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RDG Guidance Note ETCS On-Board Equipment

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Synopsis

This document provides guidance to train operators on ETCS on-board components and system architecture.

Applicability

This Guidance Note has been prepared for passenger operators. However, its content may also be of use to others.

Issue record

Issue	Date	Comments
One	October 2017	First issue

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Part 1 About this document

1.1 Responsibilities

1.1.1 Copies of this Guidance Note should be distributed by RDG members to persons within their respective organisations for whom its content is relevant.

1.2 Explanatory Note

1.2.1 RDG produces RDG Guidance Notes for the information of its members. RDG is not a regulatory body and compliance with RDG Guidance Notes is not mandatory.

1.2.2 RDG Guidance Notes are intended to reflect good practice. RDG members are recommended to evaluate the guidance against their own arrangements in a structured and systematic way. Some or all parts of the guidance may not be appropriate to their operations. It is recommended that this process of evaluation and any subsequent decision to adopt (or not to adopt) elements of the guidance should be documented.

1.3 Guidance Note Status

1.3.1 This document is not intended to create legally binding obligations between railway duty holders. This note is provided for guidance only.

Part 2 Introduction and Scope

2.1 Introduction

2.1.1 This chapter covers the fleet engineering aspects of European Train Control System (ETCS). It aims to provide an overview of the ETCS On-Board System (OBS), its components and their installation into the vehicle. Later chapters cover the First in Class (FiC) process, testing and approvals, and further fleet installation.

<u>2.1.2</u> For clarity, sections with important operator considerations have been listed below and the section reference <u>underlined</u> where applicable in the document.

3.2.6	3.2.8	3.4.14	3.5.6
3.6.3	3.6.6	3.6.7	3.8.4
3.8.9	3.8.10	4.3.3	4.3.4

2.1.3 The generic ETCS On-Board System consists of:

- European Vital Computer (EVC);
- Driver Machine Interface (DMI);
- GSM-R ETCS Data Only Radio (EDOR);
- Juridical Recording Unit (JRU);
- Balise Antenna and Balise Transmission Module (BTM);
- Odometry equipment, including Wheel Sensors and Doppler Radar; and,
- Train Interface Unit.

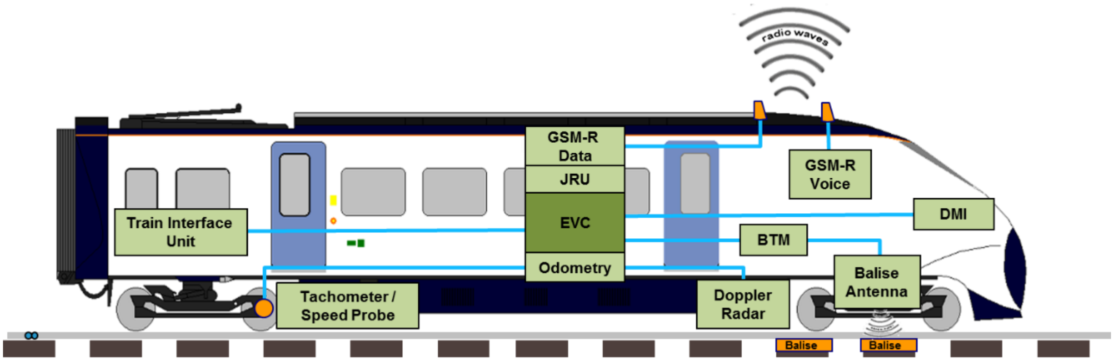

Figure 1: Generic ETCS On-Board System

2.2 Scope

2.2.1 This chapter applies to Rail Delivery Group members in relation to the implementation of ETCS. The document is written to allow Train Operators to understand the on-board system and the process for procurement, installation and entering vehicles into service.

Part 3 ETCS Components

3.1 European Vital Computer

3.1.1 The European Vital Computer (EVC) is the core of the system. Its task is to safely manage the vital functions of the On-Board Sub-System (OBS) and to provide support for diagnostic maintenance of the On-Board subsystem. It provides the following functions:

- Automatic Train Protection (ATP), including stand still protection and enables optional links to Automatic Train Operation (ATO),
- Managing the input and output of information or alerts/warnings through the drivers display(s),
- Acting on functions given to it through trackside Eurobalises or over the GSM-R Data Network,
- Interfacing with, where supported, national train control and protection systems such as TPWS and AWS, referred to as 'Class B systems' in the System Requirements Specification (SRS - Subset 026 of the CCS TSI),
- Train Management to support the Train Interface Unit (TIU), the interface with the vehicle's main and ancillary functions (odometry, speed, direction, etc.).

3.1.2 The Safety Integrity Level (SIL) is a measurement of a systems performance required when used for a safety critical process, these functional safety standards are outlined in IEC 62279. The SIL rating specifies the allowable frequency of dangerous failure, four levels are defined, with 4 being the most dependable and 1 being the least. ETCS is a SIL 4 signalling system, this requires that it should have a probability of failure per hour of at least 10^{-8} (or one failure in 100 million hours), this is the reliability of the entire system and not any one component of hardware or software.

3.1.3 To meet this level of reliability and robustness, the EVC operates on a voting principle. This means that the EVC has several processors or cards all undertaking the same processing task, and so long as the majority agrees, that result is taken as safe and carried forward. A common configuration is known as a 2-out-of-3 architecture, however other configurations are possible; such as a 2-out-of-2 platform, or a doubly redundant platform using two EVC modules both of a 2-out-of-2 configuration.

3.1.4 In the case of a 2-out-of-3 configuration; all 3 cards carry out the same processing task and so long as 2 of the 3 come to the same result it proceeds. If a card were to start producing results outside of the other twos range it would be marked as faulty and the system could continue in service as a 2-out-of-2 system would. If a second card were to fail, then the EVC would apply an emergency stop and be unfit to continue.

3.1.5 The use of each configuration is dependent on the suppliers' design of equipment and system architecture to meet the SIL rating.

3.1.6 Every suppliers' EVC differ in shape and size and can be split into several modules depending on size constraints of vehicle fitment.

