RAILCOM

Project no. 516369

Electromagnetic compatibility between rolling stock and rail-infrastructure encouraging European interoperability

Specific Targeted Research Project
Priority 6.2 - Sustainable Surface Transport

Final activity report

Period covered: from 01/12/2005 to 31/05/2009 Date of preparation: 05/01/2010

Start date of project: 01/12/2005 Duration: 42 months

Project coordinator G. van Alphen
Project coordinator organisation Movares Nederland B.V.

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Summary

http://www.railcom.info

Electromagnetic compatibility between rolling stock and rail-infrastructure encouraging European interoperability - the RAILCOM project

RAILCOM is a partly EU funded research project, Specific Targeted Research Project - STREP, and partly funded by the consortium partners. The project started in December 2005 and has ended in May 2009 after a total duration of 42 months. There are 17 consortium partners.

Focusing on the vehicle-infrastructure interfaces, especially on the TEN-T railway network, the RAILCOM project has provided practical and harmonised solutions to EMC issues and in this way contributes to railway interoperability.

During the implementation of the project a series of actions aiming at disseminating the project results has been carried out. As a result articles in journals and at conferences have been published. Project results have been written down and are available in the public deliverables as listed in chapter 2 of this document. To round off the project a final dissemination conference has been held April 2009 at the UIC premises in Paris.

Besides these activities, contacts with Cenelec WGA4-2, UNISIG and ERA have been maintained to transfer the relevant results to standardisation and contribute, amongst others, to CCS TSI and EN50238.

List of consortium partners:

Movares
Alstom
Ansaldobreda
Bombardier
VUZ
DBAG
TU Kaiserslautern
INRETS
NITEL
Siemens
SNCF
UIC
UNIFE
SBB
CD
CNTK
RFF

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Contents

1 Project objectives and major achievements

Electromagnetic compatibility between rolling stock and rail-infrastructure encouraging European interoperability - the RAILCOM project

RAILCOM is a partly EU funded research project, Specific Targeted Research Project - STREP, and partly funded by the consortium partners. The project started in December 2005 and has ended in May 2009 after a total duration of 42 months. There are 17 consortium partners.

The project has a total of 5 different work packages. The RAILCOM specific targeted research project is directed at research domain 2.7 of the objective "Advanced design and production techniques". The project addresses this domain by focussing on improvements of two specific railway vehicle-infrastructure interfaces on the TEN T railway network, at the one hand it deals with compatibility between train detection system (infrastructure) and electromagnetic interference from railway vehicles and at the other hand with electromagnetic compatibility of railway communication systems between vehicles, infrastructure, employees and passengers.

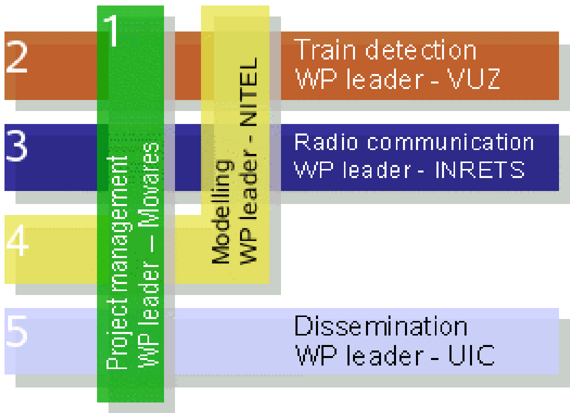

Fig.1 , Railcom Workpackage-structure and -leaders.

Focusing on the vehicle-infrastructure interfaces, especially on the TEN-T railway network, the RAILCOM project has provided practical and harmonised solutions to EMC issues and in this way contributes to railway interoperability.

The objectives of the project are:

- harmonisation of interference limits for train detection systems on TEN-T railway network;
- characterisation of the railway electromagnetic environment for communication systems, with correlation between EM emission and operating conditions of the system;
- proposals for the ongoing standardisation process within CENELEC.

