Journal of civil engineering and transport **transEngin**

2021, Volume **3** Number **1** **ISSN 2658-1698, e-ISSN 2658-2120**

DOI: 10.24136/tren.2021.001

SELECTED RESEARCH CAPABILITIES OF THE RAILWAY RESEARCH INSTITUTE TEST TRACK CENTER IN ŻMIGRÓD ON THE EXAMPLE OF EUROBALISE

Dominik **Adamski** [1,*], Łukasz **Zawadka** [2]

[1] The Research Railway Institute, Railway Traffic Control and Telecom Department, Chłopickiego 50, 04-275 Warsaw, Poland
email: dadamski@ikolej.pl, https://orcid.org/0000-0001-5897-579X

[2] The Research Railway Institute, Railway Traffic Control and Telecom Department, Chłopickiego 50, 04-275 Warsaw, Poland
email: lzawadka@ikolej.pl, https://orcid.org/0000-0001-8023-8446

* Corresponding author

Reviewed positively: 27.02.2022

Information about quoting an article:
Adamski D., Zawadka Ł. (2021). Selected research capabilities of the Railway Research Institute Test Track Center in Żmigród on the example of Eurobalise. Journal of civil engineering and transport. 3(1), 9-16, ISSN 2658-1698, e-ISSN 2658-2120, DOI: 10.24136/tren.2021.001

Abstract – The article describes trackside part of the ERTMS / ETCS system installed on Railway Research Institute Test Track Centre in Żmigród where functional tests of „trackside Control-Command and Signalling" interoperability constituent prototypes i.e. eurobalises were conducted based on the elaborated test schedule and the conditions contained in the specifications of Susbset 040 and Subset 036. Moreover structure of an exemplary telegram sent from the eurobalise to the traction vehicle through the air gap i.e. interface A1 was shown. Selected requirements for timing and distance parameters that eurobalises have to meet during designing the trackside part of the ERTMS / ETCS system were also presented. In addition, the methodology adopted during tests was characterized and the list of functional tests carried out at the selected test site was specified. The paper summary describes the conclusions of the tests and the main features of Railway Research Institute Test Track Centre.

Key words – conformity assessment, ETCS, eurobalise, interoperability constituents, data transmission, functional tests

JEL Classification – L92

INTRODUCTION

Eurobalises are devices mounted along the track axis, transmitting data to on-board ETCS (European Train Control System) devices in the form of telegrams compliant with specific requirements [2]. There are two types of eurobalises: non-switchable eurobalises - transmitting fixed telegrams and switchable eurobalises, which also transmit variable telegrams coming from railway traffic control devices (e.g. station semaphore) via the LEU (Lineside Electronic Unit) encoder.

Eurobalise as an interoperability constituent of the trackside control-command and signalling subsystem is assessed for compliance with the relevant regulations using the appropriate assessment procedure. The main document characterizing these procedures and defining the essential requirements for the eurobalise is Commission Regulation (EU) 2016/919 as amended (so-called TSI CCS) [6]. When analysing the provisions of this document it can be noticed that an important aspect in the process of conformity assessment of trackside interoperability constituents is to check whether a given component works properly in the environmental conditions for which it was designed. Thus, this requirement determines the need to conduct tests for specific criteria on a selected test site. Test scope carried out on such test sites is often multidisciplinary and despite of more and more efficient simulation methods many of them cannot be conducted on the computer or in a laboratory environment. Research possibilities of a given test site are determined, among others, by technical parameters (e.g. length, built-in railway traffic control systems, power supply systems etc.) and logistic parameters. There are accredited laboratories on the European market, offering services in the field of Eurobalise tests in laboratory environments for compliance with the requirements of subset 085 according to latest version of TSI CCS. These tests are carried out using specialized hardware and software tools and the obtained results are necessary in the certification process of this component. Moreover it is worth to mention that The Railway Research Institute has its own Test Track Centre in Poland, which due to its high availability and the infrastructure built on it, creates optimal conditions for performing a wide range of functional checks related to interoperability constituents.

The analysis of available domestic and foreign publications in the field of testing interoperability constituents in operational conditions and in particular the testing of eurobalise prototypes, showed that this subject was not considered in the available literature. Therefore this paper was created and its further part describes the research carried out on above mentioned test site in terms of eurobalise prototypes.