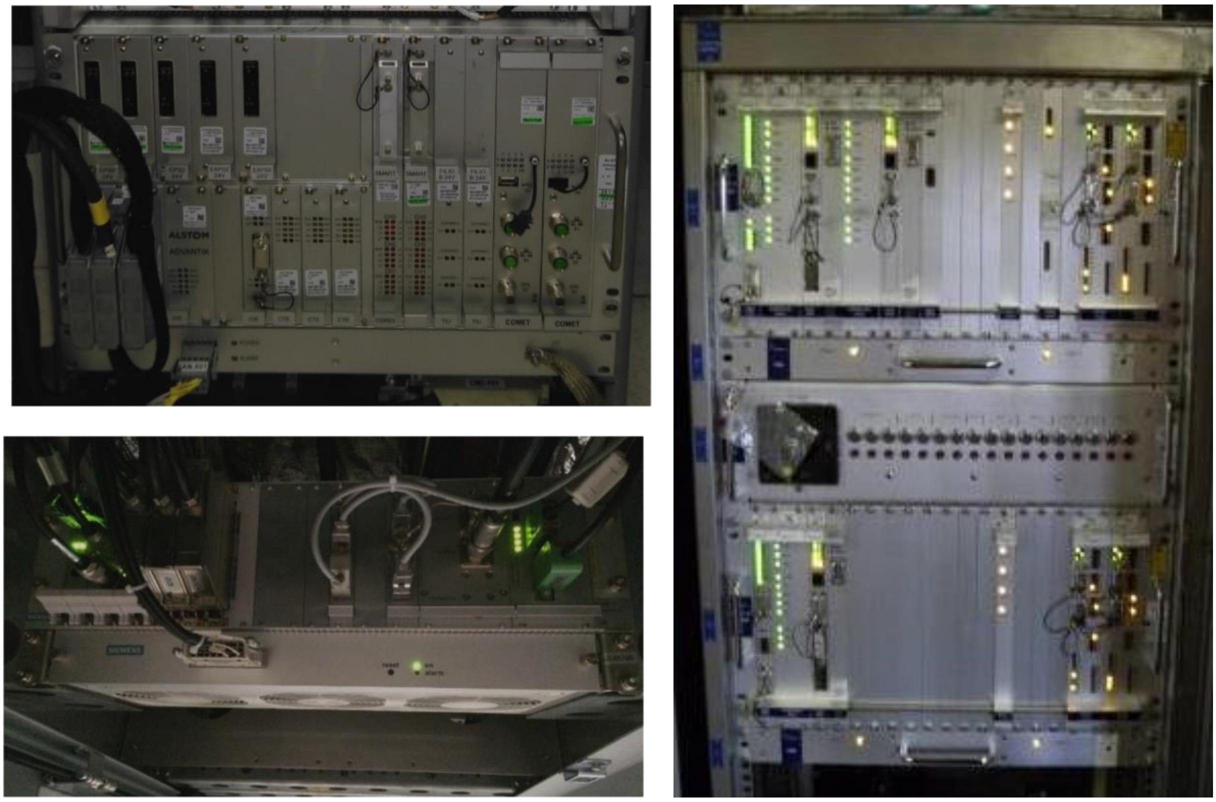

Figure 2: Examples of EVCs from different suppliers, including Alstom (top left), Siemens (bottom left), Ansaldo (right)

3.1.7 Cards can be removed for maintenance as a line replaceable unit (LRU) without taking the whole rack out but note that they are not interchangeable between supplier's equipment due to difference in design.

3.1.8 On certain suppliers' equipment, the DMI can be used to access maintenance information through a password protected menu. Allowing technicians to check the health status of various line replaceable units (LRUs), in other implementation this can be done via a laptop plugged into the maintenance port of the EVC.

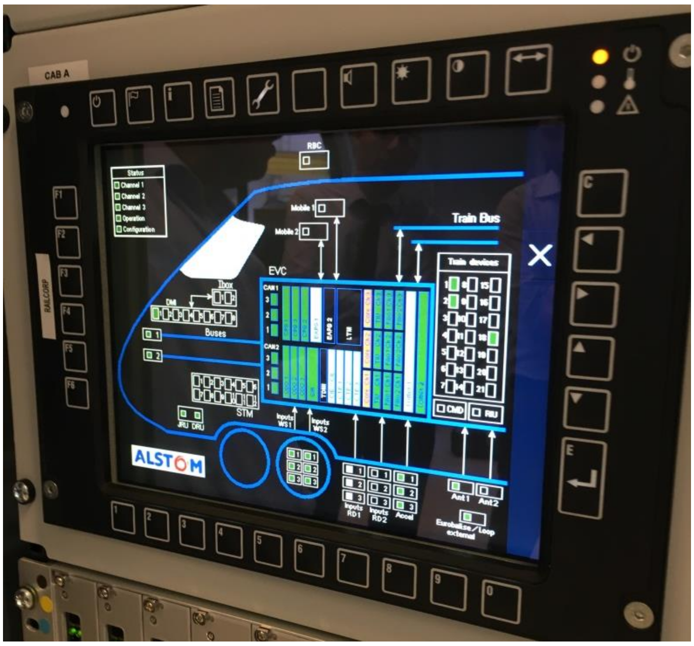

Figure 3: DMI maintenance screen on Alstom test equipment

Figure 4: Laptop connected via maintenance card, and the card shown to the right

3.2 Driver Machine Interface (DMI)

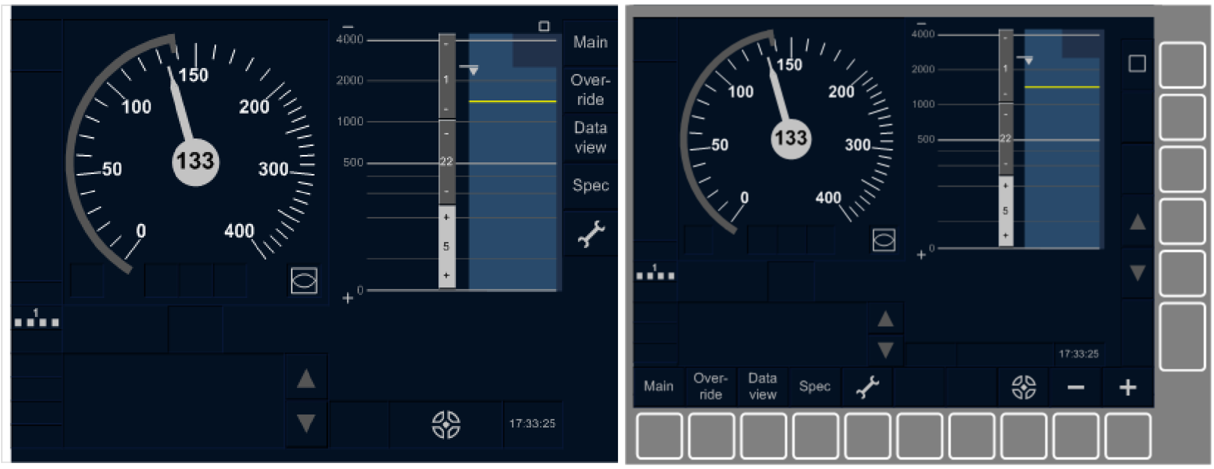

Figure 5: Touch screen DMI (left) verses soft key DMI (right)

3.2.1 The ETCS Driver Machine Interface (DMI) is the interface between the driver and the ETCS system. It allows:

- the entry of information such as driver identity and train data;
- the triggering of driver actions including selection of driving mode, confirmation and acknowledgement;
- the display of driving information; speedometer (often referred to as a Circular Speed Gauge), planning area, data menu, text message display, ETCS operating level and operating mode.

Figure 6: DMI layout

3.2.2 The ETCS DMI typically comprises of a screen panel fixed on the driving desk for control and indication functions, a voice synthesizer and configurable audible alert to inform the driver of changes to operating conditions, and uses either touch screen or soft-keys to accept data input.

3.2.3 In Baseline 2 ETCS, such as fitted on Cambrian, there were no mandatory DMI specifications published. As such, different suppliers demonstrated different ways to display the needed information. Now, the core functionality of the DMI in Baseline 3 is specified by the EURA (ERA_ERTMS_015560). This specification aims to harmonise the presentation of information on the DMI and the drivers' interaction with it, contributing to a unified operation of trains regardless of what suppliers' equipment they are fitted with. This reduces potential for human errors and the driver training requirements.

3.2.4 The DMI can consist of a complete assembly approximately 300mm x 240mm such as those provided on the Cambrian fitment below:

Figure 7: DMI fitment on Class 158 (left) and Class 97 (right)

3.2.5 Alternatively, it can be two smaller screens with separate displays, controllers and power supplies, or replicated onto existing screens such as Train Management Systems. This limits single points of failure and increases overall reliability of the DMI. In the event of a failure, the driver can use a change-over switch on the desk to display the minimum required information on the side of the DMI that is unaffected, allowing the train to continue in service until it can be brought into depot or sidings and have the unit replaced.