The research activity, including modelling and measurements, has been focused on train detection and communication systems. Harmonised calculation methods have been identified and validated through appropriate test campaigns. Strong effort has been made in order to favour harmonisation of interference limits and methods for determination of limits of train detection systems, overcoming the barriers imposed by national regulations and practice. The EM of the railway systems has been related to its operating conditions, in order to enable to forecast electromagnetic emission on the basis of the characteristics of the systems and to assess interference with communication systems.

The main objective of the “Electromagnetic compatibility between rolling stock and infrastructure encouraging European interoperability” project is to gather and focus the research potential of representative industry, research organisations, academic media, railway operators and European organisations on specific targets required for the elaboration of practical solutions and harmonised criteria for priority electromagnetic compatibility issues as a contribution to an interoperable railway system, especially on the lines belonging to the TEN-T network. These solutions and criteria are focused on EMC problems involved in train detection systems and radio-communication system of the European railway network included in the interoperability specifications for high speed, conventional lines and TEN-T priority projects.
Taking the traction units as one of the primary sources of railway generated noise, a meaningful EM characterisation of rail environment is carried out by the project. Merging the available know-how by the participation in the project of researchers with specific expertise in telecommunications from one side and power systems on the other side.

During the implementation of the project a series of actions aiming at disseminating the project results has been carried out. Besides these activities, contacts with Cenelec WGA4-2, UNISIG and ERA have been maintained to transfer the relevant results to standardisation and contribute, amongst others, to CCS TSI and EN50238.

Significant synergies between the Train detection and Communication systems activities have been envisaged as well, in order to exploit and share common modelling and measurement techniques in the respective frequency ranges. Such synergies are favoured by the respective expertise of the researchers involved in the project.

To round off the project a final dissemination conference has been held April 2009 at the UIC premises in Paris.

2 Technical outcomes

2.1 Workpackage 2

One part of the project focuses on the interaction of the trains with the train detection systems.

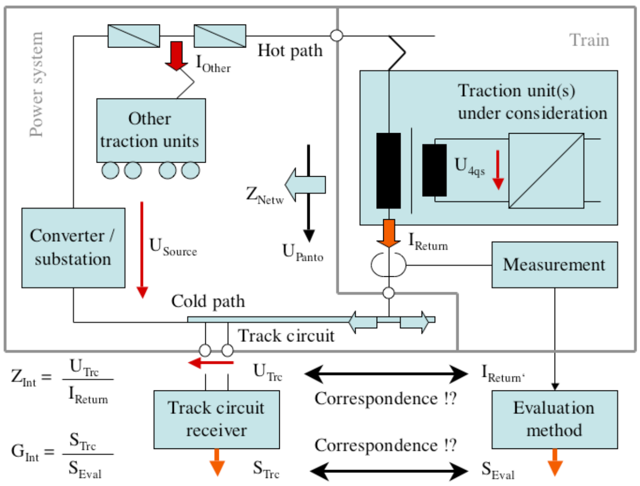

Fig. 2, Vehicle vs infrastructure.

The rails are used as conductors for the traction return current. Track circuits feed low power signals into the rails to detect whether a track section is clear or occupied. They can malfunction if the traction return current contains excess interference in sensitive frequency bands.

Computer models for the calculation and simulation of specific aspects of EMC are used by manufacturers of vehicles and signalling systems, by consultants and research institutes, and to some degree by railways. The methods and models are not standardised or harmonised, and therefore not generally trusted and accepted.

The consequence is that much more knowledge and computer modelling power is currently available than is effectively used to resolve today's EMC problems in the railway sector. The currently published standards define mainly the acceptance process, but the methods to be applied in this process often remain undefined and ambiguous, have no sound scientific foundation and are too simplistic.

The railway infrastructure managers must define the interference limits to be met by the trains but there is no standard to define suitable methods for determining how such limits are defined, and what configurations and parameters are to be considered.

According to EN 50238, the railway infrastructure managers shall define the interference limits to be met by the trains, but the standard does not define suitable methods for determining how such limits are defined, and what configurations and parameters (e.g. infrastructure and/or rolling stock failures) are to be considered. The railway operators and vehicle manufacturers shall demonstrate theoretically and by tests that the trains meet the interference limits under all operating conditions. The precise methods for the demonstration of compatibility are not defined by the standard; there are no harmonised rules for the consideration of vehicle faults.

