European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

Reference: EEIG : 09E033

Distribution date : 29/04/09
Document version : 1-

GSM-R/ETCS Integration Review

Final Report and Conclusions

by

P Booth, R García-Sanchidrián and J Hellmann

VERSIONS & MODIFICATIONS

Version No.	Date of Distribution	Comments on the modification	Responsible for The modification
1A	25-02-09	First formal draft with Appendix	PDB
1-	29-04-09	Inclusing corrections from R Behnsch	PDB

Table of contents

1. INTRODUCTION

This report contains the results and conclusions from a series of reviews undertaken under the terms of an ERTMS Users Group remit to record the experiences of a number of representative ETCS projects in the field of system integration of the ETCS to GSM-R interface. The key features of each of the projects included in the review are described together with the particular interface issues encountered by the respective project teams. A high-level analysis of common factors is provided and recommendations made for further investigation or action as appropriate.

1.1 REMIT AND PURPOSE

Many of the early ERTMS/ETCS implementation projects experienced system integration problems at the level of the ETCS/GSM-R interface. Technical solutions to these failures were found by individual project engineering teams but there has not been any specific action to facilitate the sharing of knowledge and experience in this area. It was proposed by the National Project Managers that a review be carried out to see if any relevant lessons could be learned from existing projects for the benefit of future projects.

It was originally envisaged that one of the results of this review would be the devolvement of a set of application guidelines to be used as a reference by future projects. The reviewers have reached the conclusion that such a document, even at informative status, would not be necessary or appropriate due to the significant diversity of operational needs and preferences in the development of the national GSM-R networks. Nevertheless, it is hoped that the conclusions reached from this review will be useful to those responsible for managing the implementation of future ETCS projects.

1.2 REVIEW METHOD

The chosen method for acquiring the necessary information to support this review was through personal interview with the relevant engineering staff engaged in the participating projects. The interviews were carried out at the respective project team's normal operating base.

A written questionnaire was made available in advance of each visit. The questionnaire gave a list of general questions and was intended to form a basis for discussion. The notes of each visit were recorded under the headings given in the questionnaire and are included as an annex to this report.

It should be appreciated that the nature of the review process means that only a general assessment of the projects has been possible. A detailed analysis of specific problems has not been feasible within the scope of this review. Nevertheless, the review process has been sufficient to at least identify relevant integration issues for comment and outline analysis. This report gives recommendations for further actions where appropriate in the case of issues that appear to justify more detailed investigation and analysis.

A final interview with Mr Konrad of the UIC with the reviewers and Mr Behnsch of DB was held to consider the results and agree the conclusions and recommendations prior to compiling this report.

2. THE REVIEW

The review was based on evidence gathered from interviews with a representative cross-section of ETCS project teams. A total of six project visits were made as follows:

- RFF 11/12/07
- ADIF 28-29/1/08
- ProRail 4/3/08
- SBB 1/4/08
- RFI 7/5/08
- DB 5/6/08

The notes of these meetings were based on the replies given to the questionnaire distributed prior to each visit with additional information and comments recorded during the course of each visit. The mission reports for each of these visits are reproduced in Appendix A.

A variety of system integration issues were encountered during the projects. All of these were overcome and ETCS successfully commissioned in all cases, except that some of the projects are still in the testing phase and have not yet entered commercial service. A brief summary of each meeting is given below.

2.1 FRANCE – RFF

Some experience had been gained from the early ETCS pilot project but the majority of the relevant experience had been from the implementation of ETCS on the new Paris – Strasbourg high speed line (LGV European Est). This project uses a dual layer GSM-R network for redundancy (two co-located BTSs per cell given dual coverage at each point along the route). The remaining trackside GSM-R and fixed telecoms equipment is fully duplicated. Both layers are controlled from the same MSC with a cold standby MSC which can be brought online in a few hours if the main MSC fails (or is damaged). The line uses ETCS Level 2 with fallback to TVM. No ETCS is provided outside the geographic limits of the high-speed line, KVB and conventional signalling is used outside the high-speed route. The vehicles are fitted with 3 GSM-R data Mobile Terminals; a simple sequential logic is used to ensure a strict cyclic usage of the available MTs. The three MTs share two roof-mounted antennas.

The main findings from the interview with RFF can be summarised as follows:

- The specified carrier interference levels were not achieved. In spite of this, the system works well (with the exception of a few isolated problem areas). This evidence suggests that the limits given in subset-093 may be unnecessarily demanding.

- Initial tests had show that a transmission rate of 9.6kHz at the Igsm interface is not sufficiently reliable. Satisfactory communications had been achieved at 4.8kHz.

- Interoperability problems had been experienced as a result of gaps in the EIRENE and SUBSET-037 specifications. The equipment had to be modified to resolve these problems.

- Considerable attention has been given to the creation of a redundant architecture. RFF have implemented a dual GSM BTS network to enhance system availability with a second MSC configured as a cold-standby. Three GSM-R data radios are provided to cover the failure of a single radio with no loss of performance.

- It had been necessary to use RF splitters and combiners to share radio antennas on the train roof.

- The view of RFF is that values of ETCS configurable parameters such as T_NVCONTACT should be chosen taking account of occasional temporary reductions in the specified GSM-R QOS levels.

2.2 SPAIN – ADIF

Experience of ETCS Level 2 operation with GSM-R had been gained from the verification tests of ETCS on the new Madrid – Barcelona high speed line and the Cordaba – Malaga line. The Spanish projects use a complete dual redundant GSM-R network with an MSC for each network. The BTSs are installed in an interlaced fashion with alternate BTSs from each of the two independent GSM-R networks. BTS spacing is sufficient to ensure that an acceptable minimum field strength is available from the alternate network should one network become unavailable. The Madrid – Barcelona line uses ETCS Level 2 with fallback to Level 1 and ASFA. The vehicles are fitted with 2 GSM-R data Mobile Terminals each with its dedicated roof-mounted antenna to avoid sharing of antennas. The line is in operational service at Level 1; the Level 2 overlay is currently in the testing phase and is not expected to enter operational service before the end of 2008.

The main findings from the interview with ADIF can be summarised as follows:

- The SUBSET-093 QoS requirements cannot all be realistically achieved in practice and the relevant specifications should be reviewed. ETCS reliability does not appear to be adversely affected even when the specified QoS requirements are not fully met.
- Satisfactory levels of GSM-R field strength do not necessarily guarantee lossless data transmission. Significant bit error rates were detected at certain locations, even though carrier field strength was found to be well above the EIRENE specified minimum. This problem has been traced to locations where the field strength drops quickly from a high level to a lower (but still compliant) level due to train movement.
- The GSM-R network reliability has been excellent, a product of the highly redundant architecture.
- The KMC supplied by Ansaldo has proved difficult to use from an operational point of view (need for simultaneous update of EVC and RBC, synchronisation of multiple locally held key management repositories at depots) and provides weak security (keys are distributed on removable media with no encryption mechanism).
- Some problems have been experienced with system integration at the Igsm interface and with the stability of the MT firmware.

2.3 THE NETHERLANDS - PRORAIL

A variety of ETCS Level 2 projects have been undertaken in the Netherlands, including the betuwe freight line, the new High Speed Line - Zuid and the Amsterdam – Utrecht capacity enhancement project. The GSM-R network is fully operational for voice calls with day-to-day responsibility for operation and maintenance subcontracted to MobiRail. ProRail has not been involved in system integration testing of the HSL Zuid project; this project had been contracted to the Infraspeed consortium and directly managed by the Dutch ministry of transport. Tests have been carried out with an Alstom train and a refurbished Thalys train set at low speed but ProRail had not had access to the test results at teh time of the interview. The other major ETCS project, the Betuwe freight line, has been managed as an infrastructure project. ProRail has little experience of integration with the on train equipment except for the test running undertaken using an Alstom equipped test train. Most of the practical experience gained by ProRail was acquired during the two ETCS pilot lines (Maastricht-Heerlen and Leeuwarden - Meppel).

The Dutch projects use a single network single layer GSM-R configuration but with complete redundancy of all network components, including the MSC. Although component redundancy is provided, no diversity of location is included. BTS spacing is sufficient to ensure that an acceptable minimum field strength is available from the adjacent BTS should one BTS become unavailable except for the Betuwe line. Prorail has no responsibility for train fitment and no direct experience beyond the early testing work carried out on the early pilot projects, Maastricht-Heerlen and

Leeuwarden – Meppel. None of the projects are yet in commercial service except for the Betuwe line which still had a low traffic density at the time of the interview.

The main findings from the interview with ProRail can be summarised as follows:

- There was one minor problem with the Ifix interface (RBC-MSC) which resulted in a European change request.
- ProRail's opinion is that the EURORADIO Key Management System provided for the Betuwe Line is not suitable for implementation on a wide scale due to the logistic difficulties associated with key distribution and update and the need to update all affected Onboards and RBCs (including those in neighbouring countries) in a single event.
- ProRail has had limited direct responsibility for Onboard ETCS equipment. However, a number of problems were encountered in the implementation of the Igsm interface on the pilot trains. These problems were related to misunderstandings in the Euroradio specification and use of the AT command set.
- Experience has shown that the SUBSET-093 Quality of Service requirements are not necessarily a reliable indicator of reliable end-to-end communication.

2.4 SWITZERLAND – SBB

SBB has now equipped two main lines with ETCS Level 2; the Mattstetten – Rothrist (Bern–Olten HSL section) and the Frütigen–Visp (Lötschberg) route. In addition, more than 600 rail vehicles have now been fitted with ETCS equipment. These two routes have been in regular commercial service for over a year. These projects were built on the experience gained from the Swiss ETCS pilot project on the Luzern – Olten route.

The Swiss projects use a dual layer GSM-R network for redundancy for ETCS routes. The BTSs are installed in an interlaced fashion with alternate BTSs from each of the two independent layers. BTS spacing is sufficient to ensure that an acceptable minimum field strength is available from the alternate network should one network become unavailable. Dual leaky feeders are used inside the Lötschberg Tunnel. The remaining trackside GSM-R and fixed telecoms equipment is fully duplicated. Both layers are controlled from the same MSC with a cold standby MSC which can be brought online in a few hours if the main MSC fails (or is damaged). ETCS Level 2 is used with no fallback signalling system. The vehicles are fitted with 2 GSM-R data Mobile Terminals; one of these shares an antenna with the GSM-R voice radio MT.

The main findings from the interview with SBB can be summarised as follows:

- Some optimisation of the GSM-R network was necessary at specific locations to ensure trouble-free operation of ETCS.

- Some problems with ETCS operation (network selection and attachment) were experienced in the earlier pilot project (Luzern – Olten). These problems have been solved in the ETCS border crossing Change Requests.
- The implementation of redundant dual-layer GSM-R coverage has yielded excellent network reliability.
- The use of a dedicated Call Performance Monitoring system has played a fundamental role in the identification and resolution of ETCS/GSM-R communications issues. This sub-system has had a major impact in the successful deployment of ETCS on the SBB rail network.

2.5 ITALY – RFI

In Italy, the Roma – Napoli and Torino – Milano routes are already in service while Milano – Bologna is currently under construction. The RFI implementation strategy is based on ETCS L2 with a fully redundant system architecture to eliminate the need for a fallback signalling system. It was noted that RFI have already implemented GPRS within their GSM-R network although its use is restricted to the provision of value added services for passengers (e.g. ticketing-system) at present. RFI are participating in the current round of UIC lead discussions on the possible use of GPRS for ETCS.

The Italian projects use a single layer GSM-R network. BTS spacing is sufficient to ensure that an acceptable minimum field strength is available from the adjacent BTS should one BTS become unavailable. Separate GSM-R networks are provided for high speed and conventional lines, including routes where these run in parallel. RFI's experience has shown that phased-array antennas rather than leaky feeders provide a better solution in tunnels. The trackside GSM-R and fixed telecoms equipment is fully duplicated within each MSC area of control. Multiple MSCs (3x high speed lines, 4x conventional lines) are provided to ensure that a failure of one MSC will not affect the entire rail network. The HLR in Rome is used for all MSCs but a local copy at each MSC enables the GSM-R network to continue if a connection to the central HLR is broken. the whole . ETCS Level 2 is used with no fallback signalling system. The vehicles are fitted with 2 GSM-R data Mobile Terminals and one voice radio MT with no sharing of antennas.

The main findings of the interview with RFI were as follows:

- Very few ETCS/GSM-R integration problems have been encountered with the projects completed to date. The problems that were encountered were resolved quickly and efficiently.
- The implementation of a fully redundant GSM-R network has yielded excellent reliability. When calls have been lost, these appear to have been terminated by the ETCS/EURORADIO application layers or a reset within the MT.
- RFI have found that phased array antennas in tunnels to be a better solution than relying on leaky feeders.

- GPRS is implemented on the Italian GSM-R network. Currently, use is limited to provision of value added services to passengers.

2.6 GERMANY – DB

The German GSM-R network includes seven regional MSCs, with all MSCs interconnected through a redundant network and with each MSC being fully redundant in terms of hardware and power supply. The Berlin – Leipzig line is the pilot line that has been fitted with ETCS infrastructure using four RBCs. LZB is installed parallel on that pilot line and both systems use PZB as a fallback system. DBs future plans for ETCS Level 2 are based on availability of the ETCS SRS version 300 baseline for lines with a speed above 160 kph and high density lines with short block distances (depending on technical and economical feasibility).

The Berlin - Leipzig projects use a single layer GSM-R network. BTS spacing is sufficient to ensure that, wherever practical, an acceptable minimum field strength is available from the adjacent BTS should one BTS become unavailable. The trackside GSM-R and fixed telecoms equipment is fully duplicated within each MSC area of control. The vehicles are fitted with 2 GSM-R data Mobile Terminals and one voice radio MT with no sharing of antennas. Note analogue and GSM-R voice radio are combined in a single package with a common antenna.

The main findings of the interview with DB were as follows:

- In early days DB faced difficult integration problems on the I_{GSM} interface with system timings and unexpected behaviour of the MT. They were solved by software upgrade of the Sagem MT. Nevertheless, the FFFIS for Euroradio should be extended.

- The SUBSET-093 GSM-R Quality of Service requirements are considered by DB to be unnecessarily demanding.

- Some problems with interference on GSM-R channels is thought to originate from transmissions from public band GSM.

- A comprehensive GSM-R call performance diagnostic and monitoring system would be highly beneficial

- The key management tools currently available are inadequate for the operational needs of a full network.

3. ANALYSIS OF COMMON FACTORS

The principal objective of this review was to identify common factors that have occurred across a representative selection of ETCS implementation projects. The intention is that recommendations be made based on such common factors that might benefit those involved in future ETCS implementation projects. These recommendations would be focused on avoiding specific problem areas that might otherwise be unforeseen. Equally, it is intended that examples of good engineering practice can be highlighted and brought to the attention of those responsible for managing future projects.

Having analysed the results of the individual project reviews, a number of common factors recurred to a significant extent. These are analysed point by point in the following notes.

3.1 GSM-R QUALITY OF SERVICE

The experience of the majority of projects covered in this review suggests that some of the requirements in SUBSET-093 are unnecessarily demanding. The evidence of this is the difficulty in complying fully with these requirements, particularly the transmission interference rate and recovery time requirements, yet generally satisfactory performance has been obtained in practice with relatively few lost connections. Experience has shown that the majority of lost connections (dropped calls) are caused by the layers above GSM-R (i.e. ETCS application and Euroradio) ordering call termination rather than failure of the GSM-R connection itself. This suggests that the failure detection mechanisms in the higher layers are too sensitive; one would reasonably expect the upper layers should maintain the connection until the GSM-R layers provide the information that connection has been lost. Re-establishing the connection from the ETCS layers is time consuming and is very likely to have a noticeable operational impact.

