



TREND

*TEST OF ROLLING STOCK  
ELECTROMAGNETIC COMPATIBILITY FOR  
CROSS-DOMAIN INTEROPERABILITY*

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Coordinator: CEIT

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Annex A.2 Report on Final Intellectual Property and Foreground Control – CAF I+D

Annex A.3: Report on Final Intellectual Property and Foreground Control – CEDEX

Annex A.4: Report on Final Intellectual Property and Foreground Control – IFSTTAR

Annex A.5: Report on Final Intellectual Property and Foreground Control –YORK -EMC

Annex A.6:– Report on Final Intellectual Property and Foreground Control - TRV

Annex A.7: Report on Final Intellectual Property and Foreground Control – LTU

Version	Date	Contributors	Sections Affected
1	29/05/2014	All	All
2	25/06/2014	CEIT	All

# 1 FINAL PUBLISHABLE SUMMARY REPORT

## 1.1 EXECUTIVE SUMMARY

Rolling stock electromagnetic emissions and immunity are major concerns for train manufacturers and railway infrastructure operators, as pointed out by ERA in several reports. Unfortunately, the available harmonized EMC standards (EN50121-2, EN50121-3-1 and EN50121-3-2) do not completely address interoperability issues caused by rolling stock interferences with the most common signalling systems (GSM-R and BTM for example). Moreover, these standards do not cover representative worst-case conditions derived by transients in the rolling stock behaviour typically generated by feeding and track circuits' discontinuities.

On one hand this situation causes an important waste of time and resources for train manufacturers when integrating rolling stocks and signalling systems. And moreover in already tested trains, occasionally problems may still arise. Then, not only the responsibilities but also the technical solutions are not straight forward. The duration of the field testing employed to solve this kind of problems and to go through the certification process may vary between 3 months and 12 months. And the cost of the complete process may vary between 25k€ to 1,5M€ [ERA EMC Report 2010]. On the other hand, railway infrastructure operators suffer the railway infrastructure availability reduction caused by the rolling stock electromagnetic incompatibility with the safety critical signalling systems. The previously commented problems might cause an estimated reduction of 10% of the availability in the most crowded lines.

In this context, TREND (Test of Rolling Stock Electromagnetic Compatibility for cross-Domain Interoperability) project had the objective of addressing this situation by means of the design of a test setup that enables the harmonization of approval tests for electromagnetic compatibility (EMC) focusing not only on interferences with broadcasting services but also on railway signalling systems. TREND was also conceived to identify and design the cross acceptance test sites that reproduce representative worst case conditions for steady state and transient behaviours.

The thorough analysis of this project has comprised measurement, modelization and safety and availability analysis of the effect of the railway EMIs on the neighbouring communication and signalling systems studied. These are classified in four research areas: a spot signalling system (BTM), DC track circuit, GSM-R and broadcasting services (which include TV, radio, Freight RFID, WFI and GSM). A detailed study of the physical environment of each system has permitted a precise analysis of the EMI coupling model affecting them. Thanks to the safety and availability model of these systems, and to the more significant regulatory documents for each case, TREND has designed a test procedure that recreates representative worst-case for the rolling stock electromagnetic emissions that could affect interoperability including transient phenomena.

As a summary, TREND project has positively contributed to the objectives identified in the proposal in the aim to progress the understanding of the EMC of rolling stock with the railway environment beyond the current 'state -of-the-art' for the targeted signalling and communication systems.

The summary of the work performed and the results of the work packages are here presented, as a glimpse of the project

#### **WP1: MANAGEMENT**

In this first work package, the Person-Months are dedicated to the management activities. CEIT, as project coordinator, has had the main responsibilities in such matters: administrative, financial, legal and IPR activities. The technical management with tasks review and generic progress review meetings are also CEIT's responsibilities. For the Advisory Board's meetings, CEIT and CEDEX have shared the efforts.

#### **WP2: IDENTIFICATION OF RAILWAY SYSTEM ELECTROMAGNETIC INTERFERENCES**

In the first period of the project, all the partners have shared their previous know-how and case studies relevant to the focused study areas of the project. The collection of experiences has enabled a table to be collated of the interactions between the victims and the culprits in railway systems and these are related to signalling and communications. Even though these experiences are just a cross section of the issues found on the railway they still provide a good representation of the main EMC problems associated with signalling and communication systems.