1. Characteristics of the ETCS system installed on the Test Track Center

Test Track Center in Żmigród is equipped with the ETCS level 1 system type ALTRAC 6413 manufactured by Thales with a centralized structure (LEU encoders are installed in one place) [1, 4]. The system complies with the Specification of Functional Requirements ERA / ERTMS / 003204 ERTMS / ETCS FRS version 5.0 [6] and the Specification of System Requirements UNISIG SUBSET-026 version 2.3.0d [6]. On the station track No. 1 Eurobalises are installed in accordance with the Specification of System Requirements UNISIG SUBSET-026, version 3.4.0 [6] end Subset-040 [8]. ETCS telegrams on the Test Track Centre are sent to vehicles with a usage of 13 eurobalise groups. In Figure 1 these groups are marked with consecutive numbers assigned to the red triangles. The position of the signal with three lights and W18 indicator is marked as TD 1 and the location of signal with five lights and W24 indicator as TD 2. Additionally, the blue circles mark the locations of eurobalise groups (12 and 13) selected for the tests.

2. Tests methodology

After analysing the configuration of individual eurobalise groups installed on the Railway Research Institute Test Track, two eurobalise groups were selected for the purposes of the tests:

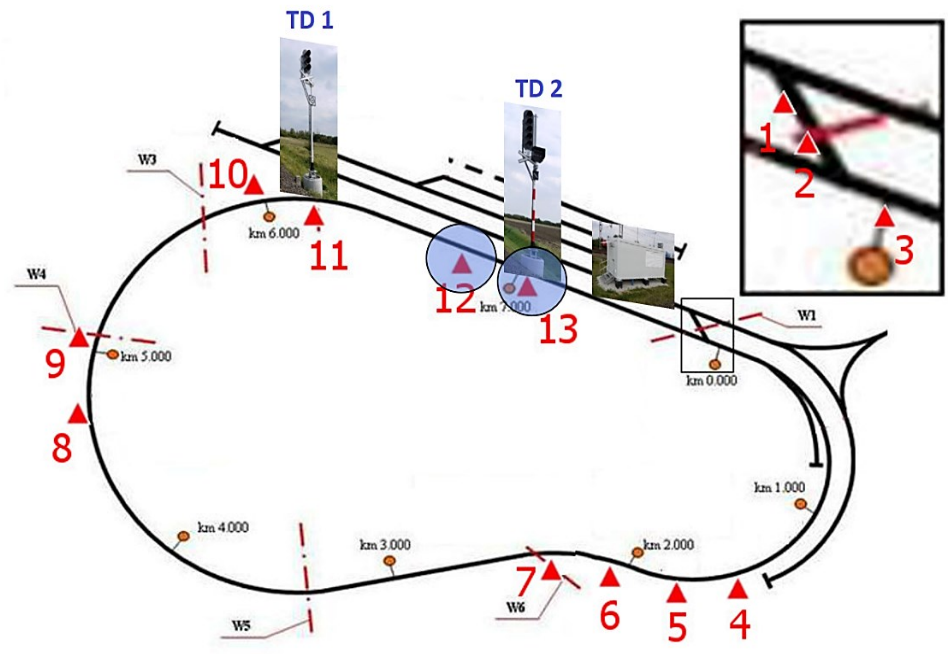

Fig. 1. Eurobalises layout on Test Track in Żmigród (own study based on [4-5])

- group 12, consisting of one switchable eurobalise, which performs the function of updating the information (infill) displayed on the signal TD2;
- group 13, consisting of two eurobalises: one non-switchable with packages of which are presented in Table 1 and one switchable related to the indications displayed on the signal TD2.

The above described selection was mainly determined by the specificity of the telegrams they sent (values of specific packets) to the on-board ETCS system devices and their logistical availability.

3. TELEGRAM PROPERTIES

Table 1 presents the values of the variables that are assigned to the telegram sent to the vehicle via the non-switchable eurobalise installed at the signal TD2. The telegram structure consists of a set of packages [3], names of which are highlighted in grey in the table 1.

Table 1. Packets values in the non-switchable eurobalise from group 13 (part 1)