The above analysis is based only on the brief generalised evidence gathered from the project visits and interviews. More specific supporting evidence needs to be obtained and a thorough analysis carried out to establish the true cause of the remaining residual level of dropped calls being experienced by different projects. The analysis would need to consider potential causal factors such as:

For calls terminated by GSM-R:

- *poor or non-optimised GSM-R radio coverage, GSM-R network out of specified limits*

For calls terminated by ETCS/Euroradio:

- *ETCS/Euroradio error detection mechanisms too sensitive.*

Furthermore, it is not obvious why the requirement for a defined response by the application layer to a break in track-to-train communication, e.g. the M_NVCONTACT response, should also lead to a request for termination of the GSM-R connection. This point is covered by ETCS Change Request 481, the current proposed solution is to introduce a new parameter, set to 60s, defining a period after receipt of the last message at which the GSM-R connection will be terminated. Hence, this is similar to T_NVCONTACT but allows the disconnection order to be separated from the maximum tolerable period between successive messages. The justification for introducing a new parameter to control call termination (rather than waiting for another event such as End of Mission) is not clear. The authors of the proposal should be asked to justify the need for this change.

SUBSET-093 requires GSM-R to establish connections using asynchronous transparent mode. There is no obvious justification for this requirement; the experience of at least one railway is that trials with Radio Link Protocol yield better performance as the retransmission process is managed entirely within the GSM-R layers. The benefits of expanding the ETCS specifications to allow the optional use of RLP should be investigated more closely.

It was significant that some problems with dropped calls were encountered in areas where the QoS parameters exceeded the specified requirements. The cause of these dropped calls should be investigated. A more detailed analysis would need to be carried out with the assistance of one or more railways to determine whether these problems are related to the GSM-R/ETCS specifications.

In conclusion, the SUBSET-093 QoS requirements should be reviewed and revised to more accurately reflect overall ETCS system requirements. Current requirements which lead to over-specification of the GSM-R network should be relaxed to the minimum necessary to ensure reliable operation. Any changes should be justified by objective analysis.

3.2 DATA TRANSMISSION RATE

The EIRENE SRS and SUBSET-037 allows for data transmission rates of 2.4, 4.8 and 9.6 kbps in CS (Circuit Switched) mode. Higher data transmission rates result in shorter delay in the delivery of track to train and train to track ETCS messages. The transmission delay translates into traffic movement delays from an operational point of view and in most situations the operators seek to reduce the impact of the signalling system on train performance, hence the highest possible data transmission rate should be used wherever possible. Most railways have found that satisfactory performance can be achieved at 4.8 kbps but not necessarily at 9.6 kbps. Hence all the projects included in the review have avoided 9.6 kbps. No railway has attempted to use 2.4 kbps, even for test purposes. As no particular problems have occurred at 4.8 kpbs there would appear to be no obvious benefits in using 2.4 kbs. Hence, the 2.4kbps data transmission rate could be safely eliminated from the interface specifications with no obvious detrimental effects on future projects.

One further problem which has been discovered is that the SUBSET-037 Euroradio specification does not define any specific protocol to negotiate the data transmission rate to be used by the GSM-R Mobile Terminal. This means that the ETCS OnBoard Unit and GSM-R Mobile Terminal must be specifically configured for the required data transmission rate. See also Section 3.3.

3.3 IGSM (EVC-GSM-R RADIO) INTERFACE

Various projects have encountered system integration difficulties as a result of gaps in the definition of the Igsm interface. The EIRENE SRS and associated GSM-R interface documents provide a complete functional description of the services available from the GSM-R sub-system. The GSM-R interface protocol is based on the standard ETSI AT command set. Unfortunately, the corresponding ETCS interface specification only describes a set of high level interface primitives, the required AT commands and associated parameter values are not defined. Furthermore, neither interface specification defines the required command sequence. The consequence of these omissions is that no interoperability of ETCS OnBoard Unit and GSM-R Mobile Terminal can be assured unless they are procured from a single supplier.

Consideration should be given to the possible enhancement of the ETCS and GSM-R interface specifications to allow complete interoperability at this interface. Interoperability is of course only necessary if the ETCS and the GSM-R Mobile Terminal are to be separately procured.

3.4 REDUNDANT GSM-R NETWORK ARCHITECTURE

The review has shown that all the railways have implemented redundant networks but they have used a variety of functional architectures to achieve this, see the individual summaries in Section 2 of this report. In each case, full protection has been provided against single point failures of network elements, including the supporting fixed telecommunications network and the associated interconnections. Some differences have been noted in the effectiveness of the chosen architecture. For example, implementations relying on a redundant MSC in cold standby will suffer greater operational disruption in the case of a failure compared with the use of a hot-standby MSC. Also, implementations using a dual radio network will enjoy much less disruption should a failure affecting more than one adjacent BTS occur.

The reviewers consider that decisions concerning network architecture are the responsibility of the relevant Infrastructure Manager and see no reason to recommend any particular philosophy. However, it was noted that very satisfactory availability had been achieved in all cases. This success appeared to be due not only to the intrinsic redundancy of the chosen architecture but also to the careful attention paid to monitoring of network performance, network optimisation activities and proactive maintenance support.

No detailed statistical analysis of equipment failure rates, associated operational cost savings and capital investment requirements has been carried out within the scope of this review. However, there is now good qualitative evidence to justify the provision of a fully redundant GSM-R network to minimise the effect of equipment failures on operational service.

3.5 DROPPED CALLS

Relatively few problems were reported with dropped calls from the projects that are now in operational service. Problems encountered prior to entry to service were generally resolved by changes to the GSM-R network, e.g. antenna realignment etc. In some cases, additional BTSs had to be installed to ensure reliable operation.

Most projects reported a small but manageable level of dropped calls. SUBSET-093 specifies a relatively demanding connection loss rate of $<10^{-2}$ which has proved difficult to achieve in practice. It was notable that locations where dropped calls occur do not necessarily coincide with areas of low radio field strength. In Spain, a significant rate of dropped calls occurred at one specific location where the field strength reduced quickly from a relatively high level to a much lower level (but still above the minimum specified limit). The precise cause of these lost connections is not known. One possible explanation is that the GSM-R Mobile Terminal automatic sensitivity adjustment has a slow response time which is unable to manage very sudden changes in received signal strength. A more detailed investigation would be needed to verify this assumption. In the meantime it is recommended that the GSM-R network be designed to avoid sudden changes in field strength along the path followed by the GSM-R Mobile Terminal antenna.

The experience of most projects has been that the majority dropped calls have been terminated in response to a disconnection order from ETCS (including the Euroradio safety layer) rather than a failure within the GSM-R layers. The potential causes of ETCS terminated connections are:

- Calls correctly terminated according to the functional requirements of the ETCS SRS, e.g. End of Mission, RBC handover etc.
- Calls terminated by ETCS lack of communication time-out (T_NVCONTACT expired)
- Calls terminated by the Euroradio safety layer due to violation of internal error checks, e.g. transmission gaps, high bit error rate etc.

The first two points do not give cause for particular concern other than the obvious need to ensure that the ETCS installation is appropriately designed and configured, including the selection of a realistic value of T_NVCONTACT.

The third point, the behaviour of Euroradio, requires more consideration. The normal behaviour expected of layered communication protocol stacks such as that used by GSM-R and ETCS is that the lower layers should react to a temporary transmission failure before the higher layer. For example, a temporary break in communication within GSM-R should be tolerated for a reasonable time period before the connection is deemed to be lost. GSM-R cell handovers are an example of this kind of disturbance. Furthermore, the responsibility for declaring an unrecoverable loss of connection should originate from the lower layers (GSM-R) which should inform the higher layer (Euroradio) that the connection has been lost. It is then the responsibility of the higher layer to request that a new connection be established. The justification for this approach is that GSM-R includes sophisticated techniques to determine the probability of a resumption of transmission based on the information it receives about the status of the radio link with the GSM-R network. If Euroradio orders a termination too soon, there is a greater probability of operational impact due to the additional time need to set up a new connection (including the Euroradio key exchange process) compared with waiting for the GSM-R recovery processes to restore the data transmission link. No safety issues would arise by adopting this approach as the T_NVCONTACT function will intervene after a defined time regardless of the actions of the communications stack.

A further consideration associated with the third point concerns the use of the GSM-R transparent mode data transmission service. In this mode, no correction of corrupted user data occurs within GSM-R, Euroradio takes full responsibility for error correction or request of retransmission of messages which cannot be corrected. Euroradio includes functionality which initiates termination of the GSM-R connection if a number of successive retransmission requests fails to deliver a correctible user data message. An alternative to transparent mode is the Radio Link Protocol (RLP) in which error correction and data retransmission is managed within GSM-R. This enables a more reliable communication channel between track and train with much lower risk of a lost connection. The disadvantage of this mode of transmission is that the transmission delay is longer and may exceed the 500ms specified in SUBSET-093. DB has carried out tests using RLP and has obtained good results. Unfortunately, Euroradio does not currently support this transmission mode. Consideration should be given to carrying out a more detailed investigation to see if the inclusion of RLP in the Euroradio specifications would yield positive benefits in operational performance of ETCS.

3.6 KEY MANAGEMENT

The current off-line key management philosophy described in SUBSET-038 is widely held to be an impractical solution for the needs of interoperable corridors. This fact is already well known to the ERTMS Users Group and a dedicated KMS Working Group has been established to improve the operational aspects of the ETCS key management functionality. A number of Change Requests have been raised and are now in discussion as follows:

- CR749 Number of keys per Onboard
- CR758 KMC – RBC interface
- CR814 Time validity period

CR749 and CR814 are closely related. The current ETCS specifications only allow for one key to be in use at any one time for each train. This creates the practical problem that if the key needs to be changed, the relevant Onboard Unit and all RBCs on the route on which the train runs (including neighbouring countries) must be simultaneously updated. This becomes very difficult to manage if many trains must be updated at the same time. These two CRs allow for more than one key to be held in the Onboard Unit and RBCs for each train with a time validity attribute to enable automatic key changeover at some future point in time. This means that the equipment can be progressively updated over an extended period in advance of the planned changeover date. Hence, these CRs overcome some of the practical problems associated with key management but do not deal with the scenario in which short-notice unplanned updates are necessary.

CR758 defines a harmonised interface for the Key Management Centre (KMC) to RBC/RIU. This is to allow interoperability of different suppliers' KMC and RBC/RIU products. This is necessary since there will normally only be one KMC from one supplier to manage the keys in one country but there will be many RBC from more than one supplier. Note that the proposed interface is still based on the off-line principle; this means that each RBC/RIU must be individually updated using a laptop or other portable terminal.

The ERTMS Users Group has jointly developed a plan with UNISIG and the ERA to implement these improvements for SRS baseline 3.

The experts interviewed during this review were all concerned about the practical difficulties inherent in operating a key management policy based on off-line management principles, even assuming the proposed changes are adopted into the next ETCS functional baseline. There was a clear consensus that ultimately the only practical approach is one based on an on-line update process.

Each project had a different KMC. A full demonstration was given of the KMC supplied by Ansaldo to ADIF. This used a Windows XP based application and general purpose PC storage media to transport keys. The impression of the reviewers was that although the user interface was clear and well designed, significant specialist knowledge of the key management principles would be required by the user. Equivalent facilities for installation of keys exist at depots but these were not seen by the reviewers. It is assumed that a degree of specialist knowledge would also be required of the depot staff. It was noted that SBB has developed its own KMC software and is making this available on a commercial basis to other rail users.

3.7 GSM-R NETWORK PERFORMANCE MONITORING

The experience of SBB in particular has been that the ability to monitor and analyse the performance of the GSM-R network has greatly assisted with the process of optimising the network to improve the reliability of the track to train communication link. The performance monitoring system has enabled the source of communication problems to be identified quickly and efficiently. GSM network equipment includes comprehensive logging facilities and the use of a centralised monitoring system enables detailed statistical analysis to be carried out. These systems allow real-time performance of the network to be compared with target Key Performance Indicators and allow Quality of Service parameters to be compiled. Changes in performance due to local influences along the route, e.g. construction work adjacent to the railway, interaction with public networks etc, can therefore be detected quickly and efficiently. Other projects without equivalent facilities have had to rely on a process of manual inspection and collation of call records and other data logs to identify the source of communication problems. This can prove to be a laborious process if the source of the reported problem is not immediately obvious. The majority of the experts interviewed during the review were convinced of the value of a comprehensive centralised network performance monitoring facility.

4. RECOMMENDATIONS

The following recommendations are made for further work and investigation leading to possible improvements in the ETCS and GSM-R specifications:

4.1. Concerning GSM-R Quality of Service requirements, it would be beneficial if a clear distinction is made between mandatory and optional requirements. It is expected that the next EIRENE SRS draft (version 8.16) will address this need. This draft is expected to be presented to the ERA in the immediate future.

4.2. The view of some of the GSM-R experts interviewed is that the currently specified GSM-R field strength requirement is unnecessarily demanding and could possibly be reduced without significant detrimental effect to the reliability of the ETCS data transmission link. A value of -98 dBm has been suggested as a target value. This suggestion needs to be validated before any possible changes to the specifications are proposed. A first check could be carried out by identifying a section of route with this field strength and comparing the historic data quality records (bit error rate etc) with those from a comparable track section in an area with field strength at the currently specified minimum level. Further action would obviously be dependant on the outcome of this investigation.

4.3. The option of using a bit rate of 2.4 kb/s for GSM-R CS data transmission could be eliminated from the specifications as no project has preferred this rate over 4.8kbps and future GSM-R supplier support for 2.4kbps is uncertain.

4.4. Consideration should be given to the possible creation of a detailed interface specification to fully define the Igsm interface. This should include the definition of the necessary interface protocol (AT commands and sequence and applicable parameter values). This is necessary to allow interchangability of different suppliers' ETCS and GSM-R equipment. Without such an interface specification, the GSM-R Mobile Terminal and ETCS Onboard Unit would need to be procured on the basis of supplier specific assurance of compatibility with due allowance made for potential modification work. A decision on this point is principally a commercial matter, it is only worth specifying an interoperable interface if there is a clear benefit in procuring the onboard ETCS and GSM-R equipment separately.

4.5. Further study is required to establish the causes of loss of communication at locations with sudden changes in GSM-R radio field strength. In the meantime, engineers are advised to take care to design the GSM-R network in a way which avoids sudden changes of field strength received by trains.

4.6. The current off-line key management functionality is not practical for large scale commercial deployment of ETCS Level 2. New key management functionality based on on-line update principles should be developed and implemented as soon as possible.

4.7. Installation of a dedicated call performance monitoring facility has been shown to greatly assist with the identification and diagnosis of network performance problems and ensure that the network Quality of Service criteria are maintained.

4.8. It has been suggested that the use of Radio Link Protocol (RLP) in GSM-R would significantly improve the lost connection rate. It is recommended that the use of RLP be analysed in more detail for potential future inclusion in the ETCS specifications.

4.9. The requirement for a 500 ms maximum transmission delay limit in SUBSET-093 should be reviewed. For example, this limit cannot realistically be satisfied if RLP is implemented but overall operational delay could potentially be reduced through the use of RLP. It is noted that GPRS includes functionality similar to RLP and it is therefore considered unlikely that a 500ms limit could be maintained after migration to GPRS.

4.10. The ETCS specifications should be expanded to enable GPRS data transmission for future projects.

5. CONCLUSIONS

This review has not revealed any major problems affecting the ETCS to GSM-R interfaces that were not previously known. However, some lessons can be learnt from past projects that could benefit future projects, these are described in Section 4 above. Some recommendations have been made for further investigations leading to possible improvements to the ETCS and GSM-R specifications.

APPENDIX A – PROJECT INTERVIEWS

Contents

ERTMS USERS GROUP

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 09-01-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Claudine Alexandre

Subject ETCS/GSM-R Integration Review meeting with RFF, Paris, 11th of December 2007

The meeting was attended by Dominique Perrin (Réseau Ferré de France), Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Alvarez Garcia-Sanchidrian (Network Rail).