#### **WP3: ASSESSMENT OF CURRENT HARMONIZED EMC APPROVAL TESTS**

The main result from this WP, entirely performed in the first period of the project, is the achievement of a thorough understanding of the gaps in the existing EMC standards for railway signalling and communication. This has been done through the analysis of the current harmonized railway EMC standards, other relevant norms, standards and subsets of the 4 research areas. Some improvements to the standards (particularly the EN50121-X series) are suggested in order close some of the identified gaps.

#### **WP4: DESIGN OF THE RAILWAY SYSTEM MODEL**

In the first steps of this WP, the main characteristics of the 4 signalling and communication systems and their environment (infrastructure and rolling stock) have been identified. Degrees of freedom have been deduced from the analysis of the availabilities of future measurements to enable validation. With that basis, the models have been developed. Due to the specific parameters of each system, the 3D electromagnetic model has been centred on the antennas and electronics of each scenario using the same tool, CST, but with special computational toolboxes.

The validation, using the real behaviour recorded in the 2 measurement campaigns organized by the project, has positively confirmed that the 3D electromagnetic model could be used to replicate the problems found in real situations. In this way, a cheaper analysis of the alternatives for future designs or for changes in the current ones is possible.

Moreover, the validation methodology, in 3 steps, has been shown to be applicable not only to the Railway EMC problem but also for electromagnetic problems in other fields.

From the global EMC problem point of view, the fast transient pulses recorded in the measurement campaigns during static testing are highly representative of the dynamic interferences that affect at the same time: spot signalling systems, GSM-R and broadcasting services. the measurements also demonstrated that the Swedish DC track circuits are highly immune to these transients.

#### **WP5: IDENTIFICATION OF REASONABLE EMC WORST CASE CONDITIONS**

With the progress made in WP4, mainly the results from the 3D CST electromagnetic models and the analysis of the immunity limits of each signalling or communication system, the parameters and the conditions that set the realistic worst case scenarios have been identified for each of the 4 research areas of the project. The most of the work of this WP has been done in the first period of the project.

**WP6: TEST SETUP DESIGN AND VERIFICATION****WP7: DESIGN AND VERIFICATION OF CROSS-ACCEPTANCE TEST SITES****WP8: DESIGN AND VERIFICATION OF TESTING PROCEDURE**

In the second part of the project, the work flow of the project has been redesigned and 4 working groups have been created, for the 4 signalling and communications under study:

- CEIT, CEDEX and CAF for spot signalling systems BTM
- IFSTTAR for GSM-R
- LTU and TV for DC Swedish Track Circuits
- Y-EMC for Broadcasting services

Each working group has dedicated its effort on the analysis, design and verification of the whole task "Test setup, test site and test procedure" of each one system (shared as presented in the list just above).

a) BTM Working group

In the second part of the project, the spot signalling system BTM has been studied from two points of view necessarily linked: balise immunity and rolling stock emissions.

These points are the two sections of the Subset 116 which is a document thought to foresee the real environments where the BTM would have to be installed. To contribute to both matters in that documents, which has some sections currently to be completed or even to be defined, the BTM working group has design the test setup, test site and test procedure for the BTM immunity tests and the Rolling stock emissions.

The activities for the first one have been realized in the laboratory, at CEDEX, where the actual setup, site and procedure have been analyzed and some improvements have been proposed. Considering the realistic interferences captured on-board the high speed trains used in that project, we consider than other structural parameters should be considered for the interference shape. The activities of the second one have been undertaken on-field (OARIS train from CAF) with the proposed loop and a dedicated data acquisition system. The analysis and the time-frequency post-processing of the signals were coordinated with the laboratory for a proper calibration of the loop. The results of both fields have been sent to the UNISIG-UNIFE subset116 working group for their consideration.

b) GSM-R working group

For the measurement of the interferences able to affect the GSM-R communication a test setup was designed to permit to compare the EM disturbances with the GSM-R useful signal. This design and implementation permits to analyse the interferences over by time windows similar to the duration of a GSM-R burst and with a time resolution which correspond to the binary rate of the GSM-R protocol.