Test-campaign

The interface between train and infrastructure is at pantograph and wheels. All requirements towards the train are formulated for this interface, whereas the interference is measured on board the train. Either the line current at the pantograph or the sum of all return currents has to be measured and evaluated.

Therefore characterisation of infrastructure as seen from the train has a major importance for interoperability. Knowledge of influence of infrastructure (and other effects like e.g. neighbouring vehicles) to results of measurements can allow to define requirements towards infrastructure to be used for tests of interoperable rolling stock in the case of electromagnetic compatibility with track circuits.

The most important cost driver for today’s compatibility tests is the repetition of tests in nearly every country. It is highly desirable that interoperable rolling stock has to be tested only once per power supply system, also for compatibility with track circuits. This requires a sufficient test environment; not every infrastructure will be suitable. Mainly the characteristics of the power circuits are of importance, not the track circuits themselves.

Thanks to measurements in the Netherlands and Switzerland a lot of knowledge about resonances existed already. With additional measurement campaigns, more data about the interface between train and power supply has been collected in several European countries.

Both line voltage and line current of a test train are measured over several days, with good accuracy and for frequencies up to 20 kHz, using a PC based data-acquisition system coupled to an emc-sturdy measurement system based on the so called D/I-technology (see the following figure).

Fig.3 , Example of data-acquisition system installation.

Finally the following campaigns were realised and evaluated:

- Switzerland: Re 460 (scheduled IC train), 15 kV 16.7 Hz
- Germany: ICE-S (test train for RAILCOM), 15 kV 16.7 Hz
- France: TGV DASYE (test train for RAILCOM), 25 kV 50 Hz, 1.5 kV DC
- Czech Republic / Poland: CD 163 (scheduled trains), 3 kV DC

Moreover Trenitalia carried out measurements of several trains in Italy (25 kV 50 Hz, 3 kV DC) which were evaluated by the RAILCOM project as well (*Given the results of the Railcom project, the Dutch IM ProRail has ordered Movares to execute similar tests as well in the Netherlands*).

The measured data were evaluated in the time domain by bandpass filtering, followed by a moving RMS function with defined time window (integration time) for different centre frequencies. A histogram was build for each of the frequency bands from the results obtained from bandpass filtering process. A final output is probability distribution of voltages and currents versus frequency for each test campaign (traction power supply system).

As an example The following figures show a compilation of the maxima of voltages and currents over all selected locations in France, both for AC 25 kV 50 Hz and DC 1.5 kV traction system.

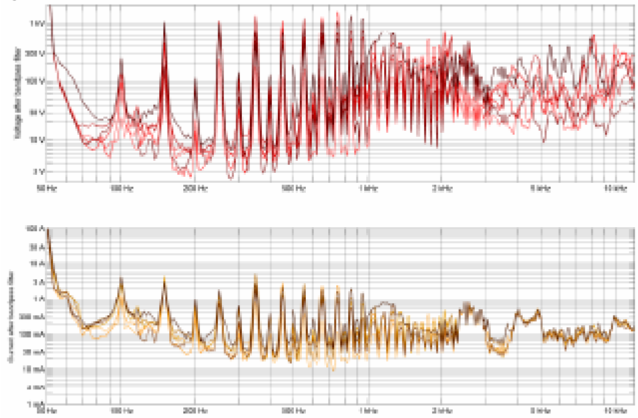

Fig. 4a, Voltage and current maxima - France, AC traction.

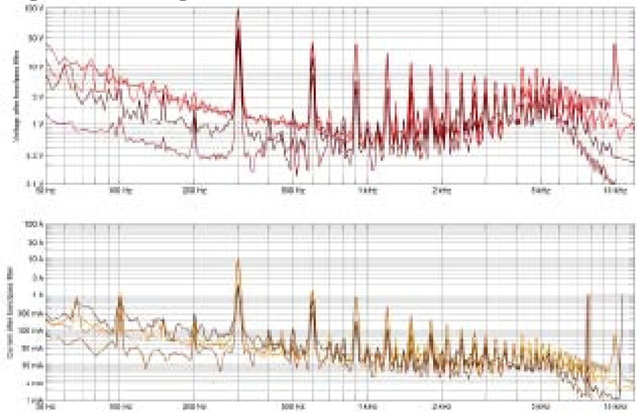

Fig. 4b, Voltage and current maxima - France, DC traction.