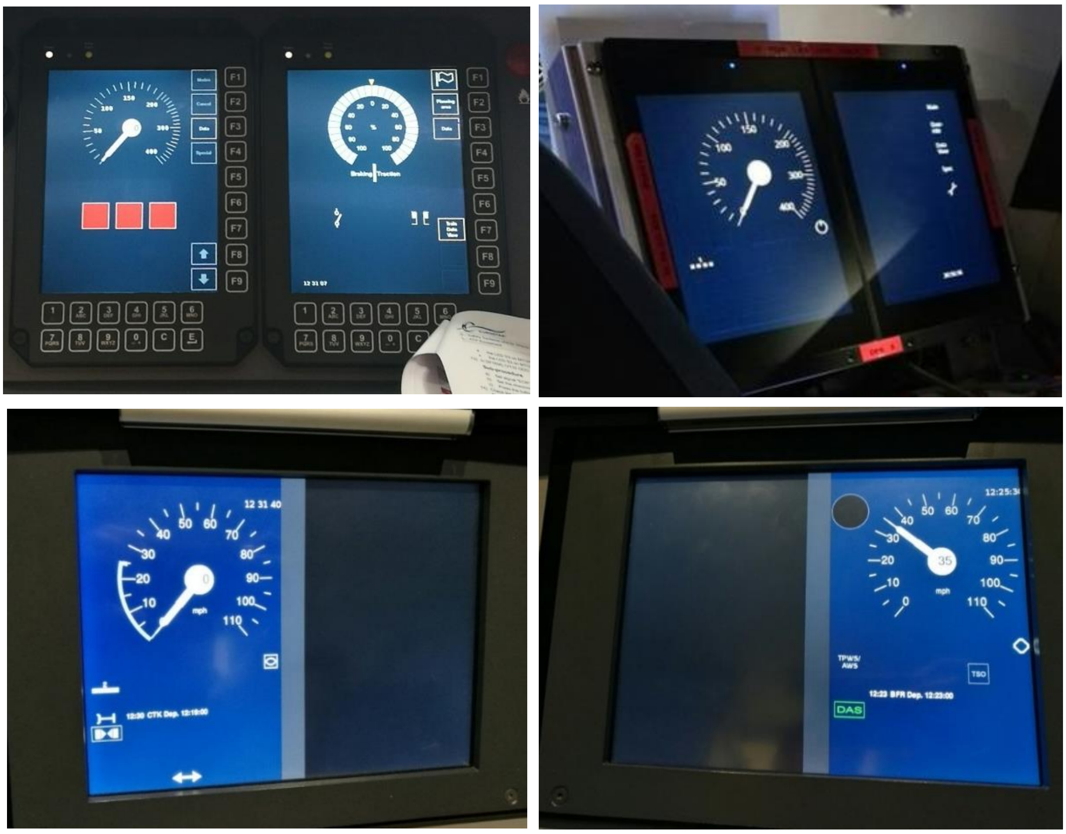

Figure 8: Dual screen DMIs: Soft Key (top left), Touch Screen (top right), Degraded Scenarios (bottom)

3.2.6 Operators need to consider human factors when integrating the DMI into a cab. The screens can be reflective, especially touch screen variants, and consideration should be given to DMI placement within the driver's direct line of sight using a shroud or cowling etc. to shield the screen from direct sunlight. Drivers uniforms can also present a problem, such as wearing white shirts on bright days casting reflections on the screen. The brightness settings can also cause issues with readability in daylight and in the dark. For more information on Human Factors considerations when designing cab fitments please refer to ATOC/RDG Guidance Note "ETCS Cab Human Factors Design Guidance".

3.2.7 On Cambrian, this issue was resolved through wearing darker grey shirts but there are technical solutions such as filters to reduce reflections and automatic sensors or manual switches to alter brightness of the screen.

Figure 9: Examples of screen reflections on DMIs

3.2.8 Operators need to consider that the DMI has specific cleaning considerations, especially touch screen variants, and care should be taken that the correct cleaning agents are being used as per the suppliers' maintenance instruction.

3.2.9 On starting up the cab desk, ETCS performs an automatic self-test, which includes proving the connection with the Driver Machine Interface (DMI), the relevant Balise Reader is verified, and other relevant ETCS on-board equipment is considered healthy by the system check. The result of the self-test is presented to the driver via the ETCS DMI.

3.2.10 There may be a facility within the cab for a mimic display of the DMI on the 2nd mans' side, usually a plug to be used to connect a dummy screen. This could be used for Driver Training and competence assessment, or for maintainers on test-rides allowing them to view the DMI without disturbing the driver. Depending on the solution used, it can use a laptop or dedicated portable screen as below.

Figure 10: Mimic panel on the second man side of a Class 158 running on the Cambrian

3.3 Specific Transition Module (STM)

3.3.1 The Specific Transition Module (STM) is often a card or module of the EVC. This takes input from other systems so that they can be interfaced with through the ETCS DMI. Allowing display of Class B systems such as TPWS and AWS for operation in Level NTC, Tilt Authorisation Speed Supervision (TASS) or even Selective Door Opening (SDO/ASDO) systems onto the DMI. This reduces separate equipment on the cab desk and system complexity on-board.

3.3.2 Depending on the supplier's solution, it can integrate the Class B system into ETCS, whereby we only have a sensor reader (in our case a TPWS /AWS magnet) connected directly to the EVC via the STM - reducing the need for more on-board equipment. The STM would need special software to decode and act accordingly for each of the Class B systems it has integrated.

3.3.3 The new Eurostar Siemens E320 fleet makes use of this to reduce the complexity of its 7 different safety systems needed for the routes it travels, by integrating the French TVM 430 into ETCS. However, at time of writing the STM for Belgium's TBL isn't available for use. The system remains separate, and a temporary installation is attached to the top of the desk.

Figure 11: Eurostar DMI with European Systems Integrated via STM

3.4 Global System for Mobile Communications – Railway (GSM-R)

3.4.1 GSM-R is the continuous digital radio system that provides voice and data communication between the track and the train. It is based on standard GSM using frequencies specifically reserved for rail applications.

3.4.2 The ETCS Data Only Radio (EDOR) uses the GSM-R network as a bearer for the transmission of variable data between the Radio Block Centre (RBC) and the train when in ETCS Level 2 and 3 using the 900 MHz frequency band:

- Uplink: 873–880 MHz used for data transmission;
- Downlink: 918–925 MHz used for data reception.

3.4.3 The data radio enables safe operation at higher speeds, and provides a near instantaneous update of the movement authority from the RBC. Rather than "searching for networks" and picking the strongest signal, the radio follows a set sequence of cells along the route – like the voice radio.

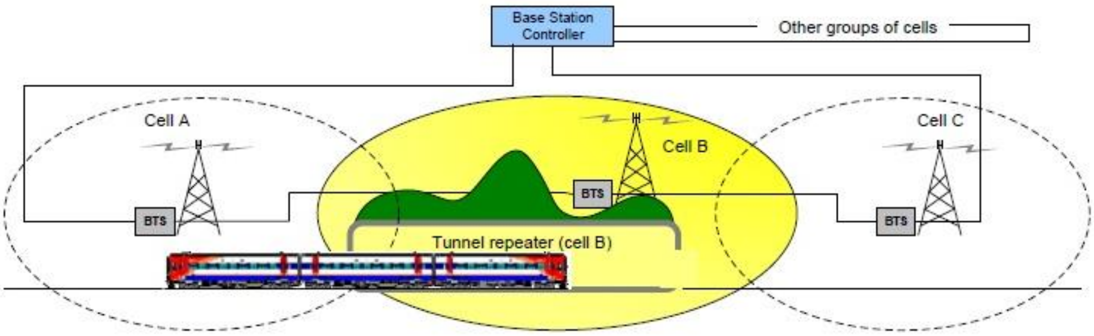

Figure 12: Train transferring from cell to cell

3.4.4 During RBC handover, the separate radios connect to the RBC cell ahead of the train in advance, while retaining the connection with the cell the train is in to ensure continuous communication during the transition between cell areas.

3.4.5 On-board installation of the EDOR usually consists of a minimum of two and normally three radio modules per EVC This increases availability and reliability of the radio bearer platform.

3.4.6 The Radio Interface software can manage 3 GSM-R data radio units (two in normal service to support RBC transitions and one for redundancy).

Figure 13: Class 700 ETCS Data Only Radio (EDOR)

3.4.7 Each radio has a separate antenna on the roof of the vehicle close to where the radio modules are located. These are installed with adequate physical separation to prevent interference issues with any other roof-mounted system.

Figure 14: Class 700 roof showing antenna separation

3.4.8 Maintenance of the EDOR modules is supplier specific, but operators should be prepared to carry out visual examinations of the modules and the antennae. Less frequently, testing of each module output power and Voltage Standing Wave Ratio (VSWR) is likely to be required. Operators should already be doing similar tests on the GSM-R voice radio, so it is unlikely that new skills or equipment will be required.