The objective of the meeting was to discuss RFF's experiences during the process of integration of the ETCS system over the GSM-R network in France.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

1. MSC-RBC interface:

a. *What issues have been encountered in implementing the I_{FIX} interface as defined in FFFIS for Euroradio?*

RFF has a single 2 Mb/s fixed MSC-RBC line, although a secondary protection line is planned to be added in the near future. A study is under way to consider the different options available:

- sharing traffic load between links or leaving one link in standby
- completely independent paths or partially shared physical layer

The MSC-RBC connection is part of RFF's backbone transport network, which is different from the transmission network that serves each BTS. This backbone transport network is an SDH network mostly owned by RFF. Some spare lines are leased to third parties in border crossings for capacity reasons. Some limited segments of the SDH network are leased from others, see response to the following question.

b. Is the I_{FIX} link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?

RFF does not consider its backbone network as an open network, even if some of the physical lines that constitute that network have been leased. These leased lines are subject to a contract with a PTO (Orange) that defines minimum QoS levels, including penalties if repairs are not completed within a given number of hours.

c. Are there any problems in complying with SUBSET-037?

So far, there haven't been problems in complying with SUBSET-037, but the current status is that only French trains run over the French ETCS system, and therefore only a 'French interpretation' of SUBSET-037 is in use over the RFF network.

However, tests in the Netherlands with French trains (by means of a simulator) prove that different interpretations of EURORADIO and EIRENE specifications can lead to serious interoperability problems. This might be the case with a very large number of parameters left to 'optional' or 'national' definition in the original specifications. Two specific examples were given:

- Differences of interpretation about how unused octets in HDLC frames are treated (by changing the number of octets in the frame header or by including padding bits in a full length frame)
- Negotiation of the data transmission rate, SUBSET-037 does not define which entity is master in the negotiation process.

A change request should be raised to the appropriate EU organization to cope with **interpretation problems** of apparently well-defined standards.

d. How is EURORADIO key management organized?

RFF uses a unique encryption key for each train-RBC connection. Each train is assigned a single key, and the train key is changed upon expiration.

e. How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?

See answer to question 1.a.

f. What were the numbering plan rules for the ports in the MSC?

RFF's numbering plan used the international format, discarding the possibility of using short codes, as defined by EURORADIO specifications. The international format coded inside the Eurobalise is as follows :

00	International prefix (2 digits)
33	Prefix for France (2 digits)
69391900X	RBC number (9 digits)
FFF	Padding (3 digits)

The 16 digits are coded in BCD with 8 bytes (2 digits per byte).

g. Is the short code LDA 1500 implemented? How is the routing for the short code implemented?

RFF has not implemented location addressing for the RBC.

h. Did your project need to take account of any particular MSC and RBC configuration considerations?

No special considerations for RFF.

2. <u>RBC-RBC interface</u>

a. How has the RBC – RBC interface been implemented?

RFF has 7 RBCs (one RBC per interlocking) connected through either open or closed networks. RBC data is not encrypted in any case.

The RBC – RBC interface is implemented through a dedicated fibre optic on which an SCI protocol is run.

b. Is the RBC – RBC link part of the GSM-R Backbone-Network?

See answer to question 2.a above.

c. Is the link implemented as part of an open network as defined in EN 50159-2?

See answer to question 2.a above.

3. <u>RBC handover issues:</u>

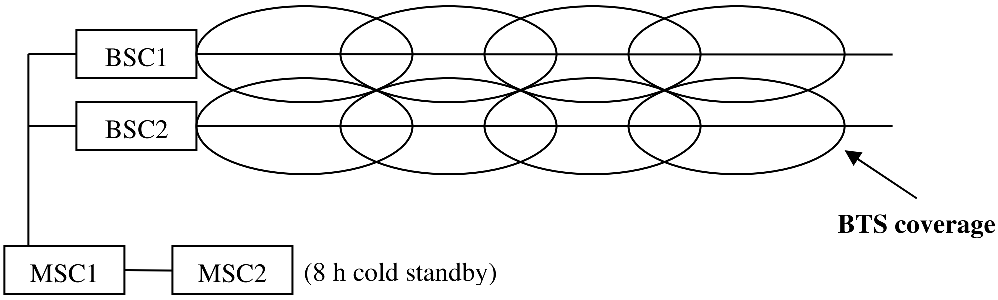
a. Did the RBC handover plan take into account the location of GSM-R handovers?

The RBC handover plan for RFF avoided all interaction between RBC handovers and BTS handover wherever possible.

b. What were the RBC handover design rules?

The rules were:

- Avoid BTS handovers.
- Just one MSC would be working at a given time: no MSC handovers in normal operations.
- The second MSC would give redundancy in cold standby – 8 hours to recover the network in case of MSC failure.
- A two-layered GSM-R coverage was designed with two BSCs but a single MSC:



c. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

See answer to question 3.a above.

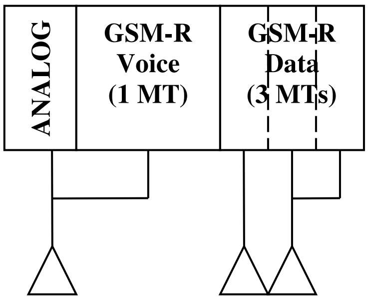
4. <u>On-board equipment:</u>

a. What issues have been encountered in implementing the I_{GSM} interface as defined by FFFIS for Euroradio?

The cab radio implemented by RFF makes use of three mobile terminals according to a **circular permutation** principle on high speed lines to provide additional redundancy:

Call 1 for RBC1 will be handled by MT1
Call 2 for RBC2 will be handled by MT2
Call 3 for RBC3 will be handled by MT3
Call 4 for RBC4 will be handled by MT1 (circular permutation)
Call 5 for RBC5 will be handled by MT2
… and so on.

RFF CAB RADIO



3 antennas

b. Which transmission rate (e.g. 2.4 kB/s, 4.8 kB/s or 9.6kB/s) is implemented?

Initially, a 9.6 Kb/s transmission rate was tested on High Speed Lines. However, a powerful and yet unidentified source of interference moved RFF to change the implementation to a 4.8 Kb/s transmission rate. Further studies might shed some light on the problem experimented at 9.6 Kb/s.

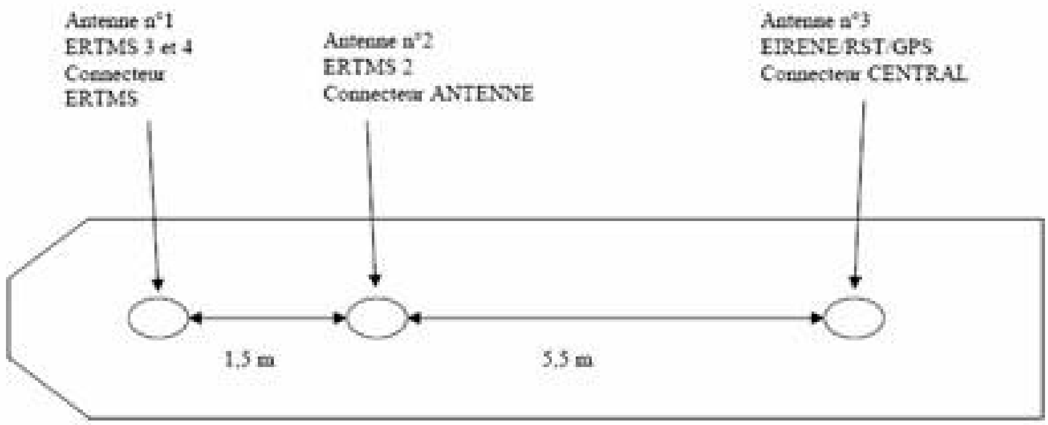
c. What constraints applied to the GSM-R antenna location?

Three antennas (see answer to question 4.a above) had to be installed on the roof of the traction unit according to specific requirements of maximum cable length due to attenuation and minimum distance between antennas. Each MT is fed with 8 W of power. In the case of a double traction unit configuration, the equipment in the second traction unit is kept in hot standby.

A fourth antenna could not be added due to a lack of space. That is the reason why two data MTs share a single antenna (see 4.a). A passive splitter-combiner is used to share the antenna with a consequent increase in insertion loss between the MT and antenna. Note that the analogue and GSM-R voice radios also share a common antenna using a splitter-combiner. A detailed schematic diagram is attached to these notes.

d. What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?

The following diagram shows the implementation for the TGV POS train in use in the LGV Est:



Principe de montage des antennes pour la configuration ERTMS en ligne

e. Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?

No measurements have been reported by RFF.

f. Was a suitable location found which avoided the need for a long antenna feed cable

Cable lengths have been detailed in the answer to question 4.d above.

g. Were any problems experienced with the vehicle power supply?

No problems with power supply have been detected for on board equipment.

h. Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?

In RFF's case, MTs are not shared between ETCS and voice GSM-R. All MTs do however share housing and power.

i. How is redundancy obtained in on board equipment?

Redundancy is obtained through circular permutation between the three MTs. A 30 minutes battery supplies power in case of power failure – the capacity of this battery will be increased to 3 hours in the future. The same battery powers GSM-R and ETCS equipment. There are no redundant cables.

j. Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?

The train number has to be entered twice: one time for the GSM-R terminal and one time for the ETCS terminals. One antenna is shared between the GSM-R MT and ETCS MT1.

5. <u>SIM card specification for ETCS:</u>

a. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

In RFF, SIM cards are issued by the same organization, but each SIM card type (ETCS and GSM-R) has a different profile. The management is piloted by RFF, but delegated on SNCF.

b. What data is stored on the ETCS SIM cards?

See document specifying SIM card profile parameters provided by Perrin.

c. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in France.

d. Which priority exists for the ETCS-Data calls/connections?

Priority 1 for ETCS data calls, priority 0 for emergency calls.

e. Did someone test the efficiency of the priority regulations? Are there existing test reports?

RFF has tested the efficiency of priority regulations, and has determined that priority might be problematic in tricky cases, like when traffic is very high and ETCS calls may block necessary dispatcher voice calls. One such example is where a queue of trains has formed due to a defect. There is a risk that the leading train might not be able to establish a connection to the RBC if the GSM-R channel capacity is fully utilised. The best solution in this case would be for the RBC to stop a data call to allow for dispatcher calls in case of data call congestion. Such action would require intervention by the signaller.

6. GSM-R QoS

a. Optimization of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

RFF has performed tests based on SUBSET-093. The only significant problem is that the RFF system is currently not really in line with the required interference values, although the network does work with that interference level at low speed. RFF will continue to test to check the limits of the system, and the possibility of the specification being too restrictive has been considered.

The goal value for interference is C/I = 16 dB.

Some problems have been experienced with a higher than expected incidence of dropped calls. These have generally occurred at locations with known high interference values. It was noted that these dropped calls have been the result of a termination request from the application (EURORADIO and ETCS) rather than failure of GSM-R to maintain the connection.

b. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

The only particular consideration taken into account by RFF when designing the GSM-R network to service ETCS was double coverage.

RFF double coverage consist in 2 BTSs in a single REB with one common mast, one common antenna, one common power supply with UPS and a 1+1 TRx configuration, using 2 different frequencies per site (one for each coverage layer).

Distance between BTSs of the same layer tends to be 4-5 Km.

The transport network is based on SHDSL over copper rings including 5 BTSs for conventional lines and SDH over fibre optic with 5 BTSs rings for High Speed Lines.

c. Where the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

RFF deems that it is still to early to give a definite answer, although it would be to be expected, since the GSM-R network was designed from the beginning with the ETCS system in mind.

d. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

The network design was correct, and the only problem detected has already been mentioned – issues with priority levels in cases of high traffic.

e. ***Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?***

The RFF GSM-R network was planned from scratch to serve the ETCS system. The major change that took place was the change in transmission rate mentioned in the answer to question 4.b due to interference. Some parameters had to be changed on the Euroradio side.

f. ***Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?***

This issue has had so far no impact over ETCS users in the RFF network.

g. ***What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)***

RFF still doesn't know whether lower coverage levels would be sufficient.

7. **<u>Network selection times for MTs – network joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.</u>**

There is no significant difference between both and all values are as expected.

8. ***RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?***

Only end-to-end ETCS RAMS is being considered by RFF, according to SUBSET-093 the GSM-R part is accounted for separately. Measurements are still underway. No major problems have been detected.

9. **<u>Network Management System</u>**

a. ***Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)***

The central management system is administered by SNCF.

b. ***Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?***

Yes.

c. ***Is the ISDN router in the RBC part of the managed network?***

There is no ISDN router in the RBC – an external V100 modem is used instead.

d. Is it possible to investigate the stored Call Data Records to solve problems?

It is indeed possible to retrieve the stored Call Data Records, but only with tools connected in order to solve a specific problem, and not as a general operational procedure.

e. Are there existing Service Level agreements? What about experiences with the compliance of the SLA?

There are SLAs with PTO leased lines and with SNCF for the management of certain aspects of the network, as well as a maintenance contract with Nortel. No major problems with compliance have appeared so far.

10. Final Remarks

P Booth concluded the meeting by asking D Perrin if she had any further comments or final remarks to make. In response, D Perrin stated that the most important points concerning ETCS/GSM-R integration were as follows:

- Resolution of gaps in the EIRENE and EURORADIO specifications which prevent true interoperability of ETCS where different suppliers are involved.
- Resolution of technical difficulties with GSM-R border crossing.
- A global end-to-end systems view should be adopted rather than considering ETCS or GSM-R sub-systems in isolation.
- The ETCS application and configurable parameters such as T_NVCONTACT should not make unreasonable demands on GSM-R. GSM-R uses radio and cannot offer the same reliability of connection as a fixed network, ETCS needs to make reasonable allowance for this rather driving requirements for over-engineered radio system.
- Closer liaison between ETCS and GSM-R specialists is required to avoid misunderstanding and ensure best use of the GSM-R resource is used to ensure full interoperability and enhance ETCS performance.

11. Summary of Key Findings

The most important findings which emerged from this meeting are summarised as follows:

- The specified carrier interference levels were not achieved. In spite of this, the system works well (with the exception of a few isolated problem areas). This evidence suggests that the limits given in SUBSET-093 may be unnecessarily demanding.
- Initial tests had show that a transmission rate of 9.6kHz at the Igsm interface is not sufficiently reliable. Satisfactory communications had been achieved at 4.8kHz.
- Interoperability problems had been experienced as a result of gaps in the EIRENE and SUBSET-037 specifications. The equipment had to be modified to resolve these problems.

- Considerable attention has been given to the creation of a redundant architecture. RFF have implemented a dual GSM BTS network to enhance system availability with a second MSC configured as a cold-standby. Three GSM-R data radios are provided to cover the failure of a single radio with no loss of performance.
- It had been necessary to use RF splitters/combiners to share radio antennas on train roof.
- The view of RFF is that values of ETCS configurable parameters such as T_NVCONTACT should be chosen taking account of occasional temporary reductions in the specified GSM-R QOS levels.

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 20-02-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Robert Dijkman

Subject ETCS/GSM-R Integration Review meeting with ADIF, Madrid, 28th and 29th of January 2008

The meeting on the 28th was attended by Ángel Arranz de Santiago (ADIF), Begoña Domingo Ortuño (ADIF), Silvia Domínguez Fernández (Tifsa), Javier Vicente Fajardo (ADIF), Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Álvarez García-Sanchidrián (Network Rail).

The meeting on the 29th was attended by Francisco Javier Grande Gómez (ADIF), José Alberto González Parrilla (ADIF), José Ignacio Polo Fernández (ADIF), Silvia Domínguez Fernández (Tifsa), Javier Vicente Fajardo (ADIF), Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Álvarez García-Sanchidrián (Network Rail).

The objective of the meeting was to discuss ADIF's experiences during the process of integration of the ETCS system over the GSM-R network in Spain.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

1. MSC-RBC interface:

i. What issues have been encountered in implementing the I_{FIX} interface as defined in FFFIS for Euroradio?

The I_{FIX} interface is provided by the GSM-R MSC (supplied by Siemens). No adaptation has been required because the MSC already provided the E1 interface (2048 Kb/s) and all the required bearer services.

a. Is the I_{FIX} link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?