The project has provided a toolbox of fully validated methods for the characterisation of train detection systems, and for the assessment of compatibility between rolling stock and train detection systems.

Table 2.2: Deliverables List WP2

Del. no.	Deliverable name	Dissemination level	Lead contractor
D2.1	Inventory of possible interference mechanisms influencing track circuits	PU	SBB/emkamatik
D2.2	Selection of the knowledge gaps, list of expected results	PU	DB AG
D2.3	Results of theoretical investigation of the knowledge gaps, proposal of the structure of the unified methods for vehicles and track circuits testing	RE	VUZ
D2.4	Selection of suitable track configurations	RE	VUZ
D2.5	Report on full-scale tests	PU	SBB/emkamatik
D2.6	Proposals of the unified methods for harmonisation	PU	VUZ

2.2 Workpackage 3

The other part of the project deals with the behaviour of the new telecommunication applications on the EM railway environment.

In the framework of WP3 workpackage, several systems were selected and have been described:
- Eurobalise and Euroloop for spot communications;
- GSM-R and TETRA for cellular systems;
- WIFI for WLAN systems.

The development of the wireless and wired communication systems constitutes an increase of the possibilities of information and control at distance. However, the railway EM environment can be particularity aggressive and can disturb the signal transmissions. The different EM perturbations can then degrade the quality of communications systems and limit the capacities of these systems. For example, concerning GSM-R protocol, when the signal is too perturbed to guaranty the transmission of the information, the signal has to be repeated. The repetition of the signal induces an increase of the time of information transmission, thus an important channel occupation.
The final objective is to achieve a comprehensive characterisation of the electromagnetic environment of the railway system, according to the significant operating conditions of the system itself including sources of interference (vehicles, substations, lines, auxiliary equipment), in order to determine the susceptibility levels of the communication systems in front of the electromagnetic interference, to guarantee the safety of the messages and the transmission of the information in a delay that e.g. respects the ERTMS and Euroradio requirements. These susceptibility levels will have to be defined for precise tests methodologies in order to guarantee the reproducibility and the repeatability of the EMC specifications and to support railway interoperability.
Important input to standards like EN50121-2, EN50121-4, EN50159-1 is envisaged as a part of dissemination activity through the partners participating in the respective working groups.

Test-campaigns

Within the framework of the Workpackage 3 two different measurement campaigns have been executed on railway operation related communication using GSM-R and Eurobalise.

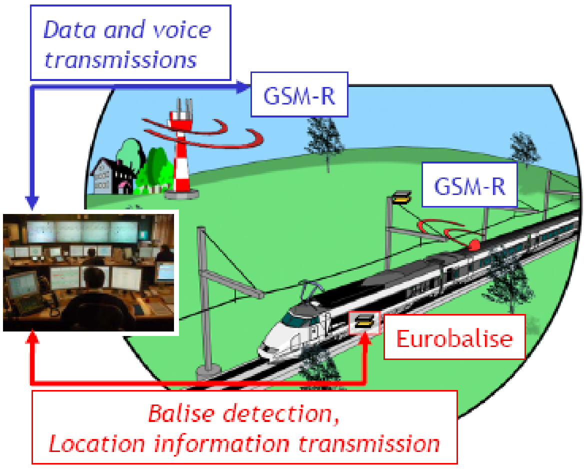

Fig. 5, Railway operation related communication.

With respect to communication purposes the EM environment consists of two parts:
1. On top of the train;
2. Under the train.

For the analysis of the GSM-R the environment on top of the train is the most important one, with respect to the Eurobalise the most important one is the environment under the train. Therefore this will be dealt with in different sections.

GSM-R

The main potential EM disturbances for the GSM-R are:
• The public GSM, UMTS 900 on frequency channels adjacent to the GSM-R frequency bands « permanent » disturbances;
•Transients coming from the catenary - pantograph sliding contact (sparks).