3.4.9 ETCS Operators have encountered data capacity problems with the GSM-R bearer and only circuit switched connections (i.e. the connection to a train is held continuously) is currently approved for ETCS operation. This has meant that, in busy traffic areas such as terminal stations and complex junctions, there is insufficient capacity to have all the trains connected to the system.

3.4.10 An alternative to circuit switching is packet switching. Whilst circuit switching offers a high-quality digital transmission well-suited to voice communications. Packet switching protocols are much better suited to data transmission such as those made supporting operations in ETCS. Firstly, packet switching allows many 'streams' of communication over a single channel – thus, allowing us to multiply our capacity for trains connecting to the system. Secondly, packet switching has some added intelligence; a protocol called 'X25' means that if a message, or part of a message, is not received – it will continue to attempt to send this until the receiver has confirmed its receipt. This means we have an additional layer of safety before a possible miscommunication poses a risk to performance or safety.

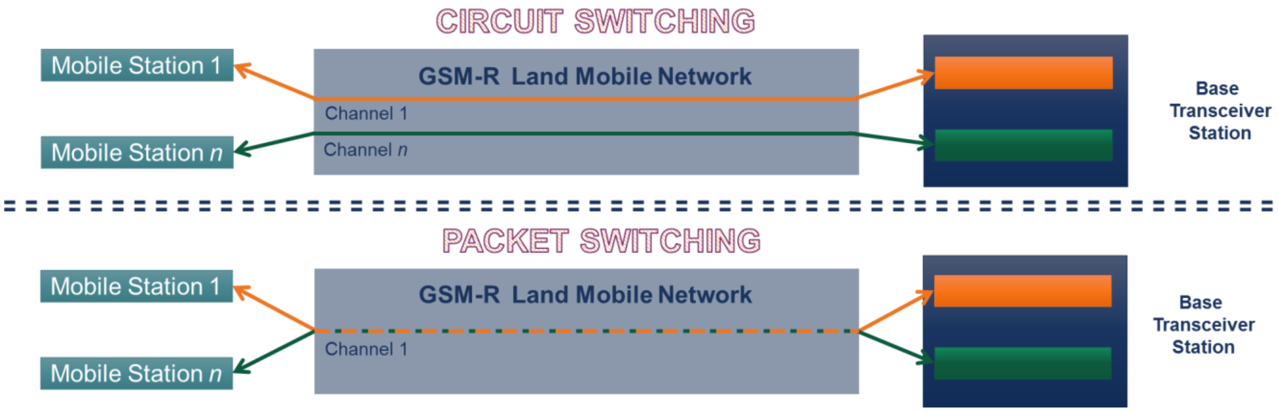

Figure 15: Diagram showing Circuit Switching and Packet Switching

Combating interference

3.4.11 The Radio Frequency interference into GSM-R from 3G and 4G public networks, is a key issue affecting railways operators today. It is prevalent where the 3G and 4G transmitters are close to the railway and the GSM-R transmitter (BTS) is some distance away, or not set-up for optimal performance, so that the signal strength of the GSM-R transmission is blocked by the high-level out-of-band transmissions or intermodulation in the mobile receiver.

3.4.12 To manage the interference, Network Rail Telecoms (NRT) made cooperation agreements in place with Vodafone and O2 which require the adjustment of transmitter power ratings and in some cases, to turn off transmitters. NRT also provided additional local repeaters for GSM-R. At the time of writing, this agreement and use of in-fil repeaters is continuing.

3.4.13 The European Telecoms Standards Institute (ETSI) developed a specification for an interference resistant transceiver. Network Rail Telecoms (NRT) has contracted Siemens to develop this for the existing GB voice radios, and ETCS procurements made since 2016 should also include the resistant EDOR.

3.4.14 Operators need to consider when procuring ETCS, that the EDOR radios should be specified correctly to the current ETSI requirements. Similarly, when procuring new trains, both the voice radio and ETCS equipment should be procured with the current ETSI requirements specified within the contract.

3.5 Juridical Recording Unit (JRU)

3.5.1 The Juridical Recording Unit (JRU) acts as the data recorder for the ETCS on-board system and is comparable to conventional On Train Monitor and Recorders (OTMR – also commonly referred to as On Train Data Recorder OTDR). The JRU records all information passed to/from and actions made by the EVC, as well as the drivers interactions with the system via the DMI. This provides detailed system data for reliability, system improvements, safety and a log of signalling activity in event of an investigation.

Figure 16: JRUs, including Alstom (top) and an Ansaldo JRU in situ on Class 158 (bottom)

3.5.2 This would operate alongside the OTMR, recording ETCS specific channels while the OTMR records other train data – as today. This can present some issues when reviewing data following an incident or failure, or as part of driver assessment, as the two logs need to be aligned to the correct time to be of use. This adds time and complexity to the process as it is likely that both systems use different software packages to view the event log.

3.5.3 To address this, the supplier fitting ETCS to the on-board can specify a timestamp event to be recorded on both the JRU and OTMR to allow easier alignment.

3.5.4 The figures below show both an OTMR and JRU download, albeit from separate vehicles. Note that the latter requires a slightly different skill set to understand what has happened, as much of the JRU's recording is event based and not live in the same sense as todays OTMR systems. The differences between the two logs make some form of alignment tool essential for maintenance and operational staff.

Figure 17: OTMR download from a Class 377 Electrostar

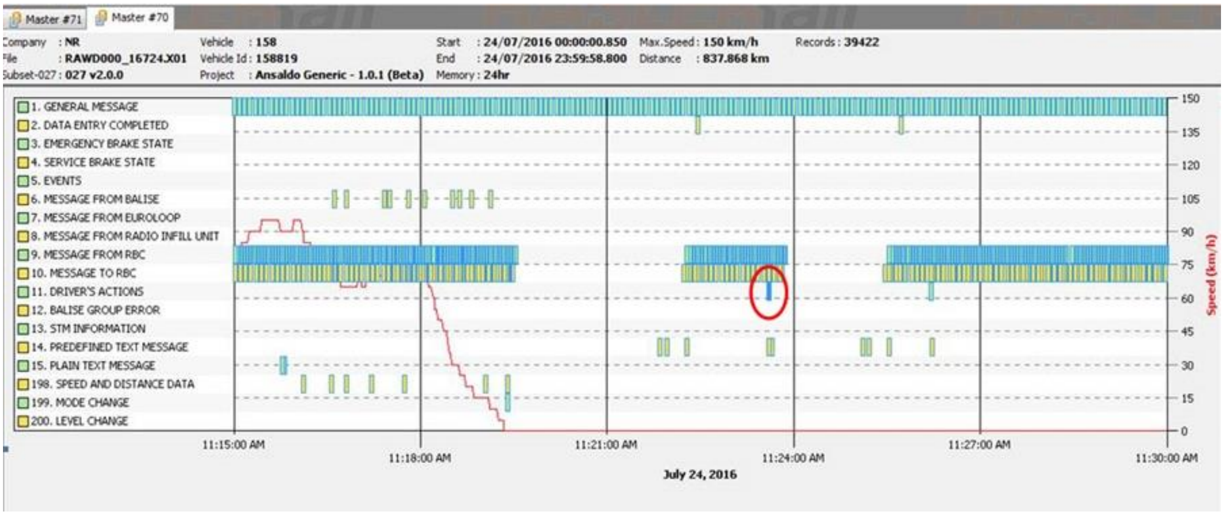

Figure 18: JRU download from a Class 158 operating on the Cambrian line

3.5.5 A solution for new builds or retrofits with limited space, would be to fit a combined OTMR and JRU unit, compliant to both GE/RT/2472 and Subset 027 of the TSI. This would reduce the volume of equipment to be fitted to space-constraint retro-fitments and reduce the points of maintenance and download that a technician would have to access.