ADIF's SDH network can not be defined as open, although it is shared with several other railway applications, and is not solely dedicated to ERTMS. However, ERTMS uses dedicated circuits within that network. No part of the SDH fixed telecommunications network used by ADIF is leased from a third party; the complete network is owned and operated by ADIF, although some maintenance procedures are subcontracted to Alcatel and Siemens.

b. Are there any problems in complying with SUBSET-037?

So far, there haven't been problems in complying with SUBSET-037, but the current status is that only Spanish trains run over the Spanish ETCS system, and therefore only a 'Spanish vendor's interpretation' of SUBSET-037 is in use over the ADIF network.

c. How is EURORADIO key management organized?

A Key Management Centre software application is being presented by every different ETCS contractor as part of their complete ETCS Level 2 package (Ansaldo, Thales and Dimetronic); one of them will be selected as the final KMC application, but the decision hasn't been done yet, since no ETCS Level 2 lines are in service yet. Currently, only the Ansaldo KMC is available in ADIF's premises.

The current KMC is installed in two different PCs connected through a direct crossover link. In the final configuration, both platforms will be placed in different locations, and one of them (KMC2) will act as a redundancy for the other one (KMC1) in hot standby. The KMC application runs under the Windows XP operating system. Databases on both platforms are simultaneously updated by a daemon, and a daily backup takes place overnight. A crossover backup between the platforms takes place whenever one of the two PCs is powered down and restarted.

The KMC software allocates two sets of keys to each RBC-EVC connection and to each component having an ETCS ID: a transport key (KTRANS) and a MAC key (KMAC). KTRANS is used to safely distribute KMAC from the KMC to the RBC or EVC that will hold the key. KTRANS also provides hash-based authentication, validation and integrity safeguards to key distribution.

Key distribution procedures have not been specified yet and, because the keys themselves are visible in unencrypted format in the application and in the files that are used for key distribution, there might be security issues in the key distribution process. Keys are distributed in the form of a small file which can be written to any standard PC removable media such as USB mass storage device, CD-ROM etc. It is anticipated that copies of these files will need to be held at each location where ETCS hardware is maintained, e.g. vehicle depots and RBC equipment rooms. A process will need to be introduced to ensure that the keys held at these various locations are maintained in an up to date state and that access to them is controlled.

Arrangements will need to be made to ensure the secure delivery of the key media and secure storage at each of the maintenance facilities.

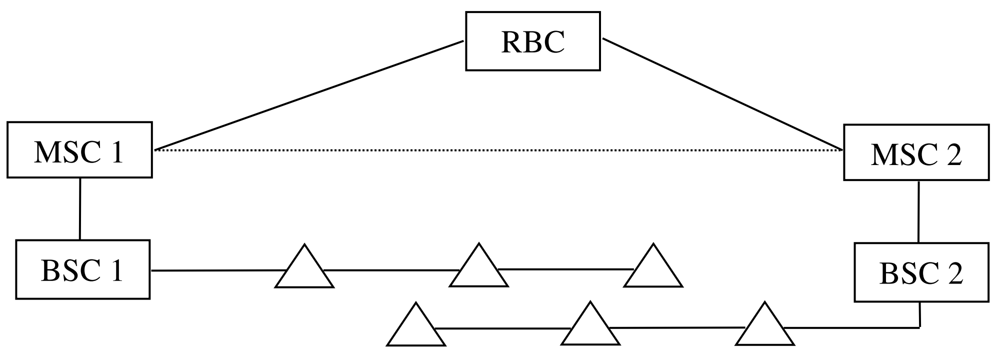
The ETCS key management process requires that the EVC and RBC are updated simultaneously when new keys are introduced into the system.

Another issue might appear in the room for human error, since the operator has to type down a text identifier for each key, instead of it being generated by the application.

A third issue might arise when keys have to be changed in the EVC, which requires that the train be stationed in a depot. In order to avoid this, the keys' validity time might be increased or an online connection might be established. ADIF currently proposes that keys are not subject to regular periodic update. The procedure to change keys is not clearly defined yet, and seems to be dependent on the specific provider. Update of keys in the RBC requires each of the three redundant processing channels to be taken off-line in turn (total of 6 cards).

d. How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?

The physical interface between the MSC and the RBC is a primary E1 link with EDSS1 protocol. This E1 link is mapped into the SDH network. No redundancy link has been established, since each RBC is connected to each one of the two redundant MSCs that compose the double independent layer architecture of the ADIF GSM-R network.



ERTMS will also be installed in some conventional lines, like in the metropolitan lines of the Madrid region. Several projects are under way.

e. What were the numbering plan rules for the ports in the MSC?

There are no numbering plan rules.

f. Is the short code LDA 1500 implemented? How is the routing for the short code implemented?

LDA 1500 has not been implemented so far. ERTMS balises tell the EVC to which new RBC it must connect at each time.

g. Did your project need to take account of any particular MSC and RBC configuration considerations?

No special considerations for ADIF, besides the double layer architecture mentioned above. The GSM-R network was explicitly designed to support ETCS Level 2 in terms of coverage levels and QoS.

2. RBC-RBC interface

d. How has the RBC-RBC interface been implemented?

Each RBC is connected to a maximum of two (2) collateral RBCs through an RS232 interface. The physical link between RBCs is implemented by serial modems connected to the SDH network. Besides, each RBC also has two E1 links to access the ISDN network. Ansaldo and Thales RBCs are linked according to the protocol defined in SUBSET-098.

e. Is the RBC-RBC link part of the GSM-R Backbone-Network?

See answer to question 2.a above.

f. Is the link implemented as part of an open network as defined in EN 50159-2?

It is not, because ADIF's SDH fixed telecommunications network is not an open network as defined by EN 50150-2. See answer to question 2.a above.

3. RBC handover issues:

d. Did the RBC handover plan take into account the location of GSM-R handovers?

The RBC handover plan for ADIF avoided all interaction between RBC handovers and BTS handover wherever possible.

e. What were the RBC handover design rules?

RBC handover design followed Subset 039, as well as proprietary information provided by the supplier. BTS handovers were avoided in all cases, as mentioned above.

f. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

See answer to question 3.a above.

4. On-board equipment:

k. What issues have been encountered in implementing the I_{GSM} interface as defined by FFFIS for Euroradio?

The modems (manufactured by Sagem and Kapsch) installed between the EVC and the GSM-R antenna caused problems. A strong dependency on modem behaviour was detected. The Sagem Mobile Terminal was especially problematic. These problems were solved by changing modem software through successive software updates.

l. Which transmission rate (e.g. 2.4 Kb/s, 4.8K b/s or 9.6Kb/s) is implemented?

Initially, a 9.6 Kb/s transmission rate was tested on High Speed Lines. Quality of service at that transmission rate, however, was very poor, and the current transmission rate is 4.8 Kb/s.

m. What constraints applied to the GSM-R antenna location?

Antenna cable length proved to be an important source of losses, so antenna location had to be chosen carefully to minimise cable length. Each mobile terminal is connected to an independent antenna, resulting in three (3) antennas per traction unit – two antennas for data and one for GSM-R voice.

n. What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?

TBC

o. Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?

TBC

p. Was a suitable location found which avoided the need for a long antenna feed cable

TBC

q. Were any problems experienced with the vehicle power supply?

No particular problems were identified, although DC voltage might change from train set to train set.

r. Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?

In ADIF's case, MTs are not shared between ETCS and voice GSM-R. Data MTs do however share housing and power, but the GSM-R voice MT is located in a different housing in most cases.

s. How is redundancy obtained in on board equipment?

Two MT are fitted for each EVC. The EVC can function using just one MT.

t. Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?

In every ADIF implementation, ETCS and GSM-R voice equipment are totally independent.

5. <u>SIM card specification for ETCS:</u>

f. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

In ADIF, SIM cards are issued by the same organization, but each SIM card type (ETCS and GSM-R) has a different profile.

g. What data is stored on the ETCS SIM cards?

ETCS SIM cards' profile is such that only data calls are allowed, and no other services (e.g. SMS) are available. Because no MTs are shared between ETCS and voice, it is possible to create different profiles without any inter-function problem.

h. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in Spain.

i. Which priority exists for the ETCS-Data calls/connections?

Priority 1 for ETCS data calls, priority 0 for emergency calls.

j. Did someone test the efficiency of the priority regulations? Are there existing test reports?

Pre-emption has been tests by ADIF, but not in real operational conditions.

6. <u>GSM-R QoS</u>

h. Optimisation of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any

capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

It was difficult to apply TI measurements as they are defined in specification O-2475, and it was much more difficult to do so at a transmission rate of 9.6 Kb/s than at 4.8 Kb/s. However, ETCS data transmission has been successfully tested at 4.8 Kb/s. A new definition of TI would be necessary to be adequate to the ETCS layer.

An important effect was identified during QoS optimisation. When coverage levels drop rapidly, even if the lower coverage level is well above -92 dBm, the MT often lost data packets. Data loss was limited to a glitch, and the problem was eventually traced to the mobile terminal, since the BTS didn't register any packet loss.

The consequence of these data losses is merely a retransmission of ETCS data, so there are no catastrophic events. However, it does lower the QoS values registered, since 20 seconds of continuous communication are necessary for a valid data packet to arrive. According to ADIF, this strengthens the idea that the QoS specifications are too demanding in should be modified.

The solution adopted to mitigate this problem was to keep BTSs and repeaters apart a maximum distance of 1800 m, instead of the theoretical maximum distance of 1900 m, to avoid having the equipment working at maximum theoretical dispersion levels.

Connection Loss Rate (CLR) is validated, according to the specification, if no connection loss occurs within 300 hours. However, the specification does not clarify whether these 300 hours apply to the whole network, to a single line or to a 100 Km section. A new definition in terms of time/Km would be in order.

There might be capacity issues in the future, as new lines are put into service, especially for major railway stations and suburban lines. More capacity would be required depending on the number of simultaneous ETCS connections.

i. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

After some protests from local residents about the location of some BTSs, BTS location has been selected in order to maximise distance to inhabited areas wherever possible.

j. Were the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

At the moment, there is no commercial ERTMS Level 2 traffic. Therefore, no data communications are being sent through the GSM-R network.

k. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

Network capacity has been sufficient so far; all 19 frequencies are being used, and negotiations with the UIC to request further frequencies are under way. C/I levels and set up times have presented no problems in Spain. All dropped calls have been adequately detected by tracing all the interfaces.

ADIF has plans to upgrade its GSM-R network to provide GPRS service to non-ERTMS clients. The necessary software and hardware upgrades are being schemed out.

l. Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?

The ADIF GSM-R network was planned from scratch to serve the ETCS system. The major change that took place was the change in transmission rate mentioned in the answer to question 4.b due to interference. No further parameters have had to be changed so far. The value selected for T_NVCONTACT in Spain is 20 seconds. However, it has been seen in the test runs that this value is too small for the delays introduced by the equipment and the network. After thorough studies of the time required to re-establish the Euroradio secure layer after a drop, ADIF intends to increase this timer to a value closer to 30 seconds. There are currently safety studies to determine what distance would be considered as the maximum one to be run without track information at the commercial speed.

m. Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?

During ETCS Level 2 testing, ADIF has detected some problems, causing the Euroradio protocol T_NVCONTACT timer (20s) to expire in some cases.

It has been proved that slightly higher than usual handover times contribute to T_NVCONTACT expiration. Neighbour cell listings and power adjustments have also been reviewed to avoid ping-pong effects between the two GSM-R network layers, as well as successive handovers between neighbour cells

n. What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)

In Spain, ADIF defined signal level requirements to be higher than -85 dBm in outdoor zones, and -70 dBm inside tunnels. These values have caused no problems, but lower values have not been tested yet.

7. Network selection times for MTs – network joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.

Network Registration Delay measurements have been taken according to specification O-2475, both in movement and on a stationary vehicle. There has been no significant difference between both and all values are as expected.

8. RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?

Very high reliability figures have been obtained (> 99.98%) due to the redundant design of the Spanish GSM-R network.

9. Network Management System

f. Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)

The central management system is administered by ADIF. The OMC/NMC equipment is located in the same building as most of the core GSM-R NSS.

g. Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?

Yes. All MSC ports are alarmed.

h. Is the ISDN router in the RBC part of the managed network?

No. The ISDN router does not report alarms to the OMC systems.

i. Is it possible to investigate the stored Call Data Records to solve problems?

Call Data Records can be inspected. These records keep track of the signalling details of the calls.. There is no data call registering or tracing available to study the content of the communication. The RBC has a debug level that can be switched on during punctual studies, but it is not tracing during regular operation

j. Are there existing Service Level agreements? What about experiences with the compliance of the SLA?

There are SLAs with Siemens for GSM-R maintenance as well as with the Joint Venture of contractors that provides the ETCS systems. SLA compliance is adequate so far. No SLA is in place at the moment for the ERTMS Level 2 system, since it is not in commercial use yet.

10. Final Remarks

None.

11. Summary of Key Findings

- QoS requirements cannot all be realistically achieved in practice and the relevant specifications should be reviewed. ETCS reliability does not appear to be adversely affected even when the specified QoS requirements are not fully met.
- Satisfactory levels of GSM-R field strength do not necessarily guarantee lossless data transmission. Significant bit error rates were detected at certain locations, even though carrier field strength was found to be well above the EIRENE specified minimum. This problem has been traced to locations where the field strength drops quickly from a high level to a lower (but still compliant) level due to train movement.
- The GSM-R network reliability has been excellent, a product of the highly redundant architecture.
- The KMC system supplied according to the current specifications has proved difficult to use from an operational point of view (need for simultaneous update of EVC and RBC, synchronisation of multiple locally held key management repositories at depots) and provides weak security (keys are distributed on removable media with no encryption mechanism).
- Problems have been experienced with system integration at the Igsm interface and with the stability of the MT firmware.

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 14-03-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Robert Dijkman

Subject ETCS/GSM-R Integration Review meeting with ProRail, Utrecht, 4th of March 2008

The attendants to the meeting were Chiel Spaans (ProRail), Hans Vanzandvoort (ProRail), Jos Nooijen (ProRail) for ProRail with Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Álvarez García-Sanchidrián (Network Rail) representing the ERTMS Users Group.

The objective of the meeting was to discuss ProRail's experiences during the process of integration of the ETCS system over the GSM-R network in the Netherlands in accordance with an ERTMS Users Group remit.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

Mr Spaans gave a brief overview of the Dutch ETCS projects and summarised the experience they had had with the ETCS to GSM-R interface on the three ETCS lines HSL-Z (Schiphol-Belgium), Betuweroute (Rotterdam –Germany) and Amsterdam-Utrecht (extension of the existing line). The GSM-R network is operational with day-to-day responsibility for operation and maintenance subcontracted to MobiRail. ProRail had not been involved in system integration testing of ETCS on the HSL South project; this project had been contracted to the Infraspeed consortium and directly managed by the Dutch ministry of transport. Tests have been carried out with a Siemens Taurus train and a refurbished Thalys train set at low and high speed but the ProRail GSM-R team has had no access to the test results. The other major ETCS project, the Betuwe freight line, has been managed as an infrastructure project within the context of Prorail. ProRail has little experience of integration with the on train equipment except for the test running undertaken using an Alstom equipped test train. Most of the practical experience regarding train-equipment gained by ProRail was acquired during the two ETCS pilot lines (Maastricht-Heerlen and Leeuwarden - Meppel).

1. MSC-RBC interface:

a. *What issues have been encountered in implementing the I_{FIX} interface as defined in FFFIS for Euroradio?*

ProRail did not experience major problems in the application of the FFFIS for the I_{FIX} interface. The physical interface (connector) had to be negotiated, since it had not been specified in the FFFIS for Euroradio.