Balise Telegram Header		
Variable	**Value**	**Interpreted**
Q_UPDOWN	1	Up link telegram
M_VERSION	16	Class 1, version 1.0
Q_MEDIA	0	Balise
N_PIG	0	I am the 1st
N_TOTAL	1	2 balises in group
M_DUP	0	No duplicates
M_MCOUNT	255	Fits with all telegrams
NID_C	399	399
NID_BG	16345	16345
Q_LINK	1	Linked
National Values (3)		
Variable	**Value**	**Interpreted**
NID_PACKET	3	3
Q_DIR	1	Nominal
L_PACKET	186	186 bit
Q_SCALE	1	1 m
D_VALIDNV	0	0.0000 km
N_ITER	1	1
NID_C(1)	399	399
V_NVSHUNT	5	25 km/h
V_NVSTFF	8	40 km/h
V_NVONSIGHT	4	20 km/h
V_NVUNFIT	20	100 km/h
V_NVREL	0	0 km/h
D_NVROLL	5	0.0050 km
Q_NVSRBKTRG	1	Yes
Q_NVEMRRLS	1	Immediate
V_NVALLOWOVTRP	0	0 km/h
V_NVSUPOVTRP	4	20 km/h
D_NVOVTRP	200	0.2000 km
T_NVOVTRP	60	60 s
D_NVPOTRP	0	0.0000 km
M_NVCONTACT	2	No Reaction
T_NVCONTACT	255	Infinite
M_NVDERUN	1	Yes
D_NVSTFF	10000	10.0000 km
Q_NVDRIVER_ADHES	1	Allowed

Table 1. Packets values in the non-switchable eurobalise from group 13 (part 2)

Gradient Profile (21)		
Variable	**Value**	**Interpreted**
NID_PACKET	21	21
Q_DIR	1	Nominal
L PACKET	150	150 bit
Q_SCALE	1	1 m
D GRADIENT	0	0.0000 km
Q_GDIR	0	Downhill
G_A	1	1 ‰
N_ITER	4	4
D GRADIENT(1)	83	0.0830 km
Q_GDIR(1)	1	Uphill
G_A(1)	0	0 ‰
D GRADIENT(2)	1405	1.4050 km
Q_GDIR(2)	1	Uphill
G_A(2)	2	2 ‰
D GRADIENT(3)	1300	1.3000 km
Q_GDIR(3)	1	Uphill
G_A(3)	0	0 ‰
D GRADIENT(4)	3320	3.3200 km
Q_GDIR(4)	0	Downhill
G_A(4)	1	1 ‰
Linking (5)		
Variable	**Value**	**Interpreted**
NID_PACKET	5	5
Q_DIR	0	Reverse
L_PACKET	108	108 bit
Q_SCALE	0	10 cm
D_LINK	1920	0.1920 km
Q_NEWCOUNTRY	0	Same country
NID_BG	16344	16344
Q_LINKORIENTATION	0	Reverse
Q_LINKREACTION	2	No Reaction
Q_LOCACC	1	1 m
N_ITER	1	1
D LINK(1)	5330	0.5330 km
Q_NEWCOUNTRY(1)	0	Same country
NID_BG(1)	16343	16343
Q_LINKORIENTATION(1)	0	Reverse
Q_LINKREACTION(1)	2	No Reaction
Q_LOCACC(1)	1	1 m
End of Telegram (255)		
Variable	**Value**	**Interpreted**
NID_PACKET	255	255

Table 2. Telegram format [7]

Shaped Data 83*11 = 913 or 21*11 = 231 bits	cb 3 bits	sb 12 bits	esb 10 bits	Check bits 85 bits

They contain the following categories of information:

- *Header* - it characterizes all information related to eurobalise (e.g.: unique eurobalise number with group number and country code, eurobalise number in the group, eurobalise order in the group, whether eurobalise has duplicates, etc.);
- *National values* - a set of driving parameters characteristic for the railway network of a given manager (e.g. maximum speed values for individual vehicle driving modes, distance and time parameters related to specific traffic situations, etc.);
- *Gradient profile* - data related to the characteristics of the railway line on which a given eurobalise is situated (e.g.: inclination or rise on particular sections, expressed in ‰ etc.);
- *Linking* - interconnection between selected eurobalise groups along with the expected reaction of the vehicle in the event of failure to read the next group in the expected location and execution of a predefined action, e.g. implementation of service braking. Additionally, in the package responsible for linking fallowing information can be found: nominal direction for linking, eurobalise detection accuracy, number of related objects as a function of road;
- *End of Telegram* - each telegram is ended with a packet of 255 which informs the on-board devices about the end of data transfer from the eurobalise.

Telegram format may be in two versions, a long format of length, nL = 1023 (= 93·11), and a short format of length nS = 341 (= 31·11) [7]. The bits of the telegram are denoted bn-1, bn-2, ..., b1, b0 (with n = nL = 1023 or n = nS = 341). The numbering with descending indices (from left to right) is chosen such that "left" and "right" conform with Table 2. The order of transmission is from left to right (but need not begin with the leftmost bit bn-1).