3.5.6 Operators need to consider in the case of retrofits, that transitioning to a single recording unit can have additional impacts on both existing systems and their operations, compared to those of adding the JRU on its own. Considering the technical impact first, the existing physical interface(s) from the train to the current OTMR may need to be moved, but a preferred solution is to put the combined unit where the current equipment is currently located. In this case, the cabling is simple as the JRU connection from the EVC is just an Ethernet cable.

3.5.7 Today, the recommended ratio of Managers to Drivers is 1 per 30 so some operators could have more than 50 incident response Driver Managers capable of download and analysis using their current OTMR system. An incident may become relatively low consequence where an incident response driver manager can download, analyse data and pass on the findings to the Driver or Operations Control so that the driver can continue with his rostered duty.

3.5.8 If a combined OTMR/JRU is implemented, there will be a need to re-train both maintenance staff and operations staff. Each of the incident response driver managers would require the new software, appropriate licence and training to be able to actively respond to incidents. Remember, this capability must be available 24/7, 365 days a year.

3.5.9 There will also be a need to maintain the two software systems during the changeover period. Analysis and comparison of operational data from both these systems will be required to look at driver behaviours over time etc. As a change of system is likely to require the ability to compare data from the old and the new both during the changeover and for some time after the complete conversion.

3.6 Balise Antenna and Balise Transmission Module (BTM)

3.6.1 An ETCS Balise (also known as a Eurobalise) is a passive data-configurable transponder permanently installed in the four-foot and powered by the receiving Antenna on the train passing over it. When activated by the train the Balise will transmit a data telegram to the on-board subsystem. This interface is known as the ‘air gap’. The amount of air gap necessary will depend upon the Antenna supplier specification but could be as large as 460mm, considering vehicle gauge clearance and the installation of the Balise relative to the top of the rail.

Figure 19: Example of ‘air gap’ interface between typical on-board Balise antenna and track-mounted Balise (left) and the Balise antenna as fitted on the Class 700 (right)

3.6.2 The mechanical dimensions of the antenna vary by supplier. It may be installed either on the vehicle underframe or under the bogie. If mounting under the Bogie appropriate shock protection is required to reduce the effect of impacts and vibration.

3.6.3 Operators need to consider the impact of RSSB Guidance Note GLGN1620 which relates to magnetic field radiation. This will require appropriate procedures to be implemented for Eurobalise readers fitted to vehicles equipped with ETCS. These will need to be electrically isolated before work is commenced within 1 m of the antenna whenever the train battery is energised.

3.6.4 For work taking place within 0.3 m of a radiating antenna, a risk assessment and additional controls are advised.

3.6.5 Antenna components generally display a suitable pictorial warning and some operators display more detailed warnings on relevant parts of the vehicle.

Figure 20: Examples of ETCS antenna safety warnings on a Siemens antenna (left) and on the front of a Class 97 locomotive (right)

3.6.6 Operators need to consider the impact of the ETCS Antenna mass – This is likely to be in the region of 15Kg so will require assessment for installation and replacement.

3.6.7 Operators need to consider the impact of underframe cleaning on the Radar unit and associated connections - Care is needed when washing underframe equipment to ensure water or cleaning fluids are not forced into electrical conduits and connections.

3.6.8 The Balise Transmission Module (BTM), to perform the previously described functions, requires the electronic components to:

- Generate and modulate the Antenna tele-powering signal;
- Filter the inputs and outputs;
- Amplify the uplink telegrams from the Antenna and pass them to the EVC in a suitable format; and,
- Check that the antenna is operating correctly.

Figure 21: Under-seat mounted BTM on Class 158

3.6.9 Depending on the vehicle type and component location, the BTM can either be incorporated into the Antenna, located in the EVC cabinet electronics, or remotely located as a separate module.

3.6.10 Where the BTM is local to the EVC, the Antenna is connected to it by a coaxial cable. Where the BTM is located separately then the Antenna still uses a coaxial cable as far as the BTM, but then the uplink signal is translated into a digital data packet and sent to the EVC via an Ethernet data bus.

3.6.11 The rationale for BTM location is generally due to the component types and design constraints on the Balise Antenna cable. For some supplier's equipment with the BTM located in the Antenna assembly, the cable to the EVC can only be separated by no more than two inter-vehicle jumpers. With greater than two inter-vehicle jumpers, the Balise (BTM) signal strength will be below the specified rate for signal integrity. If a coaxial cable is used from the Antenna to connect to the BTM then as its length extends, its diameter would need to grow proportionally making installation impractical. However, the use of a BTM at each end of longer multiple units, combined with a data-bus connection through all vehicles to the EVC, does not have the same jumper cable restrictions and therefore can provide a financial cost advantage because it permits the use of a single EVC rather than two.

3.6.12 Power consumption of the BTM can be in the region of 65W.

3.7 Operation of Trackside Balises

3.7.1 Balises are required for all levels of ETCS although for Levels 0 and NTC they are limited to announcing and commanding transitions. A Balise group can consist of up to eight Balises and each Balise group can be uniquely identified. Likewise, each Balise can be uniquely identifiable within each Balise group.

3.7.2 Multiple Balises enable the train to determine its direction of travel in relation to the Balise group sequence (i.e. nominal or reverse). This also facilitates the transmission of more data to the train and provides some redundancy because identical data telegrams can be transmitted from more than one Balise. If one Balise telegram is not correctly received by the train for some reason, the duplicate Balise can repeat the message thereby ensuring reliable delivery of the data telegram to the on-board system.

3.7.3 There are two types of Balise used for ETCS:

Fixed Balise:

3.7.4 A Fixed Data Balise is programmed using a wireless programming device and transmits the same data to every train. This data would generally consist of location and linking of Balise with others, geometry of the line and speed restrictions etc. These are used at all levels of ETCS.

Figure 22: Example of Fixed Balise

Switchable Balise:

3.7.5 A Switchable Data Balise (also known as a Controllable or Transparent Data Balise) is electrically connected to a Lineside Electronics Unit (LEU). The LEU integrates with the existing signalling system by connection to the lineside signals or signal box. These are used at ETCS Level 1 only.

Figure 23: Example of Switchable Balise showing electrical connection to LEU

Operation across the Air Gap:

3.7.6 The on-board Balise Antenna Unit and BTM provide power to the track-mounted Balises by generating a magnetic field. This field is produced from the transmitting loop of the Antenna Unit. When it passes over a Balise it induces a voltage in the receiving loop of the Balise. The voltage induced in the Balise receiving loop provides sufficient power to activate the Balise and generate the up-link telegram signal for the train Antenna (receiving loop) to receive. Although possible, the provision for Balises to receive information from the train via the down-link is not currently permitted.

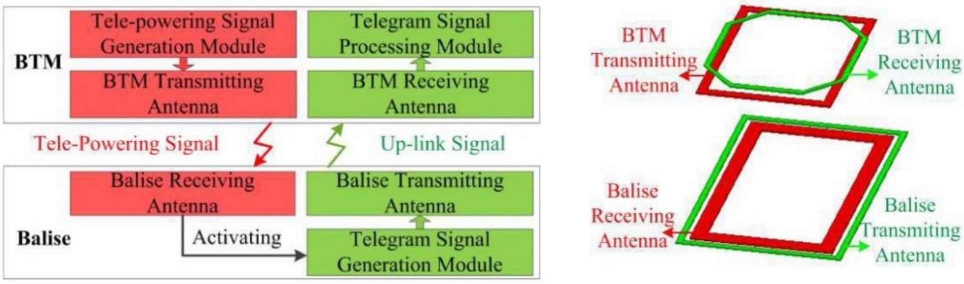

Figure 24: Diagram showing the Balise and Antenna operation across the Air Gap

3.7.7 The 'tele-powering' signal operates at a frequency of 27MHz. Once activated the Balise transmits the digital data telegram signal via the 'uplink' using frequency-shift keying with 3.951MHz for a logical '0' and 4.516MHz for a logical '1'. This permits transmission of data at a rate of 564.48 Kbit/s which has sufficient capacity to transmit three copies of a telegram to a train passing at 500km/h.