A minor problem arose because the PTO providing the leased line used for the I_{FIX} interface was using the CRC4 field for its own purposes – therefore, the physical link between RBC and MSC could not be established. This possibility is not contemplated in SUBSET-052. The problem was solved by generating locally a new CRC4 field at the modem at the RBC premises, and the problem was discussed through John Hammer. Since the EURORADIO specification was finalised a CR was not raised. This problem was not experienced in lines owned by ProRail, as opposed to leased lines.

b. *Is the I_{FIX} link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?*

In the case of the Amsterdam-Brussels High Speed Line, some MSC-RBC interfaces are implemented over circuits leased to a PTO (KPM). The Betuwe freight line, however, is serviced only by ProRail owned circuits.

No encryption or scrambling is done over either line at the transmission level – encryption is considered part of the Euroradio application.

c. *Are there any problems in complying with SUBSET-037?*

ProRail has not experienced any problems in complying with SUBSET-037. However, ProRail's experience is limited to the GSM-R network, and no information is available on this point from the ETCS side, as this has been managed by Infraspeed.

d. *How is EURORADIO key management organized?*

ProRail's Key Management Centre is implemented through an Alstom product developed for the Swiss railways.

A PCMCIA-type memory card contains all the configuration data for every one of the 3 channels of each RBC, and every update, including encryption keys updates. On ProRail request Alstom will produce new cards (9) which will be placed in the RBC's by maintenance personnel. This process requires the RBCs to be out of service for approximately 10 minutes while the new card is being installed.

The keys are provided to the Train Operators by the Key Management Centre. A Train Operator can request keys to the Key Management Centre through an E-mail form and appoint a Key Manager on their side to receive the keys. The key will then be sent through e-mail encrypted by a previously agreed transport key.

There is one key for each train, but just one, since Alstom's implementation does not allow the on board equipment to choose a key from a given list. ProRail's opinion is that the Key Management System provided for the Betuwe Line is not suitable for implementation on a wide scale due to the logistic difficulties associated with key distribution and update and the need to update all affected Onboards and RBCs (including those in neighbouring countries) in a single event.

e. *How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?*

The physical interface between the MSC and the RBC is a primary E1 link with G.703/G.704 interface to which ISDN30 is connected. This E1 link is mapped either into a ProRail owned ATM network or, in the case of the Amsterdam-Brussels HSL, into a PTO owned network, that can be either SDH or IP based.

Redundancy in the GSM-R network is provided by fully redundant NSS (MSC, IN, etc.) components that are located in a protected KPM centre. All equipment is found in a single location, however.

The BSCs are also redundant and located in the protected KPM centre.

BTSs have double coverage (not double layer) on the Amsterdam – Brussels HSL, but present no redundancy whatsoever on the Betuwe freight route.

f. *What were the numbering plan rules for the ports in the MSC?*

At Betuweroute, the MSC presents 4 E1 links being used in a sequential order, so that the first call received uses the first E1 link, the second call uses the second E1 link, and so on until the fifth call, which uses the first E1 link again. Traffic is therefore balanced amongst all the available E1 links.

g. *Is the short code LDA 1500 implemented? How is the routing for the short code implemented?*

LDA 1500 has not been implemented. No short codes are used for ETCS, and therefore a change of number would require updating the information in every balise containing this info (about 35 BG's on Betuweroute).

h. *Did your project need to take account of any particular MSC and RBC configuration considerations?*

No special considerations were taken besides the traffic balancing scheme mentioned in 1.f.

2. <u>RBC-RBC interface</u>

a. How has the RBC-RBC interface been implemented?

For HSL Zuid the Belgium part (RBC made by Alstom) is connected to the Dutch part (RBC made by Thales). Alstom designed a specific RBC-RBC gateway that is now being upgraded to a completely interoperable European interface.

For Betuweroute an interface in conformance with the SRS is used.

The three Alstom RBCs of the Betuwe route are located in the same room, so the connection between them is implemented merely through an Ethernet switch. There are still no connections to other RBCs.

b. Is the RBC-RBC link part of the GSM-R Backbone-Network?

See answer to question 2.a above. Since the link is implemented through a single Ethernet switch physically located in the same room as the RBCs, it is a closed network, but it does not belong to any backbone network For HSL Zuid a separate link is used, not par of the GSM-R backbone network.

c. Is the link implemented as part of an open network as defined in EN 50159-2?

See answer to question 2.b above.

3. <u>RBC handover issues:</u>

a. Did the RBC handover plan take into account the location of GSM-R handovers?

The RBC handover plan did not take into account the location of GSM-R handovers.

b. What were the RBC handover design rules?

RBC handovers were placed to avoid transitions between ETCS Level 2 and STM areas, as well as significant track locations, such as points or ground frames.

The current design in the Betuwe route presents a single Smartlock 300 interlocking servicing the three RBCs; the number of RBCs needed was determined by the inherent limitations of Alstom RBCs, such as the maximum number of trains served and the maximum number of gradient profiles.

c. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

No measure was necessary; no particular problems were detected.

4. <u>On-board equipment:</u>

As noted in the introduction, most of ProRail's experience of integration with the ETCS onboard equipment was gained during the two pilot line projects. During tests on the Betuweroute no principal/structural problems were reported.

a. What issues have been encountered in implementing the I_{GSM} interface as defined by FFFIS for Euroradio?

Since the I_{GSM} interface was often not included in ETCS specifications, being outside the area of interest of most of the signalling-oriented engineers that handled ETCS requirement definition, there were frequent problems with details like connector pin assignment and use of the AT command set. The result is that the behaviour of the EVC/GSM-R interface largely depends on the supplier.

b. Which transmission rate (e.g. 2.4 Kb/s, 4.8K b/s or 9.6Kb/s) is implemented?

Tests were carried out at 9.6 Kb/s, but Alstom has currently standardised the transmission rate to 4.8 Kb/s. Sufficient to say both speeds are supported and can be used.

c. What constraints applied to the GSM-R antenna location?

Following a Siemens report based in a study carried out during the West Coast Main Line project in GB, the installation procedures maintained a minimum distance of 2.5 m between two GSM-R antennas, and a minimum distance of 1.5 m between a GSM-R antenna and an analogue antenna.

No problems related to antenna position have been reported so far.

d. What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?

See answer to question 3.c above.

e. Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?

See answer to question 3.c above.

f. Was a suitable location found which avoided the need for a long antenna feed cable

A suitable location was found.

g. Were any problems experienced with the vehicle power supply?

Problems with power supply have been a common occurrence, to the point that diesel generators were sometimes used during the tests to keep on board equipment separate from overhead line power.

Some older trains had already been fitted with adequate power supplies when analogue radios were installed in them.

h. Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?

No MTs are shared. However, MTs do share housing and power supply.

i. How is redundancy obtained in on board equipment?

ProRail has not, to date, been responsible for procurement of onboard ETCS equipment, except for the rail cars used for the pilot projects.

j. Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?

Train number transfer is used in Bombardier-supplied trainborne equipment on TRAXX loco's. No antennas are shared between ETCS and voice radio GSM-R.

5. <u>SIM card specification for ETCS:</u>

a. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

ProRail issues SIM cards for all users and manages card profiles and configuration. Therefore, a single management of SIM cards has been implemented. Card configuration follows FFFIS guidelines.

b. What data is stored on the ETCS SIM cards?

There are approx. 25 different SIM card profiles available, including for ETCS on board equipment, GSM-R voice cab radio equipment and handheld mobile phones for trackside workers.

c. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in the Netherlands.

d. Which priority exists for the ETCS-Data calls/connections?

Priority 1 for ETCS data calls, priority 0 for emergency calls. Following FFFIS guidelines.

e. Did someone test the efficiency of the priority regulations? Are there existing test reports?

The priority based pre-emption mechanism has been tested, but the high number of available channels and the relatively low number of users has not forced pre-emption in real operational conditions yet.

6. <u>GSM-R QoS</u>

a. Optimisation of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

ProRail's opinion about SUBSET-093 is that, although some parameters seem to be adequately chosen, others are not; e.g., transmission interference parameters are, in ProRail's experience, unbalanced. It is possible for a GSM-R network to be non-compliant with those parameters and to become compliant with very little improvement. A different approach to the calculation of transmission interference is needed in the opinion of ProRail.

At the same time, ProRail has experienced that very good application performance can take place over theoretically non-compliant networks. For example, the carrier to interference ratio appears to be critical to reliable data transmission, much more so than the carrier field strength.

It has also been detected during drive tests show an overall message loss of under 1% of cases, leaving the application level largely unaffected.

ProRail's network currently has no capacity problems, and dropped calls are a very rare occurrence.

b. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

Cell handover locations were planned to keep a train within the same cell for adequate amounts of time for certain tasks, e.g. registration, and to avoid unnecessary cell handovers. This required several iterations of parameter refinement, evaluation of neighbour cell lists, etc…

c. Where the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

ProRail's planning for the GSM-R network on HSL and Betuweroute took the requirements for ETCS into account from the very beginning. Although the coverage on all other national lines meets the ETCS requirements, the national GSM-R network is not designed to handle ETCS in future without any change. The changes will be related to availability (redundancy), capacity and QoS/Transmission Interference. Maybe GPRS can be used then.

d. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

The capacity on HSL and Betuweline was designed to handle 133 simultaneous ETCS calls on each line. The capacity on the Amsterdam–Utrecht line initially planned was not sufficient, and more carriers had to be added.

C/I levels have always represented a problem because carrier frequencies have had to be reused with relatively close geographic separation. This has resulted in some message loss. However, the number of dropped calls has been very low.

e. Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?

The modifications needed were limited to the addition of carriers to increase capacity and the normal optimization procedures (antenna tilt and azimuth adjustment, BTS power adjustment, etc.) needed in any GSM-R network during the testing and commissioning phase.

f. Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?

Cell handovers do not pose too many problems in the Netherlands, as long as the mobile terminal remains registered within the same cell for a certain period, and a constant handover process between cells in an uncontrolled fashion is avoided. Handover times tend to be less than 300 ms.

Neighbour cell lists have been carefully selected to avoid an excessive number of cell handovers.

g. What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)

The ProRail GSM-R network has been planned to provide coverage of -90 dBm over 95% (time, area) of the network, and therefore presents coverage levels higher than those specified by EIRENE. There is no information about whether the system would work reasonably with lower levels of coverage.

In ProRail's experience, C/I has proved a more critical parameter than signal level.

7. Network selection times for MTs – network-joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.

ProRail's GSM-R network is a countrywide network, and therefore presents no occurrences where a train might join the network during movement.

8. ***RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?***

ProRail's GSM-R network does not have specific RAMS requirements. Service Level Agreements with MobiRail, which is the maintainer of the GSM-R network, have been set in place of RAMS requirements and contains a.o. requirements for availability, error recovery time, reporting etc. for each functionality provided by the network. Addittionally the ETCS projects had specific requirements for the availability.

9. **<u>Network Management System</u>**

a. ***Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)***

MobiRail maintains ProRail's GSM-R network from its own management centre. Within three months, ProRail will have access to a software tool connected to centralised records; this will allow for an investigation of the behaviour of the network and the terminal equipment on call basis.

Additionally, the Kapsch K15 tester is used to measure network condition.
Any problems detected are reported to the Train Operators.

b. ***Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?***

Yes. All MSC ports are alarmed.

c. ***Is the ISDN router in the RBC part of the managed network?***

The ISDN router is supplied and managed by the ETCS layer supplier (Infraspeed resp. Alstom).

d. ***Is it possible to investigate the stored Call Data Records to solve problems?***

Call Data Records can be inspected, but only manually, and only related to the MSISDN. This is a lengthy process, because ETCS numbers are independent of train numbers and not always a MSISDN is know by the train driver/owner.

e. ***Are there existing Service Level agreements? What about experiences with the compliance of the SLA?***

ProRail's GSM-R network is maintained by MobiRail through a Service Level Agreement. SLA for the ETCS layer is covered by the supplier (Infraspeed).

The SLA covers a countrywide network of 350 BTSs, 1 MSC, 8 BSCs and 620 radio cells. Availability is contracted on the basis of different functionalities (voice recording, functional numbering, etc.).

The SLA demands the following requirements:

- Voice availability: 99.8% (national network).
- ETCS bearer availability: 99.95% (Betuwe route)
- Functional recovery within 4 hrs (95% of the cases)

The performance of the GSM-R network is reported to Infraspeed on a monthly basis. 30 to 35 complaints about the voice network are registered every month, but only a 1% of the cases are related to problems in the network; the rest are linked to user errors. So far, 100 technical failures have been detected, but only 10% of them with any impact on network performance.

The reports from MobiRail show a 99.991% availability for the GSM-R network and a 99.92% availability for the ETCS layer on the Betuwe route. These figures exclude dispatcher terminals, planned works and failures due to external factors.

10. Final Remarks

None.

11. Summary of Key Findings

The main points which emerged from the discussion are summarised below:

- There was one minor problem with the Ifix interface (RBC-MSC) which was reported but has not resulted in a European change request.
- ProRail's opinion is that the EURORADIO Key Managment System provided for the Betuwe Line is not suitable for implementation on a wide scale due to the logistic difficulties associated with key distribution and update and the need to update all affected Onboards and RBCs (including those in neighbouring countries) in a single event.
- ProRail has had limited direct responsibility for Onboard ETCS equipment. However, a number of problems were encountered in the implementation of the Igsm interface on the pilot trains. These problems were related to gaps in the Euroradio specification and use of the AT command set.
- Experience has shown that compliance with all of the SUBSET-093 Quality of Service requirements is not always necessarily a prerequisite to reliable end to end communication.

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 04-04-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Robert Dijkman

Subject: ETCS/GSM-R Integration Review meeting with SBB, Bern, 1st of April 2008

The attendants to the meeting were Jan Richard and René Fankhauser for SBB with Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Álvarez García-Sanchidrián (Network Rail) representing the ERTMS Users Group.

The objective of the meeting was to discuss SBB's experiences during the process of integration of the ETCS system over the GSM-R network in Switzerland in accordance with an ERTMS Users Group remit.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

Mr Richard and Mr Fankhauser gave a brief overview of the Swiss ETCS projects and summarised the experience they had had with the ETCS to GSM-R interface on the two ETCS lines Mattstetten–Rothrist (Bern–Olten HSL section) and Frutigen–Visp (including the Lötschberg tunnel). Each line has a single RBC and, because the lines are not interconnected, no RBC-RBC transition is necessary.

1. MSC-RBC interface:

a. *What issues have been encountered in implementing the I_{FIX} interface as defined in FFFIS for Euroradio?*

SBB did not experience special problems in the implementation of the I_{FIX} interface. The interface is implemented through a 2 Mb/s redundant point-to-point link with no encryption protocol. Retransmission is handled by the application layer, and not at the physical layer.

b. Is the I_{FIX} link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?

SBB uses a closed SDH network for the I_{FIX} interface, with all elements (fibre and equipment) owned by SBB. No connexion to PTO is provided, and the network has different routing rules that make such a connexion very difficult. Because of the isolation provided by the configuration of the network, no encryption was deemed necessary.

c. Are there any problems in complying with SUBSET-037?

The only major problem experienced during the implementation of SUBSET-037 was that some disconnection requests from the locomotive upon leaving ETCS Level 2 track were ignored, and the disconnection would take place by time-out rather than by a proper disconnection process. The time-out occurred at the HDLC layer within the EuroRadio functionality on the on board equipment. Apparently, this problem has now been solved.

d. How is EURORADIO key management organized?

SBB developed a specific Key Management Centre (KMC) software application for the management of ETCS keys; this application is now commercially available to other administrations (point of contact: Stefan Bauer).

SBB defines a single KMAC key per locomotive (OBU). This KMAC key is used to connect to both RBCs.

Once generated by the KMC software, keys are distributed through a physical memory medium like a CD or a USB memory stick.

e. How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?

In SBB's lines, the physical interface between the MSC and the RBC is a primary E1 link. No specific issues were encountered.

f. What were the numbering plan rules for the ports in the MSC?

A conventional national numbering plan has been developed for the ports in the MSC. The numbers primarily used on the Mattstetten–Rothrist line will be replaced by an international standard (prefix: 0041).

g. Is the short code LDA 1500 implemented? How is the routing for the short code implemented?

LDA 1500 has not been implemented. No short codes are used for ETCS.

h. Did your project need to take account of any particular MSC and RBC configuration considerations?