The GSM-R test set-up was improved and assessed in laboratory applying noise scenarios including transient disturbances initially collected during different railway campaign measurements. The results showed that the test set-up is available whatever the EM noise conditions and on the site on which these conditions were observed. Only one limitation was identified concerning the automatic estimation of the GSM-R useful signal: it was noticed that the estimation is imperfect when the GSM-R covering is very low and the impact of the interferences collected can be underestimated.

Finally, a complete GSM-R test set-up and procedure was defined. This test procedure included the creation of a reference base which permits to directly link the characteristics of the measured interferences with the impact on the GSM-R communication quality. The test procedure requires to fix the parameters of configuration of the measurement equipment such as they were defined during the base reference creation. The studies here performed in TREND showed also that it is primordial that the measurements are carried out with a GSM-R antenna and in its operational position.

c) DC Track Circuits working group

The objective of the DC track circuit working group was to analyze and propose a test setup, test site and test procedure for the worst case conditions pointed out in the first period of the project for DC track circuits. This work has been coordinated between LTU and TV. TV has supported the former with the appropriate data drawings, information from interviews and, obviously, the track control of all the equipment around the track circuits, on field, so that can be defined in the test setup. With the data and the analysis performed by the maintenance unit of LTU, the design of the test setup, test site and test procedure has been performed and validated.

The three case studied have resulted in a proposal that may be considered in future revision of the safety documents for this kind of detection system. TV is actually currently planning to include the tests in their documentation.

d) Broadcasting Services working group

The broadcasting services working group has focus the efforts on the test setup, test site and test procedure to measure the total radiated power from the arcing interferences. For that, the test configuration, parameters and procedure have been tested and validated in a proper location: a reverberation chamber.

First, preliminary measurements of the representative tests have been set up in the chamber. With those results, the test procedure requirements could have been defined, with proposal on how to operate with the arcing wheel in order to produce representative measurements according to the one found in the real railway environment. The final design of the test site included the application of the environment external to the laboratory. The worst case conditions recreation has been managed by changing the parameters of the test setup to vary gap length, wheel speed etc. The results have been verified when compared to results taken outside the chamber. This also includes some work into the new draft versions of EN50121 to determine the relation between the measurements and the new standards.

## **WP9: DISSEMINATION AND EXPLOITATION**

The 6 activities proposed for dissemination have been considered during the whole process of the project. In the first part of the project, all the items have been started, excepting the contribution to standards as this requires the final information. But this has been the main effort during the second part of the project, as a result of the “test setup, test site and test procedure” design developed by each working group. The more significant results are here listed:

- Publication of the main results of the projects in the deliverables
- Results directly disseminated to main stakeholders in railway and EMC standardization
- 1 technical journal
- 10 conference papers
- 2 railway EMC courses
- 7 participations in railway magazines and industry forums
- 1 workshop for EMC railway
- 1 online workshop for Train Signalling System Interference Estimation

<b>List of Beneficiaries</b>
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No	Name	Short name	Country	Project entry month	Project exit month
1	CENTRO DE ESTUDIOS E INVESTIGACIONES TECNICAS	CEIT	Spain	1	30
2	CONSTRUCCIONES Y AUXILIAR DE FERROCARRILES INVESTIGACIÓN Y DESARROLLO, S.L.	CAF I+D	Spain	1	30
3	CENTRO DE ESTUDIOS Y EXPERIMENTACION DE OBRAS PUBLICAS	CEDEX	Spain	1	30
4	INSTITUT FRANCAIS DES SCIENCES ET TECHNOLOGIES DES TRANSPORTS, DE L'AMENAGEMENT ET DES RESEAUX	IFSTTAR	France	1	30
5	YORK EMC SERVICES (2007) LIMITED	Y-EMC	United Kingdom	1	30
6	TRAFIKVERKET - TRV	TV	Sweden	1	30
7	LULEA TEKNISKA UNIVERSITET	LTU	Sweden	1	30

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<b>Project logo and website</b>
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