Data Telegram Construction:

3.7.8 Balise data telegrams contain information to support the operation of ETCS fitted trains and are made up of multiple packets. When ETCS fitted trains pass over Balise groups in either direction, individual packets can be made valid for either or both directions of travel.

3.7.9 A Balise transmits a 'telegram' of either 1023 bits or 341 bits in the channel encoding with 11 bits per symbol. After configuration data- the effective payload of signalling information is 830 bit for the long telegram and 210 bit for the short telegram.

3.7.10 The payload data consists of a header followed by multiple packets defined in the ERTMS protocols. Typical packets are:

- Packet 5 – Balise Linking Data
- Packet 21 - Gradient Profile
- Packet 27 - International Static Speed Profile,
- Packet 41 - Level Transition Order
- Packet 44 – Non ETCS Message e.g. TASS
- Packet 255 - End of information

3.7.11 Linking data informs about the distance to the next Balise group (one linking packet per direction) and the required train reaction if the next Balise group is missed (e.g. train stop).

3.7.12 Almost all packet types contain information confirming if it is relevant for the "nominal" or "reverse" direction (or both). If a train sees Balise 1 before Balise 2 then it passes over the group in the nominal direction. Consequently, some packets may be dropped by the application software of the receiver if they are not designated for the relevant direction.

Functional Testing:

3.7.13 Normal maintenance is regular visual inspections of Antenna. Functional checks are carried out less frequently and require the use of a laptop interfacing with either the EVC or the BTM directly.

Further Information:

3.7.14 Further information specific to Balises and their operation can be found in ERA Subsets 26/36/40/41/85.

3.8 Odometry

3.8.1 The odometry system within ETCS provides both speed and distance travelled information. This information must be high integrity and so is usually provided by more than one measurement from unique sources. ETCS can make use of rotational sensors (such as speed probes or tachometers), radar based systems, GNSS (Global Navigation Satellite Systems), optical sensors and Accelerometers.

3.8.2 In a typical configuration, the EVC will receive input from two tachometers or speed probes, on separate axles and opposing sides, and a Doppler radar mounted underneath the train facing downward to either running rail. There may also be a GNSS signal used to provide accurate time/date and back up positioning information. Alternative arrangements can be made to suit vehicle specifics.

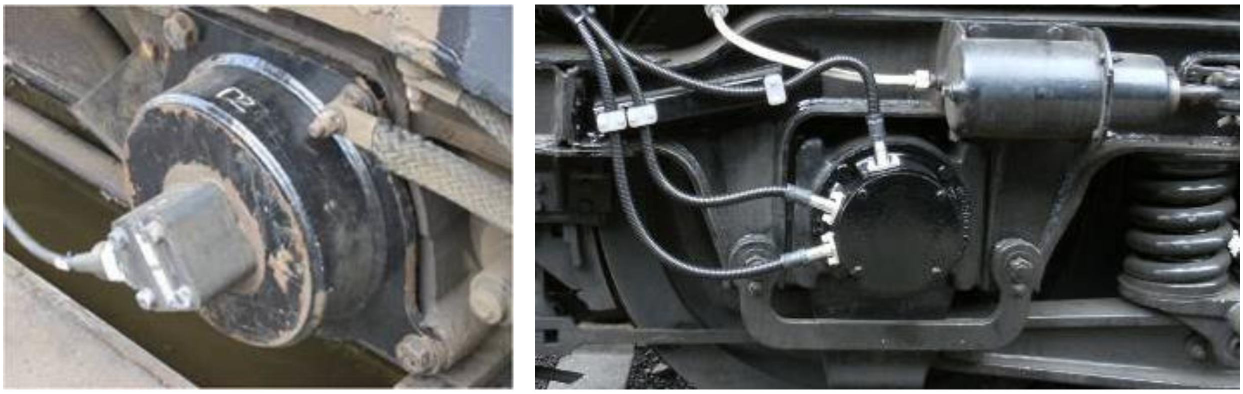

Figure 25: Odometry Examples: Tachometer on Class 158 (left) and Speed Probes on Class 97 (right)

3.8.3 The Tachometers or Speed Probes can be located either inboard on the axle or on the axle-end. These measure the rotational speed of the axle and require accurate wheel sizes to correctly calculate the linear speed and distance travelled. This form of measurement is well proven in rail application however it can be susceptible to wheel slip and slide under poor adhesion whilst taking traction and braking respectively.

3.8.4 Operators need to consider that the ETCS system requires accurate wheel sizes for the axles fitted with speed sensors. This means that the wheel sizes must be input into the system after each tyre turning, so that the system continues to accurately calculate distance travelled. Wheel sizes / tyre thicknesses are routinely measured at periodic intervals for wheel management purposes, and are accurately known at tyre turning events. ETCS fitment should not increase the frequency at which these measurements are taken and the required accuracy is no more difficult to achieve than that required today.

3.8.5 Automatic odometry calibration is an option that can be implemented, requiring no maintainer intervention at all. Two examples of such a system involve fitting Balises on a straight, plain section of track – ideally on exit from the wheel lathe or depot, and programming them such that, either:

- The EVC monitors the number of revolutions taken to pass between a pair of fixed Balises that are a known distance apart, and then calculating the new radius of each required wheel set; or alternatively,
- The EVC monitors the number of revolutions taken to read a single Balise on both the front Balise antenna and rear Balise antenna, where the distance travelled is the distance between both antennas, and the calculating the new radius of each required wheel set.

3.8.6 To maintain the systems level of robustness, the speed sensor feed is not normally taken from an existing system / sensor. However, several speed sensors can be fitted to the same axle or axle-end, as is common in other rail applications and demonstrated on the Class 97 shown above, in figure 25.

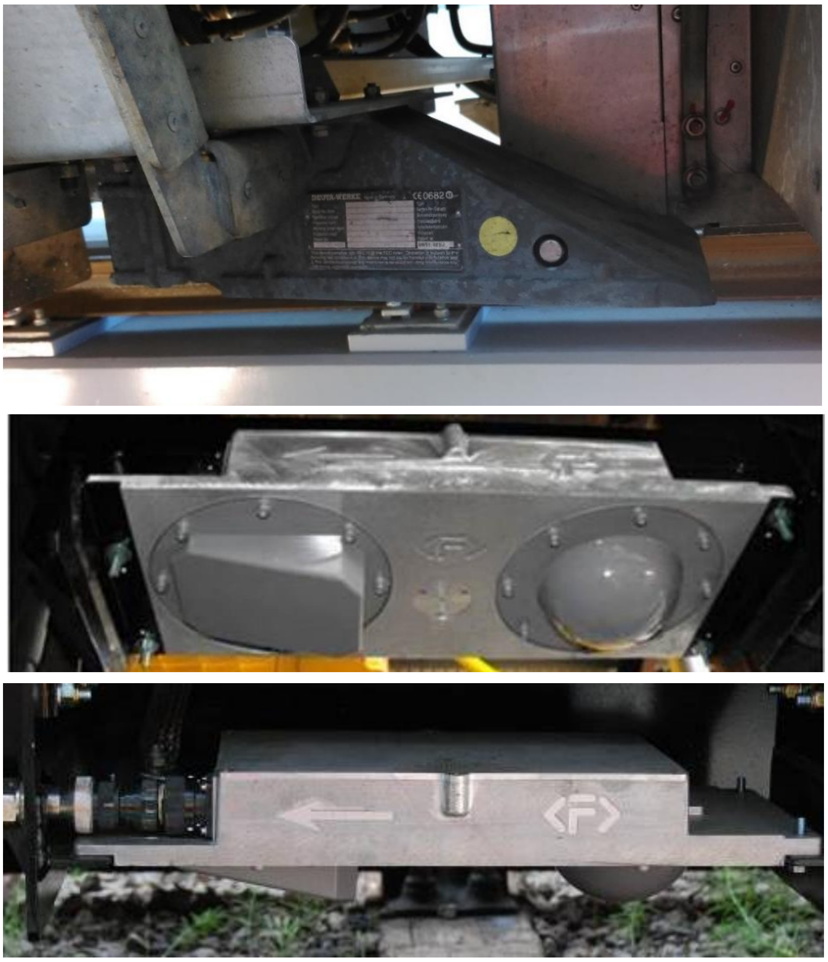

Figure 26: Examples of Doppler Radar: Deuta (top) and Faiveley (bottom)

3.8.7 A Doppler Radar uses the Doppler effect to measure instantaneous speed of the train by bouncing a microwave signal off the track-bed / running rails, and measuring the shift in frequency of the returned signal. This shift in frequency is caused by the motion of the train as per the Doppler effect. The frequency shift is used to calculate the trains linear velocity and can also be converted into distance over time. The Doppler Radar contains two separate antennas known as the Doppler and Intercorrelation antenna respectively, which face backwards and forwards, allowing the radar to cope with dynamic movement of the train in either direction.