The connection between RBC and MSC is redundant: two different physical paths have been provided in each case. Some diverse cables are routed through a common duct at building entry points. SBB's view is that this practice should be avoided to minimise risk of common-mode failures due to rodent activity.

2. <u>RBC-RBC interface</u>

a. How has the RBC-RBC interface been implemented?

The two RBCs currently in use in SBB's network cover two physically separated railway lines. Therefore, no RBC-RBC transition is made, and no RBC-RBC interface has been needed so far.

b. Is the RBC-RBC link part of the GSM-R Backbone-Network?

See answer to question 2.a above.

c. Is the link implemented as part of an open network as defined in EN 50159-2?

See answer to question 2.a above.

3. <u>RBC handover issues:</u>

a. Did the RBC handover plan take into account the location of GSM-R handovers?

The RBCs cover isolated track sections, and no RBC-RBC handovers take place. Therefore, the location of GSM-R handovers did not take RBC-RBC handovers into account.

b. What were the RBC handover design rules?

See answer to question 3.a above.

c. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

See answer to question 3.a above.

4. <u>On-board equipment:</u>

a. What issues have been encountered in implementing the I_{GSM} interface as defined by FFIS for Euroradio?

SBB reports no special issues in the implementation of the I_{GSM} interface. A variety of suppliers' equipment has been used; Sagem (with Alstom ETCS) and Kapsch (old version with Siemens, new version with Bombardier).

b. ***Which transmission rate (e.g. 2.4 Kb/s, 4.8K b/s or 9.6Kb/s) is implemented?***

The transmission rate currently in use onboard SBB trains is 4.8 Kb/s. The 9.6 Kb/s data rate has not been tested on the track; only in laboratory conditions.

c. ***What constraints applied to the GSM-R antenna location?***

Besides the minimum distance rules mentioned in 4.d below, the installation of antennas in 10 different types of locomotives showed very few general characteristics. The installation solutions were highly dependant on the configuration of the locomotive; installation was therefore a case-by-case affair.

The only common element mentioned by SBB is that a metallic ground frame had sometimes to be placed between the antenna and the rest of the train whenever the train roof was not metallic to avoid EMC problems.

d. ***What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?***

The installation followed rules for minimum distance extracted from the Siemens report based in a study carried out during the West Coast Main Line project in GB (minimum distance of 2.5 m between two GSM-R antennas, and a minimum distance of 1.5 m between a GSM-R antenna and an analogue antenna).

e. ***Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?***

During installation, measurements of cable and connector losses and reflection factors were performed once a location for the antennas had been selected. In some cases, these measurements showed the need to move the antennas to a different location. However, no specific measurements of antenna influence seem to have been performed.

f. ***Was a suitable location which avoided the need for a long antenna feed cable found?***

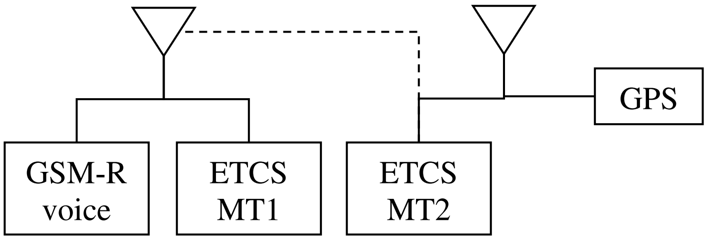
A different compromise between cable losses due to cable length and other factors affecting antenna location had to be reached for each one of the ten different types of locomotive fitted by SBB. Again, the solutions were based on case-by-case studies.

g. ***Were any problems experienced with the vehicle power supply?***

Power supply and battery voltage were a problem in two or three types of locomotive, but not in the rest. Both electric and diesel locomotives have been fitted by SBB.

h. ***Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?***

No MTs are shared. Two different MTs are used for ETCS data transmission, one being the replacement of the other in hot-standby (there is no need to have two connections for RBC-RBC handovers, because no RBC-RBC handovers currently take place in SBB's network). Two antennas are used, with each antenna shared between one of the ETCS MTs and either the GSM-R voice MT or a GPS receiver (this antenna being a dual band GSM-R/GPS antenna).



i. How is redundancy obtained in on board equipment?

Redundancy is obtained by means of the two MTs used for ETCS data transmission. Additionally, the cab radio display can work as a fallback DMI in case of DMI malfunction.

j. Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?

Train number transfer takes place from the ETCS MT to the GSM-R voice MT, but not the other way around for safety reasons. The train number on the cab radio can be changed independently in the Alstom equipment, but not in the Siemens cab radio.

5. <u>SIM card specification for ETCS:</u>

a. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

SBB issues SIM cards for all users and manages card profiles and configuration. Two different profiles are used: one for GSM-R voice terminals, and one for ETCS data terminals.

b. What data is stored on the ETCS SIM cards?

Data stored in SIM cards follow FFFI specifications. The ETCS profile includes roaming information for three networks: SBB (Switzerland), DB (Germany) and RFI (Italy).

c. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in Switzerland.

d. Which priority exists for the ETCS-Data calls/connections?

Following FFFIS guidelines: priority 1 for ETCS data calls, priority 0 for emergency calls, priority 2 for GSM-R voice calls.

e. Did someone test the efficiency of the priority regulations? Are there existing test reports?

The priority based pre-emption mechanism has not been tested in Switzerland.

6. <u>GSM-R QoS</u>

a. Optimisation of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

SBB initially defined its own QoS parameters for the first ETCS pilot line. Nowadays, SBB has developed a new test case based on the QoS parameters defined in SUBSET-093, and a series of tests have been run using new Kapsch equipment. Measurements have been performed at every layer of the communications protocol stack.

Capacity issues have been negligible so far, because the level of traffic has been relatively low.

SBB has experimented some problems with dropped calls. Initially, SBB's network dropped on average four calls every 100 hours, which is a value above the defined limit of one dropped call every 100 hours. The source of these problems was identified as being a cell handover at a tunnel entrance (solved through signal level adjustment by repeater) and an area where an additional BTS was deemed necessary.

The sources of these problems were detected only after a series of statistical analysis of dropped calls. The use of a Call Performance Monitoring system was the key to the identification of these causes and the solution of the problems.

b. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

SBB defined two different classes of GSM-R network layouts: a Class A layout for lines that needed ETCS coverage and a Class B layout for lines that only needed GSM-R voice coverage.
In the Frutigen–Visp line (including the Lötschberg tunnel), a double layer network (redundant coverage, with independent BTS locations and independent BSCs) was built from the very beginning all along the line.

The Bern–Olten line initially had a double layer everywhere except inside the tunnels. Since then, repeaters and BTSs have been added to provide double coverage inside the tunnels as well.

c. Where the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

In the lines provided with ETCS, the GSM-R network was planned with ETCS in mind from the beginning.

d. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

SBB needed to perform corrections in two locations (see answer to question 6.a); otherwise, the planification was sufficient.

C/I levels have not caused problems so far. However, SBB foresees problems in areas close to neighbouring countries due to the limited number of frequencies available.

e. Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?

SBB has not deemed necessary to modify internal GSM-R configuration parameters. The only GSM-R parameter modified so far has been signal level (see answer to question 6.a).

f. Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?

No additional problems were noticed with cell handovers besides the one described above (see answer to question 6.a).

g. What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)

SBB has not attempted to use coverage levels lower than those defined in the EIRENE specification. Coverage levels are higher than 49 dBµV/m at 99% HOSR.

7. Network selection times for MTs – network-joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.

SBB has not experienced network reselection due to coverage loss due to very high coverage levels in its two lines.

8. RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?

No reliability figures have been obtained yet, and values seem to be very dependent on traffic. In general, however, the results seem very good.

9. Network Management System

a. Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)

SBB has set up a Network Management Centre in Bern to handle the operation, control and maintenance of both the fixed telecommunications network and the GSM-R radio network.

No second management centre exists, but a second MSC is located in Basel, ready to replace the working MSC within four hours (cold standby).

b. Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?

The fixed network OMC system in the Network Management Centre would register an alarm from the ISDN ports in the MSC. Should the MSC be disconnected, the GSM-R OMC centre would also raise an alarm.

c. Is the ISDN router in the RBC part of the managed network?

The ISDN router alarms through the RBC and its separate alarm system.

d. Is it possible to investigate the stored Call Data Records to solve problems?

Call Data Records can be inspected, but only manually, and have not been deemed sufficient to diagnose faults within the GSM-R network. SBB installed instead a Call Performance Monitoring (CPM) system that allows for a statistical analysis of coverage levels and monitors dropped calls and their causes.

e. Are there existing Service Level agreements? What about experiences with the compliance of the SLA?

SBB has not defined any SLAs so far. However, an internal “SLA-like” agreement could eventually be drafted between the signalling ETCS department within the organisation and the GSM-R department.

10. Final Remarks

No special remarks. The ERTMS Users Group team enjoyed successful journeys under ETCS level 2 operation on the way to and from Bern.

11. Summary of Key Findings

The following key points were noted during this visit:

- Some optimisation of the GSM-R network was necessary at specific locations to ensure trouble-free operation of ETCS.
- Some problems with ETCS operation (network selection and attachment) were experienced in the earlier pilot project (Luzern – Olten). These problems have been solved in the ETCS border crossing Change Requests.
- The implementation of redundant dual-layer GSM-R coverage has yielded excellent network reliability.
- The use of a dedicated Call Performance Monitoring system has played a fundamental role in the identification and resolution of ETCS/GSM-R communications issues. This sub-system has had a major impact in the successful deployment of ETCS on the SBB rail network.

ERTMS USERS GROUP

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 03-06-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Robert Dijkman

Subject: ETCS/GSM-R Integration Review meeting with RFI, Rome, 7th of May 2008

The attendants to the meeting were Nazzareno Filippini, Daniele Caronti, Massimilano Ciaffi and Diego Schiavoni for RFI with Paul Booth (Network Rail), Josef Hellmann (Deutsche Bahn) and Rodrigo Álvarez García-Sanchidrián (Network Rail) representing the ERTMS Users Group.

The objective of the meeting was to discuss RFI's experiences during the process of integration of the ETCS system over the GSM-R network in Italy in accordance with an ERTMS Users Group remit.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

Mr. Schiavoni and Mr. Caronti presented the Italian GSM-R and ETCS networks and the projects both completed and currently under development.

Mr Filippini gave a brief overview of the ETCS projects in Italy. The Roma – Napoli and Torino – Milano routes are already in service while Milano – Bologna is currently under construction. The RFI implementation strategy is based on ETCS L2 with a fully redundant system architecture to eliminate the need for a fallback signalling system. It was noted that RFI have already implemented GPRS within their GSM-R network although its use is restricted to the provision of value added services for passengers (ticketing- system) at present. RFI are participating in the current round of UIC lead discussions on the possible use of GPRS for ETCS.

1. MSC-RBC interface:

a. *What issues have been encountered in implementing the IFIX interface as defined in FFFIS for Euroradio?*

RFI did not experience special problems in the implementation of the IFIX interface. The IFIX interface presents in every case an N+1 redundancy, with N being the number of RBCs connected to each one of the seven MSCs available within the RFI GSM-R/NSS network.

b. *Is the IFIX link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?*

RFI uses a closed SDH network for the IFIX interface, with all elements (fibre and equipment) owned by RFI. Additionally, compliance with EN 50159-2 is ensured by upper protocol layers, as per SUBSET-037. The following defence techniques have been implemented for each threat defined in EN 50159-2:

	Time Stamp (application level)	Time Out (Euroradio)	Feed-back Message (application level)	Source and Destination Identifier (Euroradio)	Message Identification Process (Euroradio)	Safety Code (Euroradio)
Repetition	X					
Deletion			X			
Insertion			X	X	X	
Resequencing	X					
Corruption						X
Delay	X	X				
Masquerade			X		X	

c. *Are there any problems in complying with SUBSET-037?*

RFI reports a full compliance with SUBSET-037, and presents a series of values adopted for some ETCS Level 2 configuration parameters for the two different ETCS suppliers currently operating in Italy.

	T1	N1	N2	K
Alstom	**1,55 s**	**248***	**3**	**20**
Ansaldo	**1 s**	**1024**	**5**	**20**

The following table, extracted from SUBSET-037 of Euroradio FIS Rev. 2.0.0, explains the values mentioned in the table above:

Table 40 Layer 2 configuration parameters[16]

Parameter	Symbol	Defined range of values	Applied value(s)	Comments
Address		A, B	Calling entity: A Called entity: B	
Window size	k	1 - 127	9 - 61	The window size can be different in both directions. Recommended value = 20
Acknowledge time	T1	> 500 ms	0,8 - 2 s	T1>T2+2*transfer delay
Local processing delay time	T2		< 80 ms	Implementation dependent
Out of service time	T3		T3 >> T4	Matter of implementation (to be used only if T4 is supported)
Inactivity time	T4		Recommended value T4 >N2 * T1	T4 >> T1 Matter of implementation
maximum number of bits in a I frame	N1	> 0	240≤N1≤1024.	Flags are not included. Receive buffers shall support N1 =1024. Recommended value for transmission = 312 (This is equal to 4 frames per 1 TPDU
Maximum number of retransmission attempts	N2	> 0	3 – 6.	Note: ISO/IEC 7776 specifies the number of transmissions = N2+1 Recommended value: 5
Error detection and correction			FCS-16	No options

The differences in value between the two suppliers are due to different approaches to the solution, while keeping within the limits defined by SUBSET-037. For example, Alstom's choice of 248 bits (instead of 312 as suggested by Table 2) has been made to transmit a General Message (without optional linked packets) into one single frame. With N1=248, the data field is 26 bytes and the total lenght of HDLC frame is 33 bytes.

flag	address	control	data	FCS	flag
1	1	2	26	2	1

N1=248 bit (31 bytes)

d. How is EURORADIO key management organized?

RFI is developing an Ansaldo Key Management Centre (KMC) for the new Milan – Bologna High Speed Line. For the moment being, and until this new KMC is developed, key management is manual, and keys are associated to ETCS elements in an Excel spreadsheet. Keys are sent to the suppliers making use of a cryptographic certificate to be uploaded to the equipment.

Although keys are manually generated, the Excel file where they are kept complies with SUBSET-038.

Currently, keys are embedded in the core of equipment software, so a new key requires a new software version. However, this trait will be changed in the future, when the key will be kept in an external memory, to allow interoperability with foreign rolling stock using RFI infrastructure.

Two different solutions have been implemented for the moment being; one making use of a single key for each ETCS component and another one having one different key per RBC for each ETCS component.

e. How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?

COTS devices (access servers) are used to implement lower protocol layers (ETC 300 011 + V.110). Upper protocol layer are implemented in Alstom device (HDLC, T.70, X224 and Safety layer).

f. What were the numbering plan rules for the ports in the MSC?

The numbering plan makes use of the international standard format, with all numbers taking the prefix 0039.

g. Is the short code LDA 1500 implemented? How is the routing for the short code implemented?

LDA 1500 has not been implemented. No short codes are used for ETCS.

h. Did your project need to take account of any particular MSC and RBC configuration considerations?

As mentioned before, RBC – MSC links have an N+1 redundancy in the Italian network.

2. <u>RBC-RBC interface</u>

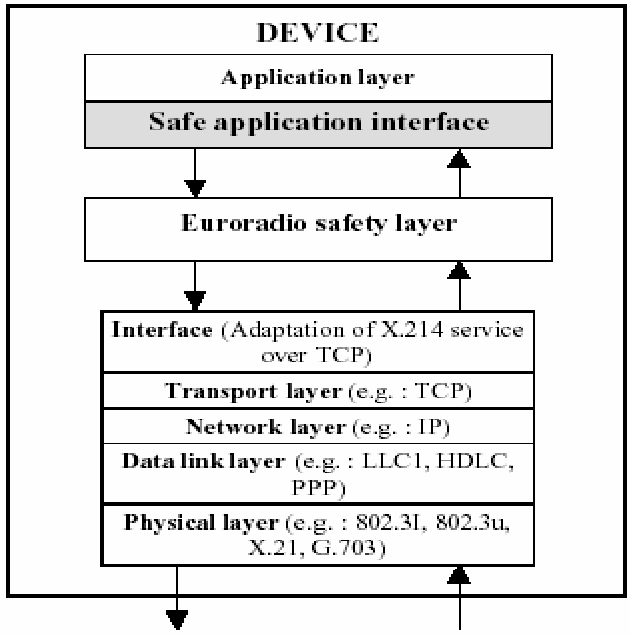
a. How has the RBC-RBC interface been implemented?