On-board measurements and laboratory tests have been carried out. The principal parameter evaluated was the BER (bit error rate) related to the duration and the repetition rate of the transients.

For GSM-R a method to determine the characteristics of the EM-environment on top of a train has been developed. The results obtained using this method are dependent on the type of antenna used, indications exist that the distributions observed in experiments are strongly influenced by the antenna characteristics.
However, as real GSM-R systems will be using similar antennas, with similar characteristics, still the main distribution of important parameters of transients like rise time and duration time, as seen by the train borne equipment will not change to a major extent. Of course, another important parameter is the repetition rate of the transients, which is not influenced by the characteristics of the antennas used.

Eurobalise

For the Eurobalise the environment under the train is the most important one. During the EMC ARTS programme this has lead to the development of a “standardised” antenna, which can be used under a vehicle. Basically the antennas used consist of square loops which are placed under the vehicle. The test campaigns have identified and agreed among the UNISIG partners in the RAILCOM project the laboratory practical test arrangement, dimensions of the inductive loop, and noise characteristics in time and frequency domain.

Railcom proposal, to determine the characteristics of the EM-environment under a train. An overview of the main components of the setup is given below.

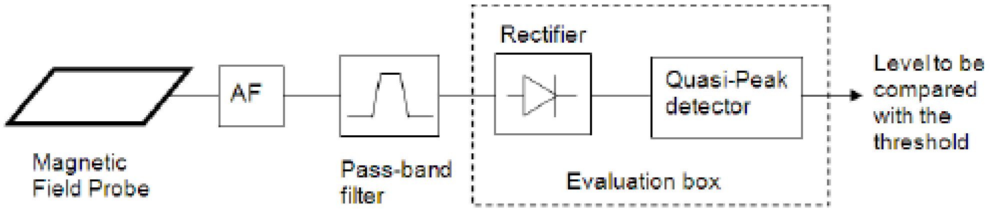

Fig. 6, Overview of main components of setup.

Main characteristics are:
- Dimensions of the antenna : 310 mm x 190 mm;
- Metallic plate (350 mm x 250 mm) 10 cm above the magnetic field probe;
- Flat response between 1 MHz and 8 MHz.

In order to obtain a flat response between 1 MHz and 8 MHz, an antenna filter is used. The result is that with respect to the emission measurements a flat frequency response is obtained, which enables a more simple evaluation method.

The RAILCOM documents have been already offered to UNISIG which had created in parallel a working group with the task to agree on the common methods being applied.

The measurement technique developed is linked to the immunity requirements. For the immunity, a wide loop antenna is used to generate the noise. An antenna similar to the antenna used for the emission measurements, is used to calibrate the level of the noise generated. Subsequently the behaviour of the system (Balise detection, BER) is tested, using defined test signals, at the immunity levels given.
Therefore, the method proposed is suitable to give a direct indication if the EM environment under the train is acceptable for a correct functioning of the Eurobalise Antenna.

Table 2.3: Deliverables List WP3

Del. no.	Deliverable name	Dissemination level	Lead contractor
D3.1	Selection of relevant communication systems	RE	INRETS
D3.2	Victims/aggressors matrix	RE	INRETS
D3.3	Extraction of the physical safety criteria	RE	INRETS
D3.4	Methodology for characterisation inside trains	PU	INRETS
D3.5	Methodology for characterisation outside trains	PU	INRETS
D3.6	Test reports – study of the reproducibility	RE	INRETS
D3.7	Test reports – confrontation	PU	INRETS
D3.8	Immunity protocols and levels	RE	INRETS

2.3 Workpackage 4

The objectives of WP 4 Modelling are the harmonisation of theoretical models, calculation methods and simulation procedures for the determination of interference from the railway system apparatus to signalling systems in general and track circuits in particular. For this purpose, the main work of Technische Universität Kaiserslautern, the vehicle modelling, together with substation, line, track and signalling system modelling provided by the project partners, is to be carried out based on theoretical and simulation models available from the results of foregoing projects and from scientific and technical literature.
Based on the results in the past reporting periods, the work performed in the reporting period is related to harmonisation and integration of subsystem models, case studies concerning sensitivity and compatibility issues, and recommendations for modelling techniques, procedures as well as software implementation.