3.8.8 Whilst the Doppler Radar is highly accurate, it can report incorrect values in harsh weather conditions or on iron bridges. A such, some forms of radar are designed with shielding around the antenna faces to protect them from the elements, such as the Deuta radar pictured above.

3.8.9 Operators need to consider the impact of RSSB Guidance Note GLGN1620 which relates to magnetic field radiation. For work taking place within 0.3 m of a radiating antenna, a risk assessment and additional controls are advised.

3.8.10 Operators need to consider the impact of underframe cleaning on the Radar unit and associated connections - Care is needed when washing underframe equipment to ensure water or cleaning fluids are not forced into electrical conduits and connections.

Figure 27: Example of a Test Rig for Doppler Radars

3.8.11 The EVC uses this information to calculate the train’s speed and position so that it can supervise the train effectively. The EVC can also use this information to periodically report its position to the trackside RBC equipment.

3.8.12 The EVC’s odometry is subject to a level of acceptable error of 50m±5%. To cope with this the EVC “grows” the front end of the train in expectation of this error, to maintain a fail-safe operation. As the train passes position references stored in trackside Balise Groups, it corrects this perceived error back to 0m (i.e. the real front-end). If the perceived error grows beyond the limit, the train will be tripped on an odometry failure.

3.8.13 As part of the route information given from the RBC, the EVC knowns where to expect position reference Balise Groups in the route. For example; on passing Balise Group 1, the EVC expects to read Balise Group 2 in 4km. The EVC will tolerate a single missed Balise Group, however on missing a second consecutive Balise Group, the EVC trips the train on a Balise Read failure.

3.9 Power Supply

3.9.1 The ETCS On-Board equipment power supply must be smooth and reliable. Depending on the manufacturer of the equipment, total power requirements are typically no greater than 500w peak power consumption.

3.9.2 A lesson learnt from Cambrian applies to Diesel units or locomotives being retrofitted, there the ETCS equipment was susceptible to a sudden voltage drop or “Brown-out” on engine start up where available voltage drops (There were similar issues with the GSM-R Voice Radio’s Drivers Control Panel fading out on start-up). Similarly, cross feeding had to be installed on the Class 158s to allow the unit to continue to power the EVC when power is lost to that vehicle (e.g. following engine failure) by feeding power from the working vehicle. Some existing DMUs already possess this functionality but require manual set up, such as switching circuit breakers. This should not be an issue with new or more modern rolling stock.

3.9.3 If there is a complete power failure on the train, the ETCS will continue to operate on battery power. Both the EOSS and ENTOSS specify a minimum time which the train should be able to support the ETCS systems continued operation.

3.10 Isolation Switch

3.10.1 In the event of an ETCS failure, it should be possible to isolate the system and continue under Class B signalling (conventional signals and TPWS/AWS) or under written orders to progress at degraded speeds to clear the line. This is done using an isolation switch in the cab, similarly to TPWS and electric supplies.

3.10.2 Typically, these switches are fitted in either driving cab, and within the EVC cubicle. Following practice of other isolation switches, the switches in the cab are to be fitted out of the drivers’ normal reach and are operated using a driving key, they can only be reset using a maintainers’ pronged key. This means that on isolating the ETCS system, the train can only continue under Class B protection and signalling, or be removed from service.

Figure 28: Isolation Switches on Thameslink Class 700

3.11 Soft Reset Switch (ERPIS)

3.11.1 A lesson from the Cambrian implementation was to fit a soft reset switch, called the ERPIS – ERTMS Power Isolation Switch. This switch temporarily isolates power to the ETCS system, facilitating a partial reboot that is quicker than a full power cycle of the system. This allows the driver to recover from faults such as Balise Read Errors or frozen DMIs rather than isolating the system and proceeding at a degraded level of protection or signalling. On Cambrian, this feature is stated to recover around 70% of ETCS issues, without needing to isolate the system.

3.11.2 This functionality is not common across all suppliers and may or may not be included within the on-board system.

Figure 29: ERPIS Switch on Class 158

3.12 Train Interface Unit (TIU)

3.12.1 The Train Interface Unit (TIU) consists of various interfaces between the existing train systems and the ETCS system (e.g. Brakes, Traction cut-off, existing safety systems, train status wires, etc.). It typically consists of a lot of electrical connections, relays and circuitry that are unique to each train class and supplier application. Whilst the TIU is commonly thought of as a single box of connections, it is more commonly distributed throughout the train depending on where suitable system access is located and certain design constraints on the level of safety integrity the interface is to have (i.e. serial and/or parallel connections).

3.12.2 The Train Interfaces include binary feeds (either on/off) and analogue signals for more complex interactions. Some common feeds include:

- Direction,
- Cab Active,
- Service and Emergency Brake Demands,
- Traction Cut-Off,
- Tilt/TASS (where required),
- Change of Traction system (where required),
- Pan Up/Down through neutral sections (where required),
- Selective Door Opening - SDO (where required),

- Train Data from Train Control & Management System (i.e. train data from MiTrac).

3.12.3 The use of some complex interfaces, such as that to traction or door systems, is dependent on the requirement and suitability of the train, and will more likely be provided on new rolling stock.

Part 4 ETCS Design Considerations

4.1 Design Options

4.1.1 When fitting ETCS to a train, there are several options to consider. The first of which is whether to group the in-train equipment within a single cabinet, or distribute the equipment throughout the train as space allows.

4.1.2 A cabinet variation will commonly be used as the ETCS On-Board equipment is common with signalling equipment, so usually found in similar assemblies, for example the 19” rack. If space permits to fit the equipment in this manner then is confines access to a single point, reducing cabling and making maintenance easier.

4.1.3 If fitting ETCS to units with less space, for example a single car unit or locomotive, the equipment can be distributed throughout with a mix of under-seat, luggage space, or roof mounted modules. The distributed option adds complexity, cabling and connections which may impact reliability of supplier’s equipment.