For lower protocol layers, AN Ethernet link is used on the RBC-RBC interface. In layers above the network layer, the protocols used to manage link redundancy and safety requirements are compliant with SUBSET-098 V1.0.0. This interface is compliant with class 7 open transmission systems (see EN 50159-2).

In the Italian application, a ”standard” interface proposed by ANSALDO-ALSTOM has been implemented both for RBC-RBC and RBC-IL interfaces. In particular, the Euroradio Safety Layer is encapsulated in a new stack by defining:

- A Safe Application Interface (SAI) which complements the Euroradio Safety Layer towards Application Layer

- An Adaptation Layer called TLE (Transport Layer Emulation) on top of TCP/IP, which deals with packetization and redundancy.



b. Is the RBC-RBC link part of the GSM-R Backbone-Network?

See answer to question 2.a above.

c. Is the link implemented as part of an open network as defined in EN 50159-2?

See answer to question 2.a above.

3. <u>RBC handover issues:</u>

a. Did the RBC handover plan take into account the location of GSM-R handovers?

In RFI's opinion, there is no relationship between RBC-RBC handover and BTS-BTS handover. To begin with, neither RBC-RBC handovers nor BTS-BTS handovers are fixed in space or time; both are event-triggered mechanisms driven by different and unrelated events. The GSM-R network is designed to provide sufficient coverage and QoS levels to successfully perform RBC-RBC handovers in any location.

A second call is established between on board MT2 and RBC2 when the last Movement Authority is extended over the boundary of RBC1. Thus, in keeping with the 40 seconds of advance in the establishment of the second call, handover boundary areas (where two calls are established) can be as big as 10 Km in High Speed Lines. In such a large boundary zone, several BTS-BTS handovers are likely to occur. However, BTS-BTS handover have been optimised to try to avoid RBC-RBC handover areas; this has been part of network optimization, rather than part of the original planning of the network.

Experience shows that in most cases (circa 90%) the second call can be established within 15 seconds, so this boundary area could be much reduced without a major impact in the behaviour of the system. RFI's opinion is that the 40s allowance should not be taken as an absolute requirement for triggering of the message to contact the second RBC. The GSM-R network can be designed for a 15s notification time which will cover the majority of cases. Those requests that take longer than 15s will result in a small delay as the train is forced to slow down before receiving authorisation to enter the second RBC's area of control.

As for handover between different GSM-R suppliers, the situation has not yet been encountered in the Italian projects.

b. What were the RBC handover design rules?

RBC-RBC handover design followed all requirements defined in SUBSET-026. In particular:

- RBC-RBC boundary shall be placed in the handover area between the last IL linked to a RBC and the first IL linked to the next one.
- RBC-RBC boundary shall not necessarily be set at the physical junction of track circuits;
- Specific balises with RBC transition order shall be placed at RBC-RBC boundary.

c. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

BTS-BTS handover must be completely transparent for the RBC application. No problems or necessary measures have been identified so far. The only recommendation is to make sure that the RBCs belonging to same network are connected to the same MSC (different phone number but same ISDN channels).

4. <u>On-board equipment:</u>

a. What issues have been encountered in implementing the I_{GSM} interface as defined by FFFIS for Euroradio?

RFI reports no special issues in the implementation of the I_{GSM} interface. Two suppliers' equipment has been used for the MT: Sagem (with Alstom ETCS) and Marconi-Selenia/Selex (with Ansaldo ETCS).

b. Which transmission rate (e.g. 2.4 Kb/s, 4.8K b/s or 9.6Kb/s) is implemented?

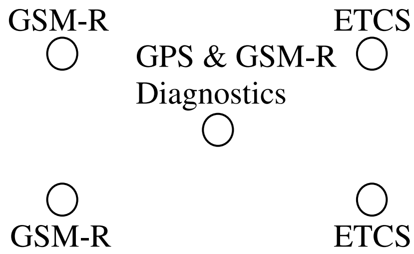
The transmission rate currently in use onboard Trenitalia trains is 4.8 kbps. The 9.6 kbps data rate has been tested, but QoS was compromised by higher interference levels on the track. The OoS parameters defined in SUBSET-093 could not be achieved using 9.6 kbps

c. What constraints applied to the GSM-R antenna location?

The only constraint to antenna installation was planned to guarantee no influence between antennas, including GSM-R voice antennas and GPS antennas.

d. What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?

The installation followed a square antenna distribution, with all antennas being installed in the same cabin as the ETCS on board equipment. The following diagram generally shows antenna distribution in Italian trains:



e. Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?

No specific measurements of antenna influence have been performed.

f. Was a suitable location which avoided the need for a long antenna feed cable found?

Cable length did not represent a problem in the Italian implementation.

g. Were any problems experienced with the vehicle power supply?

Redundancy has been built in the power supply system, with a redundant power source feeding the on board MTs and working in hot standby. No major problems have been experienced with the on board power supply.

h. Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?

No MTs are shared. Two different MTs are used for ETCS data transmission, needed to establish two simultaneous data calls during RBC-RBC handovers. Completely independent MTs (redundant) are used for GSM-R voice communication.

As mentioned above, the power supply is redundant, and both MTs and power supply share a common housing.

i. How is redundancy obtained in on board equipment?

Redundancy is obtained by means of the two MTs used for ETCS data transmission and through a redundant power supply.

*j. **Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?***

No antennas are shared, but train number is automatically transferred from the ETCS MTs to the GSM-R MT via MVB.

5. <u>SIM card specification for ETCS:</u>

a. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

The process of request, configuration and provisioning (SIM cards, HLR, IN, other databases), activation and modification is coordinated for all subscribers by RFI's National Operating Centre.

b. What data is stored on the ETCS SIM cards?

Data stored in SIM cards follow FFFI Specifications, while it follows MORANE specifications for GSM-R voice cards. EF VGCS and EF VBS are set to deactivate their services, allowing only for data bearer services.

c. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in Italy.

d. Which priority exists for the ETCS-Data calls/connections?

Following FFFIS guidelines: priority 1 for ETCS data calls, priority 0 for emergency calls, priority 2 for GSM-R voice calls.

e. Did someone test the efficiency of the priority regulations? Are there existing test reports?

The priority based pre-emption mechanism has not been tested in Italy.

6. <u>GSM-R QoS</u>

a. Optimisation of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

RFI disclosed the following QoS measurements for the Turin – Novara HSL:

- GSM-R radio coverage level: between -50 dBm and -70 dBm with 95 % coverage (samples every 100 m)

- Call set-up time MT to modem:
  SUBSET-093 requirement: <8.5 sec (95% <10 sec (99%)

Type of Call	# of samples	MIN value	50%	95%	99%	MAX value
4.8 Kb/s	> 1000	4.6	5.0	5.4	5.4	6.2
9.6 Kb/s	> 700	4.6	5.0	5.4	5.8	8.0

(when connected to BRA interface of MSC)

Type of Call	# of samples	MIN value	50%	95%	99%	MAX value
4.8 Kb/s	> 100	4.6	4.8	5.0	5.4	5.4
9.6 Kb/s	> 500	4.6	5.0	5.2	5.2	5.4

(when connected to BRA interface of PABX – No authentication)

Type of Call	# of samples	MIN value	50%	95%	99%	MAX value
4.8 Kb/s	250	5.2	5.6	6.0	6.0	6.2
9.6 Kb/s	250	5.0	5.6	6.0	6.0	6.2

(when connected to BRA interface of PABX – With authentication)

- Connection Establishment error ratio:
  SUBSET-093 requirement: <1%

Type of Call	# Connection Requests	Connection Established	Error Ratio %
4.8 Kb/s	1627	1625	0.12
9.6 Kb/s	1380	1378	0.14

Measurement method: Network
Connection Establishment error ratio = 1-(Σ alerting / Σ channel requests)   Timeout = 7.5s

Type of Call	# Connection Requests	Connection Established	Error Ratio %
4.8 Kb/s	1627	1625	0.12
9.6 Kb/s	1380	1378	0.14

Measurement method: End-to-end
Connection Establishment error ratio = 1-(Σ failed attempts / Σ Connection requests) Timeout = 10s

- Maximum end-to-end transfer delay:
  SUBSET-093 requirement: < 500 ms (99%)

4.8 Kb/s	# of samples	MIN Value	50%	95%	99%	MAX Value
1 Char	450	305 ms	330 ms	361 ms	364 ms	368 ms
10 Char	700	325 ms	358 ms	372 ms	374 ms	405 ms
30 Char	700	379 ms	391 ms	393 ms	396 ms	418 ms

9.6 Kb/s	# of samples	MIN Value	50%	95%	99%	MAX Value
1 Char	500	272 ms	288 ms	302 ms	320 ms	327 ms
10 Char	500	280 ms	300 ms	322 ms	330 ms	334 ms
30 Char	200	317 ms	336 ms	344 ms	346 ms	346 ms

RFI performed the measurements on the Turin – Novara HSL with an 8W on board MT taking samples every 0.6λ (25 cm). A compliance with SUBSET-093 and the

EIRENE FRS and SRS requirements was achieved. No connection losses were detected except the losses forced by the application, and there was no impact on train service due to any lost call.

However, RFI verified that QoS where too stringent when a test run with half of the GSM-R base stations disconnected caused no problems at the ETCS application level.

b. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

RFI set the following contractual requirements for the GSM-R network:

- -92 dBm with 95% coverage in normal conditions
- -98 dBm with 95% coverage with one BTS failure
- C/I > 25 dB in normal conditions
- C/I > 15 dB with one BTS failure

In order to attain these values, the following strategies where adopted:

- Reduced distance between BTSs: 4 km (on average)
- Typical number of TRX per BTS: 2

In case of fault or outage of one BTS the adjacent BTSs provide the radio coverage and GSM-R traffic channels necessary to maintain the safe connection; no interruption to the train service takes place.

ETCS requirements to GSM-R availability (Italian SRS AV) are:

- 1 ETCS TCH ("vital" applications) and 1 Voice service TCH ("non vital" applications) for every track section and every running direction in the nominal case;
- 2 ETCS TCH and 1 Voice service TCH for every track section and every running direction in every RBC-RBC handover area.

RFI used phased array antennas in tunnels rather than leaky feeder. The reasons for this preference is improved access for maintenance combined with good RF performance.

Coverage levels inside the rail cars have been measured to be approximately 30-40 dB lower. This is only relevant to potential users of the GPRS value added services.

c. Where the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

In the lines provided with ETCS, the GSM-R network was planned with ETCS in mind from the beginning.

d. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

Planned levels where sufficient.

e. Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?

No modifications where necessary beyond normal network optimization adjustments.

f. Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?

Because RFI had to define a very small value (7 seconds) for the T_NVCONTACT timer, there have been instances where the transfer time of a Movement Authority message reaches 5 seconds due to corrupted/lost messages retransmission in cell handover areas. In this case, a short application of the service brake takes place, but without dropping the call.

This implementation is necessary due to the request of Italian national railway regulation authorities.

g. What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)

RFI has not attempted to use coverage levels lower than those defined in the EIRENE specification.

7. Network selection times for MTs – network-joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.

RFI defined automatic recognition of new networks as its preferred network reselection technique. Public GSM is available for GSM-R cab radios as a fallback solution.

8. RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?

RFI has used a fully redundant network for GSM-R, including the HLR. The reliability figure obtained so far are less than 20s delay per run during last year. The main root cause of delays is loss of radio connection (due to Onboard issues or to Mobile Terminal reboot).

9. Network Management System

a. Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)

OMC is handled in four centres spread over Italy: a central OMC centre in Rome Tuscolana, and three centres for each one of the three High Speed Lines in Italy:

- OMC Centre in Rome Termini for the Rome – Naples HSL.
- OMC Centre in Settimo Torinese for the Turin – Novara HSL.
- OMC Centre in Bologne for the Milan – Bologne HSL.

Each HSL centre presents both a Radio Commander and a Switch Commander, as well as being locally collocated to each line's MSC and BSC. The centre in Rome Tuscolana includes the OTS and SPOTS servers, as well as a Radio Commander and a Switch Commander capable of handling any of the NSS and BSS of the three HSLs.

b. Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?

The fixed network OMC system in each Network Management Centre would register an alarm from the ISDN ports in the MSC. Should the MSC be disconnected, the GSM-R OMC centre would also raise an alarm.

c. Is the ISDN router in the RBC part of the managed network?

The ISDN router alarms through the RBC and its separate alarm system.

d. Is it possible to investigate the stored Call Data Records to solve problems?

Call Data Records can be inspected, but only manually.

e. Are there existing Service Level agreements? What about experiences with the compliance of the SLA?

RFI has defined a SLA with Alstom for the maintenance of ETCS trackside infrastructure on the Rome – Naples HSL, and a different SLA with Alstom for the maintenance of on board equipment has been signed by Trenitalia.

The only major problem with SLA compliance was a catastrophic failure during one night, when an RBC-MSC gateway crashed and a new procedure failed to put the mirror RBC in service automatically. The event did not affect any commercial services.

10. <u>Final Remarks</u>

The interviewers were impressed by RFI's record of achievement to date. It would appear that RFI has had fewer problems with integration of ETCS and GSM-R than might typically be expected. No major problems had been encountered beyond minor debugging tasks that could be expected with any major signalling project. The underlying reasons for this success did not emerge clearly through the course of the review. Further enquiries with RFI into staff competence and associated project management aspects may well yield useful information.

11. Summary of Key Findings

The following key points were noted during this visit:

- Very few ETCS/GSM-R integration problems have been encountered with the projects completed to date. The problems that were encountered were resolved quickly and efficiently. The underlying factors leading to this success could not be clearly established during the course of the review. The reviewers' opinion is that staff competence and RFI project management methods are likely to have been major contributors.
- The implementation of a fully redundant GSM-R network has yielded excellent reliability. When calls have been lost, these appear to have been terminated by the ETCS/EURORADIO application layers or a reset within the MT.
- RFI have found that phased array antennas in tunnels to be a better solution than relying on leaky feeders.
- GPRS is implemented on the Italian GSM-R network. Currently, use is limited to provision of value added services to passengers.

European Economic Interest Group –
European Rail Traffic Management System.
133 Rue Froissart -1040 Brussels - Belgium.
Phone (02) 673-99-33/fax 673-41-50. TVA 455-935.830

MISSION REPORT

Date: 03-07-08

From: Rodrigo Alvarez Garcia-Sanchidrian & Paul Booth

To: Robert Dijkman

Subject: ETCS/GSM-R Integration Review meeting with DB, Frankfurt-an-Main, 5th of June 2008

The attendants to the meeting were Andreas Winter and Josef Hellmann for Deutsche Bahn with Paul Booth (Network Rail) and Rodrigo Álvarez García-Sanchidrián (Network Rail) representing the ERTMS Users Group.

The objective of the meeting was to discuss DB's experiences during the process of integration of the ETCS system over the GSM-R network in Germany in accordance with an ERTMS Users Group remit.

The discussion followed a previously arranged set of topics, and this report is structured according to the topics discussed.

Mr. Winter and Mr. Hellmann gave a brief overview of the implementation of GSM-R in DB's railway network, with the use of a combined analogue + GSM-R radio – the previous analogue system is expected to be kept on minor lines for the foreseeable future, while GSM-R is replacing it in all main lines. The German GSM-R network includes seven (7) regional MSCs, with all MSCs interconnected through a redundant network and with each MSC presenting redundancy in terms of equipment and power supply.