A general evaluation of the most important theoretical models for electrical lines in frequency and in time domain has been performed; the positive and negative aspects of each representation have been pointed out (i.e. application fields, approximations and requested CPU time for elaboration) and innovative models available for future applications have been presented.

Concerning the net-impedance activity, co-ordinated by NITEL, the AC substation, the autotransformer, the impedance bonds, the track circuit and the traction line models have been presented in detail and then assembled to build a complete model of a railway system. The effects on net-impedance behaviour of each apparatus and sub-system connected to the line have been identified and evaluated; the relationship between line length, number of autotransformers and the net impedance itself has been considered too.

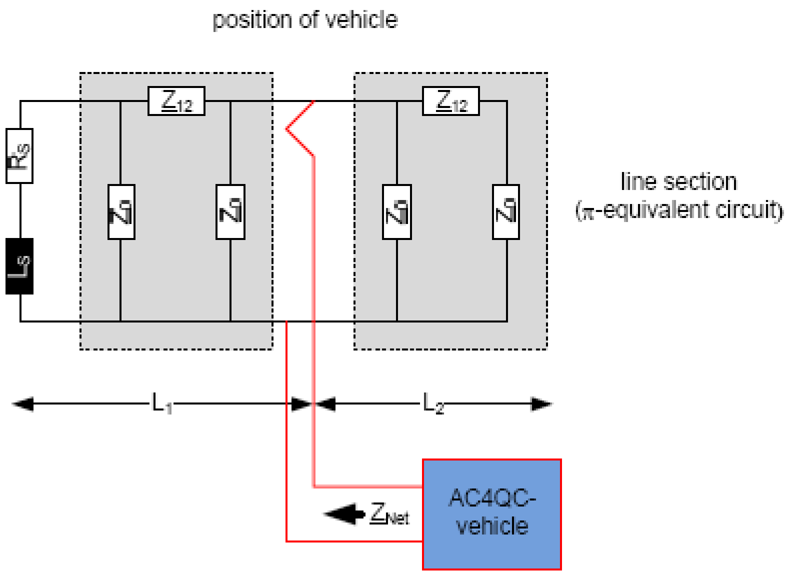

Fig. 7, Equivalent circuit to simulate supply network with vehicle at defined position.

The model and the simulation tool have been validated by comparison with the results of measurements on the Betuweroute 2x25kV AC 50 Hz railway line performed by MOVARES and ProRail.

The measurement campaign performed by Trenitalia on several Italian railway lines (both 3000V DC and 2x25kV AC) has been considered too; the analysis and discussion of those data (in term of FFT and time-frequency diagrams) has allowed to point out the influence of the different apparatus, in terms of characteristic and non-characteristic harmonics due to train, substation etc., as already underlined in previous theoretical activities.

The activity related to the above tasks has been performed by NITEL with the contribution of MOVARES, ProRail and Trenitalia for the measurements and Omega Ti for the preparation of part of the code for processing of measurement results.

The DC Substation activity has been finalised: the dc substation has been characterised as harmonic voltage source and the maximum envelope of harmonic voltages has been derived, including effects of distortion of primary voltage and of load characteristics. A simplified formula for conservative estimation of voltage harmonics has been proposed.

Table 2.4: Deliverables List WP4

Del. no.	Deliverable name	Dissemination level	Lead contractor
D4.1	Collection and test of available models	PU	NITEL
D4.2	Identification of indicators	PU	NITEL
D4.3_4	Description of frequency and time domain modelling	PU	NITEL
D4.5_6	Subsystem models integration and options for SW implementation	PU	TUKL
D4.7	Application to test cases	RE	TUKL
D4.8	Revision of previous activities	PU	NITEL
D4.9	Final recommendation	PU	TUKL

3 Dissemination and use

During the implementation of the project a series of actions aiming at disseminating the project results has been carried out. As a result articles in journals and at conferences have been published. Project results have been written down and are available in the public deliverables as listed in chapter 2 of this document. To round off the project a final dissemination conference has been held April 2009 at the UIC premises in Paris.

