the interoperability tests there. However, depending on the situation, a low number of tests are needed to be performed in the field.

It is important to highlight that the validation process does not finish when track (or lab) testing is done; the tests require further analysis time. This is a very important phase, where design and functionality are taken into account, further information is requested to the engineering of the project and clarifications are needed. After that, a report is issued and evaluated to get the “Circulation Authorization” for a train or for a line the “Put in Service Authorization”. This analysis is based on:

- What has been observed in the cabin during the track testing?
- The JRU data registered by the train.
- The information provided by the suppliers regarding track and on board equipments.

Different types of bugs and issues have been found in this last phase of the implementation of the system, the Complementary Tests. These problems are related to:

- Components malfunctioning (EVC, balises...)
- Issues related with Specifications
  - o Different specs interpretation
  - o Open issues
  - o Migration problems /Change Requests implementation
  - o Errors in the implementation
- Issues dealing with Operational Rules and normal operation
- Design of the system

Some of the examples related with components malfunctioning (baby failures) are: Balise transmission, EVC system failures, JRU problems, Odometry problems related with dust, snow, slab track or gauge changers.

To speak about issues related with the Specifications, an important one is the Specifications Interpretation. For example, requirement 3.7.1.1.b: “Mode profile and Signaling related Speed restriction shall always be sent together with the MA to which the information belongs”. There were two interpretations for the infill information: for the track, in the same balise telegram and for the OBU, in the same balise telegram and after packet 136. The track sent the packets in the following order: Packet 80 (OS mode profile), packet 136 (infill information) and packet 12 (MA). In this way the on board unit did not

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process the mode profile as infill information (because packet 80 was placed before infill information). The practical consequence of this was the entry in OS Mode in the signal at a very high speed. This different interpretation was solved sending packet 80 after packet 136.

Another important type of issues related to the specifications are those linked to migration problems. These are issues that emerge due to the implementation of Change Requests. These issues are very important to overtake possible future migration problems. Some examples are CR-445 or CR-504.

In the case of CR-445 (*When the train passes to TRIP/SR mode, all TSR must be stored.*) it is related to the train subsystem. In the Spanish lines, if a train passes through a red signal that protects a switch, the signal balise group sends a TSR that covers the switch area. The practical application of this CR is the next: if the on-board system has this CR implemented, the EVC will store the TSR after overpassing the red signal and will manage it. If the on-board equipment has not implemented the CR, the TSR would not be managed. This is a practical example of how the different ERTMS implementations need to be analyzed and known, because the expected results can be very different.

The CR 504 (3.8.4.2.a) *When the time out has expired, the following shall apply: the EoA/LoA shall be withdrawn to the entry point of the revoked section, the National/Default Value of the Release Speed shall apply.*) has deep impact in the design of the track subsystem. The practical consequence of this CR is that the track 2.2.2 was designed having into account that, the on the on-board system new EoA after expiration, has no Release Speed. Train 2.3.0.d will make an EoA with Release Speed. This can mean that safety distances can be not protected. In the new line Madrid-Valencia tests have been made to verify the correct behavior of the system with a 2.2.2+ (this means with some CR implemented) train on a 2.3.0.d line.

Other issues related with the Specifications are the Open Issues, such as: Braking curves definition, Key Management System, DMI representation and level-crossing management. And other issues are related to dealing with Operational Rules and Normal Operation and the Design of the system (like transitions ...)

The number of inconsistencies has been progressively decreasing in parallel with an increasing level of common understanding of the SRS.

Up to now, 4 track suppliers (Ansaldo, Thales, Dimetronic and Alstom) and 5 OBU's (Siemens, Ansaldo, Alstom, Bombardier and Dimetronic) have been tested in Spain. Once the problem detected during Complementary Tests is solved, no more additional issues have arisen during commercial exploitation. This is the demonstration that the way adopted has been the right one.

## 4. CONCLUSIONS

The Complementary tests are constantly changing and re-debugged, they are alive and their progress is linked to the progress of the whole system. And it is important to mention the enormous effort done in the set up of an ERTMS L1 and L2 laboratory to run in it part of the "Complementary Tests", where TIFSA and CEDEX involvement is crucial.

The Complementary tests have been not only important for the opening of the lines and the commercial service of the trains but also for having a solid knowledge of the system. This experience and knowledge is being used in Spain for different objectives like overtake migration problems, the harmonization of the lines. (To harmonize the functionality of the lines equipped with the ERTMS system, ADIF has developed, together with experts of all the areas involved, a document that contains the ERTMS requirements for the track system, which specify the track system that the manufacturers have to provide with the new implementations.) Also has resulted in the shaping of groups of people with a wide "know-how" in the system, and huge expertise in the resolution of issues before starting commercial service.

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The key to achieve the level of ERTMS implementation in Spain has been the definition, execution and technical evaluation of a set of tests which practically guarantee the interoperability among different suppliers. The Complementary Tests have been a vital contribution to ERTMS real deployment in Spain, where the commercial service is clearly demonstrating that technical interoperability is a reality.

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