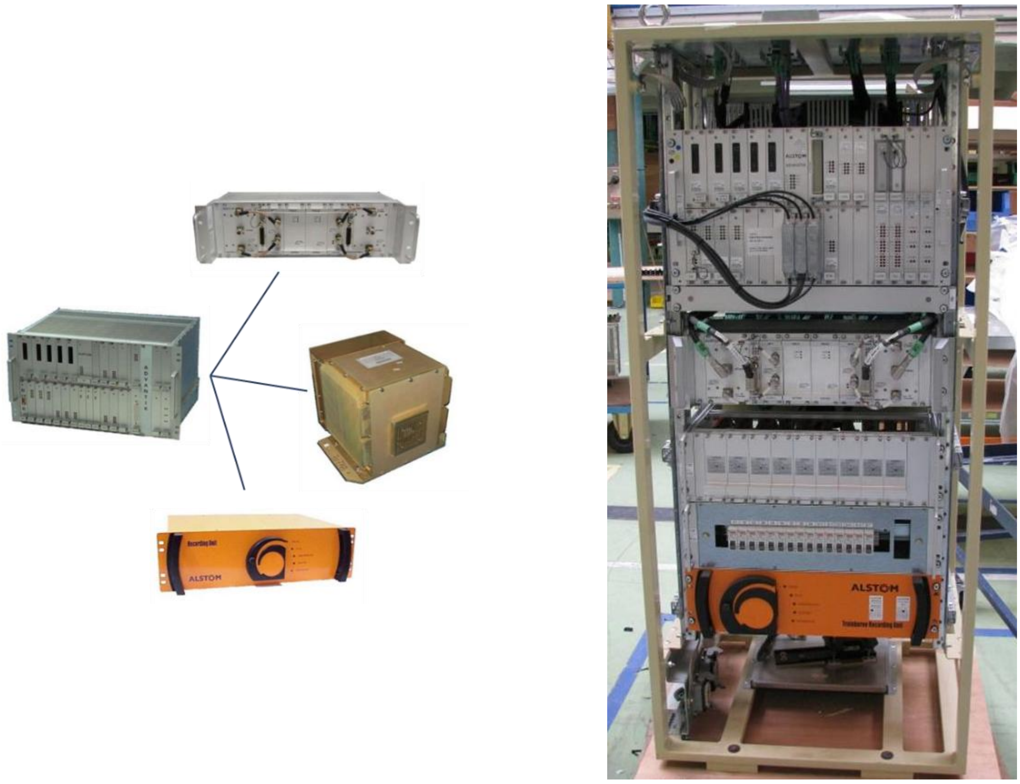

Figure 30: Example of EVC within a 19” rack (right) and split into modules (left)

4.1.4 The other main consideration is whether a train requires a single EVC solution or two. The rationale for selecting either of the two solutions (single EVC and two EVC) is mainly due to the design constraint on the Balise antenna cable. Generally, this cable can only be separated by no more than two inter-vehicle jumpers. With greater than two inter-vehicle jumpers, the Balise signal strength will be below the specified rate for signal integrity.

4.1.5 There are solutions to permit a single ETCS On-Board system on a greater than a five-car multiple unit consist through use of a Balise Transmission Module (BTM), as introduced above. A BTM uses a data backbone running throughout the train instead of a coaxial Balise antenna cable. The Balise antenna signal can then be transmitted across more than two cars i.e. more than two inter-vehicle jumpers.

4.1.6 As well as this, there is often a cost consideration. The cost of additional inter-vehicle jumpers and BTMs may pass that of an additional EVC. An added benefit of a two EVC solution is that you can run short or long formation trains without worrying about jumpers, and units can run in hybrid formations made up of spare stock or crash damaged partial units to maintain passenger capacity and flexibility of the fleet. This also means that an EVC failure only affects one driving direction as the rear EVC should still function.

4.1.7 In general, a single EVC solution suits short (five and less cars) multiple units as well as locomotives and Driving Van Trailers (DVTs). Whereas longer units benefit from having a two EVC solution, with a separate EVC in either driving end vehicle.

4.2 Examples of Cab Fitments

4.2.1 The below images show a few different implementations of ETCS within the cab, both new builds and retro-fitments. In either case the design constraints remain the same, and best practices for designing cab fitments should be applied. For more information on Human Factors considerations when designing cab fitments please refer to ATOC/RDG Guidance Note “ETCS Cab Human Factors Design Guidance”.

Figure 31: Class 700 at Three Bridges with Dual DMI shown

Figure 32: Class 374 (E320) with temporary TBL installation

Figure 33: Class 800 Intercity Express Programme train for Virgin Trains East Coast

Figure 34: Class 345 Aventra being introduced for Crossrail

Figure 35: Bombardier's ERT1000 on Italian High Speed Line

Figure 36: Class 37 (Now 97) Locomotive on Cambrian: Ansaldo fitment (left) and Hitachi (right)

Figure 37: Class 158 retro-fitment by Ansaldo, in-progress (left) and the finished job (right)

Figure 38: Network Rail owned Class 313 fitted by Alstom as a ETCS test train

Figure 39: Class 66 Retro-fitment in Holland

Figure 40: Italian High Speed Bombardier ERT500, highlights the separation between ETCS and their national system - SCMT

4.3 System Optimisation – Train Data

4.3.1 There are two Braking Models that the EVC can use to calculate the safe parameters:

- Gamma has 28 specific train characteristics and is loaded into the EVC as a pre-set which the driver can select at start of mission;
- Lambda uses a Braked Weight Percentage entered by the Driver at the start – it is the sum of the braked weight of all vehicles divided by the total weight of the train.

4.3.2 Gamma and Lambda profiles differ in their accuracy and trueness to the trains real-world behaviour. Gamma models have gone through a process of testing and fine-tuning to optimise performance from the train and drivability compared to today. Lambda models make use of much fewer characteristics that are entered into TOPs by the train preparer and then entered into the system by the driver at Start of Mission.

4.3.3 Operators need to consider that there may be a need for “fine-tuning” braking data to maintain or improve the trains existing performance and driveability. Those familiar with the introduction of Automatic Train Protection (ATP) on Western or Chiltern will already be aware of this. This fine-tuning is likely to be a supplier activity during the First in Class retro-fitment or first of class for a new build fleet.

4.3.4 Operators need to consider that obtaining accurate and sufficient data for the braking model may not be easy. This might be because it was not a requirement when the vehicle was built or braking data may not be available in the required format for older retrofitted vehicles. These vehicles may require some additional testing post-retrofit to obtain and validate driveable braking curves. For newer vehicles, it is likely that sufficient data can be obtained. Trains being procured with ETCS should have this information available as a result of pre-delivery testing. Access to braking data may also be subject to Intellectual Property Rights (IPR). Availability, accessibility and ownership of this data is likely to vary for each type of vehicle. Access to braking data is expected to be arranged by the vehicle owners with the Design Authority, as appropriate.

Glossary of Acronyms

The following acronyms appear in this Guidance Note:

(A)SDO	(Automatic) Selective Door Opening
ATO	Automatic Train Operation
ATOC	Association of Train Operating Companies
ATP	Automatic Train Protection (GB Train Protection System)
AWS	Automatic Warning System (GB Train Protection System)
BTM	Balise Transmission Module
CCS	Command, Control & Signalling
(C-)DAS	(Connected) Driver Advisory System
CMD	Cold Movement Detection
DfT	Department for Transport
DMI	Driver Machine Interface
DMU	Diesel Multiple Unit
DR	Digital Railway
DRACAS	Defect Recording and Corrective Action System
DVT	Driving Van Trailer
EDOR	ETCS Data Only Radio
ENIF	ETCS National Integration Facility (Hertford Loop)
ENTOSS	ETCS New Trains On-board Sub-System Specification
EOSS	ETCS On-board Sub-System Specification
ERPIS	ERTMS Power Isolation Switch
ERTMS	European Rail Traffic Management System
ETCS	European Train Control System
ETSI	European Telecommunications Standards Institute
EURA	European Union Rail Agency
EVC	European Vital Computer
FiC	First in Class
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GSM-R	Global System for Mobile Communications - Rail
JRU	Juridical Recording Unit
LEU	Lineside Electrical/Encoder Unit
LRU	Line Replaceable Unit
NRT	Network Rail Telecoms
NTC	National Train Control
OBS	On-Board System
OTDR/OTMR	On Train Data Recorder/Monitor and Recorder
RBC	Radio Block Centre
RDG	Rail Delivery Group
RIDC	Rail Integration Development Centre
ROSCO	Rolling Stock Company
RSSB	Rail Safety and Standards Board
SCMT	Sistema Controllo Marcia Treno (Italian Train Protection System)
SIL	Safety Integrity Level
STM	Specific Transition Module
TASS	Tilt Authorisation Speed Supervision
TBL	Transmission Balise-Locomotive (Belgian Train Protection System)
TIU	Train Interface Unit
TPWS	Train Protection and Warning System (GB Train Protection System)
TSI	Technical Standard of Interoperability
TVM	Transmission Voie-Machine (French Train Protection System)