Besides these activities, contacts with Cenelec WGA4-2, UNISIG and ERA have been maintained to transfer the relevant results to standardisation and contribute, amongst others, to CCS TSI and EN50238.
The European Railway Agency has launched an EMC Working Party, aiming (in the first step) in specifying target limits/test methods for train-track compatibility of track circuits under 15 kV and DC power systems for their inclusion into CCS TSI. The basis for this activity are outcomes of CENELEC and Railcom activities.

List of publications during the course of the project

Workpackage 2

- SIGNAL + DRAHT 06/2008 - article "Interoperability between rolling stock and track circuits - a "mission impossible"? (authors Gert-Jan van Alphen / Karel Benes / Markus Meyer)
- European Rail Technology Review - RTR 1/2009 - the same article as in SIGNAL + DRAHT 06/2008
- Workshop "EMC of Railway Systems, a new European Approach" at "Symposium on Electromagnetic Compatibility", Zürich, 01/2009 - presentation "The Relation between RAILCOM and CENELEC" (authors Gert-Jan van Alphen / Karel Benes)
- "RAILCOM Final Reporting Interactive Conference", Paris, 04/2009 - presentation "Electromagnetic compatibility at train-track interface - low frequency domain" (author Karel Benes)
- Conference "Interaction 2009", Thun, 06/2009 - presentation "Infrastructure characterisations from the Railcom test campaigns" (author Markus Lerjen, co-authors Gert-Jan van Alphen / Karel Benes)
- Presentations of Markus Meyer to CENELEC WGA4-2 (WP2 inputs to EN 50238-2) - "Harmonic current generation: Infrastructure conditions for rolling stock tests", Spring 2008
- The WP2 results were presented as the inputs to EN 50238-2, first related to "Harmonised rolling stock test method", 2008 till Spring 2009
- Rolling stock vs Rail-infrastructure – contributing to standardisation and interoperability, EDPE 2009

Workpackage 3

- V. Deniau, N. Ben Slimen, S. Baranowski, H. Ouaddi, J. Rioult and N. Dubalen, “Characterisation of the EM Disturbances Affecting the Safety of the Railway Communication Systems”, Reliability in Electromagnetics Systems organised by The Institution of Engineering and Technology, Paris, 24-25 May 2007
- V. Deniau, J. Rioult, N. Ben Slimen, H. Ouaddi, N. Dubalen and Railcom consortium, Characterisation of the electromagnetic disturbances received by GSM-R antennas in usual railway operating conditions, EMC workshop, 14-15 Juin 2007, Paris
- N. Ben Slimen, V. Deniau, S. Baranowski, N. Dubalen, B. Démoulin, Consortium Railcom,“on-board measurements of the railway’s electromagnetic noise with moving trains”, EMC Zurich 2007, Munich, 24-28 septembre 2007
- N. Ben Slimen1, V.Deniau1, Marion Berbineau - Ricardo Adriano- Sylvie Baranowski- Philippe Massy Analyse temporelle des perturbations transitoires observées à bord d’un train en mouvement afin de protéger les systèmes de communication embarqués, CEM2008, Paris, mai 2008
- Ricardo Adriano, Nedim Ben Slimen, Virginie Deniau, Marion Berbineau and Philipe Massy, Prediction of the BER on the GSM-R communications provided by the EM transient disturbances in the railway environment, Proceeding of EMC europe 2008, pp 771-775, hamburg, septembre 2008
- V. Deniau, N. Ben Slimen, , S. Baranowski, H. Ouaddi, J. Rioult and N. Dubalen : “Characterisation of the EM Disturbances Affecting the Safety of the Railway Communication Systems », European Physical Journal –Applied physics, , vol 43, p 225-230, 2008.

- V. Deniau, R. Adriano, S. Dudoyer, N. Ben Slimen, J. Rioult, P. Massy, B. Meyniel, M. Berbineau, A. Raux and E. Smulders Study of the immunity of the GSM-R against electromagnetic disturbances present on moving trains , EMC zurich 2009