The Berlin – Leipzig line is the pilot line that has been fitted with ETCS infrastructure, presenting four (4) RBCs. LZB is installed parallel on that pilot line and both systems use PZB as a fallback system. However, a migration plan has been prepared, according to which the following lines will be fitted with the ETCS levels indicated:

ETCS-Level 2

- New track sections with Vmax > 160 Km/h
- Tracks with high density blocks
- Extensions of ca. 2.500 km, (with ca 650 km of new lines)
- Phase out of LZB beginning from 2020

ETCS-Level 1

- Aachen – Belgian Border, ca. 7 km
- Part of the Paris Est TGV – South Germany line – Palatine Forest section, ca 34 km

ETCS SRS 2.3.0 d

- Berlin – Leipzig (2.2.2 +), (ca 145 km)
- Aachen – Belgian Border (ca 7 km)
- Paris Est TGV – South Germany line (ca 99 km)
- Nurenberg – Ingolstadt - Munich (ca 166 km)

ETCS SRS 3.0.0

- The rest - different ETCS levels will be supplied depending on technical and economical feasibility, especially ETCS L1 Limited Supervision, where feasible

1. MSC-RBC interface:

a. *What issues have been encountered in implementing the I_{FIX} interface as defined in FFFIS for Euroradio?*

DB does not report any particular issues in the implementation of the I_{FIX} interface.

Additionally, some problems with the software of the ISDN router were detected, causing channels to block upon restart. With an update to a new version the problems were solved.

b. *Is the I_{FIX} link implemented as part of an open network as defined in EN 50159-2? If so, what means has been employed to ensure the security of this link?*

DB implemented the I_{FIX} interface as part of an open network, considering Euroradio Subset 037 specification sufficient as far as data encryption goes.

The different I_{FIX} interfaces are implemented over three separate networks: one of them is owned by DB Netz and the two others are owned by PTO carriers (Arcor and T-Com), as a consequence of DB Telecoms outsourcing carrier capacity in the past. The choice of transmission network depends on the region, while the DB Netz network was originally intended to be used for safety related communications. A new, fully redundant, DB owned transmission network is being rolled out at the moment, and all telecommunications will be migrated to it when it is completed. But all communications have to be considered to be making use of an open network, according to the definition of EN 50159-2 because of using the network for different IT and Telecoms applications.

c. Are there any problems in complying with SUBSET-037?

Currently, no problems are experience in the compliance with SUBSET-037. All on board equipment is being supplied by Siemens, and no trains from the SNCF or any foreign operator are running over DB infrastructure yet.

However, DB is aware that interoperability problems may arise once foreign operators begin to run ETCS fitted trains over DB infrastructure.

d. How is EURORADIO key management organized?

DB has set up a Key Management Centre (KMC) in Berlin. A dedicated PC has been set up there with a software application that generates the key and checks its strength.

Two different persons separately generate one half of the key each. Each half is printed over a secure paper with a needle printer (like bank PIN number letters), but no transport key is used. Both half-keys are then separately delivered to the local key manager provided by the manufacturer (only the supplier of the RBC and EVC have the software tool to change the keys), who will upload them on the equipment.

One different key is generated for each locomotive, and that key is valid for every single RBC on which it is listed.

The KMC software application was developed by DB, with Volker Jurisch being responsible of its development, but the KMC software developed by SBB might be acquired in the future, when a new system will be set up. DB considers that the current system is not suitable for a high number of RBCs and EVCs.

e. How is the physical interface implemented? What specific issues have been encountered in hooking up the RBCs to the MSC?

Two (2) redundant E1 links have been set up between each RBC and its correspondent MSC, with two different carriers (DB Netz and a PTO) transporting each E1 link. A single alarm management centre handles alarms generated by both E1 links at all levels (from the physical to the application layer) by monitoring the MSC interfaces.

f. What were the numbering plan rules for the ports in the MSC?

A single numbering system has been set up for the DB network, where every ETCS application number follows the format:
0049 1835 999 0X YYY

X: No of the MSC to which the RBC is connected.
YYY: No of the RBC.

A few balises still have a short number from an older implementation; those numbers will be updated in the future to conform to the format defined above.

g. Is the short code LDA 1500 implemented? How is the routing for the short code implemented?

DB has implemented and tested LDA 1500, but it is not currently being used. The routing tables are implemented in the MSCs.

h. Did your project need to take account of any particular MSC and RBC configuration considerations?

No special considerations were necessary, except for the ISDN router.

2. RBC-RBC interface

a. How has the RBC-RBC interface been implemented?

The RBC-RBC interface was implemented over a dedicated redundant pair of fibres, without encryption; this fibre is owned by DB Netz in all cases, and this transport link is considered a closed network under the definition of EN 50159-1.

The protocol used in this interface is a special proprietary protocol implemented by Thales (former Alcatel), while the physical layer makes use of long distance optocouplers. DB foresees that Subset 098 will have to be implemented for the RBC-RBC interface.

b. Is the RBC-RBC link part of the GSM-R Backbone-Network?

No; it is a closed network based on point-to-point dedicated dark fibre.

c. Is the link implemented as part of an open network as defined in EN 50159-2?

See answer to question 2.a above.

3. RBC handover issues:

a. Did the RBC handover plan take into account the location of GSM-R handovers?

GSM-R planning was done well before ETCS planning, and it only considered higher coverage values in areas were ETCS was to be provided. So far, this strategy has not caused major problems.

b. What were the RBC handover design rules?

RBC-RBC handover takes place in the borders between interlocking equipment. Although a single RBC could combine information from more than one interlocking, the system has been simplified up to now by establishing a one-to-one relationship between RBCs and interlockings.

Additionally, the only MSC-MSC handover occuring in the pilot line takes place in the same area as an RBC-RBC handover.

c. If the RBC handover plan did not take GSM-R handovers into account, was any measure necessary after implementation to solve problems related to GSM-R handovers?

No problems have been detected by DB so far.

4. <u>On-board equipment:</u>

a. What issues have been encountered in implementing the I_{GSM} interface as defined by FFFIS for Euroradio?

No problems have been identified on the ETCS side. However, DB has encountered difficult integration problems of the EVC with the Sagem MT, mainly due to undefined timings and unexpected result codes. This was cured by several SW updates of the MT. Furthermore, DB has identified disturbances in other areas of the GSM-R Voice network caused by interference affecting all GSM-R channels. This interference comes from the harmonics generated by public GSM networks. The reasons for this effect are under investigation.

Since DB does not yet plan to introduce ETCS Level 2 inside large main stations before end of the next decade, there is no complete plan put in place to solve frequency shortage. One solution could be the usage of Micro Cells. Another solution could be for a train to use ETCS L1 LS to leave the station. Later on this problem will be solved by ETCS over GPRS.

b. Which transmission rate (e.g. 2.4 Kb/s, 4.8K b/s or 9.6Kb/s) is implemented?

The transmission rate currently in use onboard DB trains is 4.8 kbps. The 9.6 kbps data rate was tested during QoS tests, but quality was compromised by higher interference levels on the track.

c. What constraints applied to the GSM-R antenna location?

A theoretical study on inter-antenna influence was prepared before the installation, but it led to impractical results, with minimum distances over 20 m. Instead, different measurements were needed for each type of locomotive in order to place GSM-R voice and data antennas.

The GSM 05.05 specification presented stricter requirements to MIM that allowed a minimum distance between antennas of 6 m. DB has defined, together with its suppliers, a series of criteria for spurious emission and blocking to achieve shorter antenna distances.

d. What were the rules against influence from other antennas (e.g. distance between antennas, antenna decrement, characteristics, etc.)?

See answer to question 4.c above. A different solution had to be implemented for each different type of locomotive.

e. Did someone measure the influence of the different antennas? Are there existing measurement reports about the results?

Measurements were performed during the installation of GSM-R voice antennas in each different type of locomotive and places for additional antennas for data-applications (ETCS) were defined.

f. Was a suitable location which avoided the need for a long antenna feed cable found?

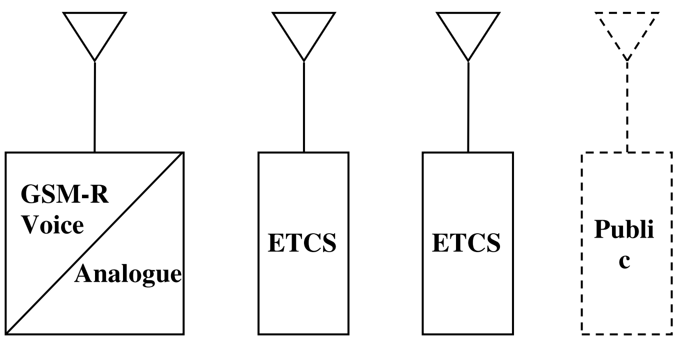
Cable length did not represent a major problem in DB's locomotives, because the on board equipment was located in the centre of the locomotive. DB requested that loss free antenna cables be used, with a maximum cable loss of 3 dB. The resulting installation was very expensive, due to the need to provide a grounding plate for the antenna placed on a plastic surface.

g. Were any problems experienced with the vehicle power supply?

DB experienced no problems with the on board power supply. Redundancy has been provided by using two power supplies per locomotive. The equipment rack's backplane presents a wiring based in printed circuits, avoiding small wiring problems.

h. Are MTs shared between ETCS and GSM-R? Do different MTs share housing, power or any other element?

All ETCS MTs share housing (19"-rack) and a common backplane, with completely different power supply and housing for EVC interfaces.. No MTs are shared between voice and data, but the voice MT is shared between GSM-R and the analogue system.



The BR101 model additionally presents an extra MT and antenna that allows data communication (e.g. diagnostics) between the locomotive and the repair workshop.

i. How is redundancy obtained in on board equipment?

See answer to question 4.h above.

j. Is there any commonality between the ETCS and voice radio GSM-R equipment, e.g. automatic transfer of train number, sharing of antennas, etc?

No antennas are shared, and no automatic transfer of train number takes place. There are no commonalities between ETCS and GSM-R Voice MTs. There are plans to share train number in future via proprietary interfaces with the MVB.

5. <u>SIM card specification for ETCS:</u>

a. Has ETCS SIM management been co-ordinated with management of GSM-R voice radio SIM cards?

DB has created a single management centre for all SIM cards, and this centre is handled by DB Systel – although the owner of the GSM-R network is DB Netz, the network operator is DB Systel.

b. What data is stored on the ETCS SIM cards?

A special profile is stored in ETCS SIM cards. The profile is defined by DB Netz, but the actual SIM card writing is performed by DB Systel. Group calls are not enabled for ETCS SIM cards, but SMS and telephony calls are enabled,.

c. What happens in the case where MTs are shared between ETCS and GSM-R?

This is not the case in Germany.

d. Which priority exists for the ETCS-Data calls/connections?

Following FFFIS guidelines: priority 1 has been assigned to ETCS data calls, priority 0 to emergency calls and priorities 3 or 4 to point to point voice calls.

e. Did someone test the efficiency of the priority regulations? Are there existing test reports?

DB tested pre-emption in a laboratory and in track during BTS installation by artificially closing channels. However, these test reports are not public.

6. GSM-R QoS

a. Optimisation of GSM-R QoS network parameters for ETCS; does your experience suggest that the specified GSM-R QoS parameters are appropriate to the needs of ETCS data transmission (for example: are call set-up times fast enough to support ETCS operations? Are there any capacity issues? Interference issues? Problems with dropped calls? Handovers? Etc).

In DB's opinion, QoS parameters, as defined by the specifications, are extremely over-dimensioned, especially in the case of the interference rate and the error free period ("recovery time"). Long data packets unnecessarily increase the interference rate, but no problems have been detected with dropped calls or handovers.

The requirement for having a maximum connection set up time of six (6) seconds was deemed unreasonable; experience proves a minimum time of 7 to 8 seconds. A specific DB report deals with the issue.

b. BTS location – are there any particular considerations that were taken into account related to the application of GSM-R to ETCS?

Coverage was the only consideration taken into account when planning BTS location. In one occasion, two additional BTS were necessary in the area close to Berlin, and the frequency plan had to be changed to increase coverage.

To minimize handover between BTSs (ping-pong) it was identified that a minimum stay of 8 seconds in a given BTS cell was necessary.

c. Where the characteristics planned for the GSM-R voice network sufficient for the ETCS system?

The minimum requirement for an ETCS system has not been fully tested in DB's first pilot line. However, the expectation is that, provided the coverage level is high enough to avoid interference problems, the characteristics of the GSM-R network should be sufficient for the ETCS system.

d. Was the capacity of the network sufficient? Were C/I levels sufficiently high? Were set up times sufficiently low? Were dropped calls adequately detected?

No dropped data calls have been detected so far, except when the called number was wrong in the configuration in the RBC after an update.

Dropped voice calls have been adequately detected in other areas of the GSM-R network. The reasons for dropped voice calls are actually under investigation. It is assumed that MTs with better filters on the harmonics from Public GSM emissions will solve the problem.

The data call register can be inspected to investigate dropped calls, but the inspection must be done manually. DB considers that a software application to automatically detect dropped calls would be desirable.

e. Modifications of other network parameters – was it necessary to adjust internal GSM-R configuration parameters (e.g. timers) to obtain reliable operation?

No modifications where necessary beyond normal network optimization adjustments.

f. Is there any noticeable problem with cell handovers? What, if anything, has been done to minimise the impact of the handover process? Were handover timings all right? Did neighbour cell listings cause any problem?

No problems have been detected with cell handovers.

g. What was the relationship between EIRENE specified field strength and actual measurements (i.e. is the specified coverage level adequate? Could we get away with lower coverage levels? How does the system work in zones of lower coverage?)

The nominal coverage level in DB's GSM-R network is -95 dBm for ETCS L2 < 220 km/h and -92 dBm for ETCS L2 < 300 km/h.

During the Installation of the ETCS track equipment between Jüterbog and Berlin, DB tested the effects of a coverage level of -98 dBm before additional BTSs were installed to increase the level to the nominal value. During these tests at -98 dBm, no connection was lost and the application successfully handled the consequently higher interference levels.

7. Network selection times for MTs – network-joining procedure from a moving vehicle as opposed to a stationary vehicle after coverage loss.

The maximum network selection time in Germany is of 15 seconds, with a maximum of 30 seconds in the case of manual reselection.

8. RAMS – What was the way to deal with GSM-R RAMS as part of an end-to-end system reliability? What figures of reliability have been obtained so far?

No RAMS values have been defined for DB's GSM-R network so far. RAMS values for ETCS include Mean Team Between Failures, as defined in EN 50126 and EN 50129.

9. Network Management System

a. Do you administrate a central Management System for the GSM-R-Network? (e.g. as a basis for an OMC/NMC)

DB’s Operation and Maintenance Centre is located in Berlin, and it works from 8 am to 7 pm on weekdays. Additionally, technical laboratories are located in the same premises. Another laboratory is located in Eschborn, close to Frankfurt-am-Main.

The Network Management Centre is located in Dresden, and it works 24 hours over the seven days of the week.

OMC and NMC both use a 24/7 Call Centre in Eschborn.

b. Does a problem with the ISDN-Ports in the MSC used for ETCS cause an alarm?

Such a problem would cause an alarm in the Berlin OMC and the Dresden NMC.

c. Is the ISDN router in the RBC part of the managed network?

In DB’s implementation, the ISDN router seems to fall under no defined responsibility, and is not being monitored. Alcatel’s new server might be able to switch off the power of the ISDN router, should it present a problem. This would cause an alarm in NMC and OMC.

d. Is it possible to investigate the stored Call Data Records to solve problems?

Call Data Records can be inspected, but only manually. It is expected that the new “Nexus” software, the one used by the SBB, would speed up this process.

e. Are there existing Service Level agreements? What about experiences with the compliance of the SLA?

SLAs have been established between different DB departments and for the lines leased to PTOs. There has yet been no experience with a lack of SLA compliance.

Leased lines are protected by redundant connections, so the SLAs contemplate a repair time of 24 hours.

10. Final Remarks

11. Summary of Key Findings