3.1. TEST SITE

The contents of the packets of listed eurobalise groups were copied and uploaded to the tested prototypes. Then so prepared eurobalises were installed in the locations marked with a blue circle in Figure 1. The switchable eurobalises were connected to the appropriate LEU encoder. The next step was to deactivate legacy installation with a special cover in order to eliminate its influence on the operation of ERTMS/ETCS on-board equipment. The method of covering these eurobalises and arranging the tested prototypes is shown in Figure 2.

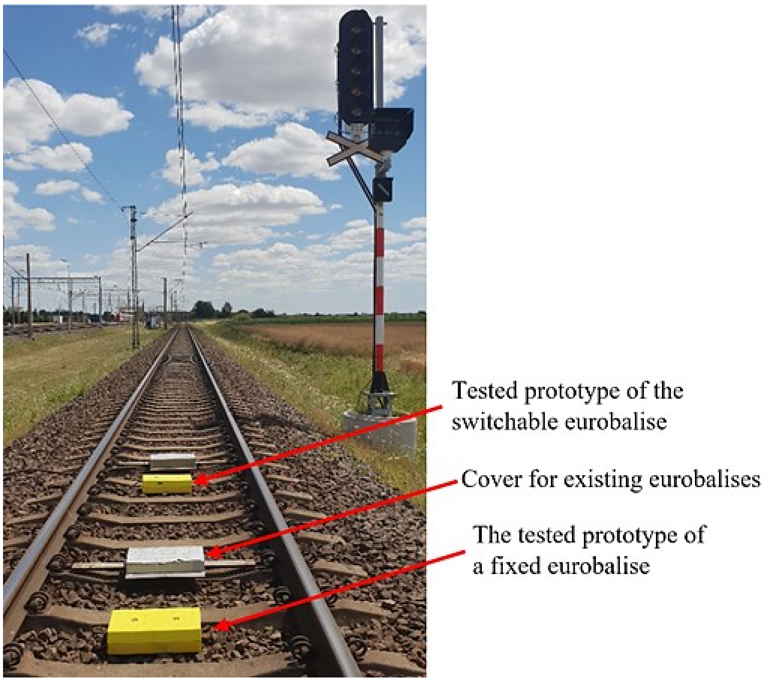

Fig. 2. Installation of a switchable and non-switchable eurobalise in group 13 (own elaboration)

The functional tests of eurobalises prototypes consisted of checking the reaction of the vehicle, equipped with the on-board ERTMS / ETCS system devices, to the telegrams from these eurobalises send through the air gap. The vehicle - eurobalise transmission is performed using the A1 and A4 interfaces (see Figure 3).

3.2. Timing and Distance Requirements

The time delay between the end of transmission of the current eurobalise (that is 1.3 m after the centre point of the current eurobalise) in a cluster of eurobalises, and the availability of data for the ERTMS/ETCS Kernel (location refer-ence information and the data from this current eurobalise) shall be less than Tn. The requirement is in general applicable in terms of constraints on distances between eurobalise groups.

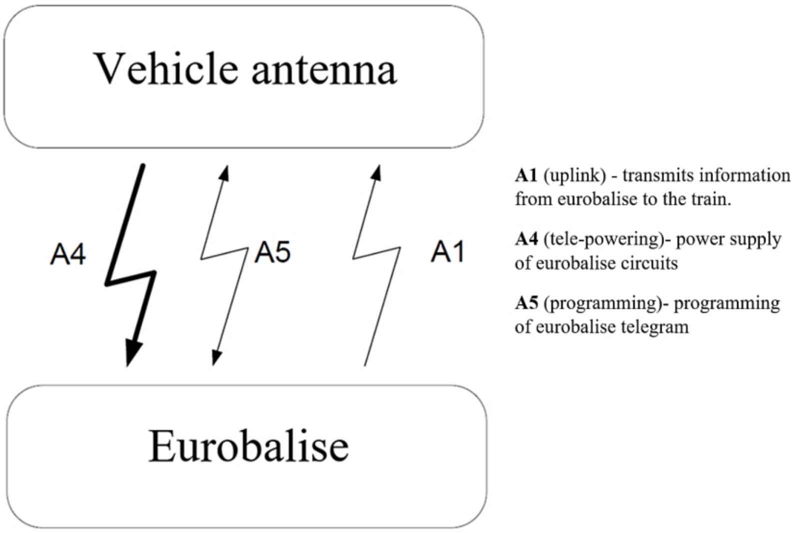

Fig. 3. Interfaces between eurobalise and vehicle's antenna (own study based on [5])

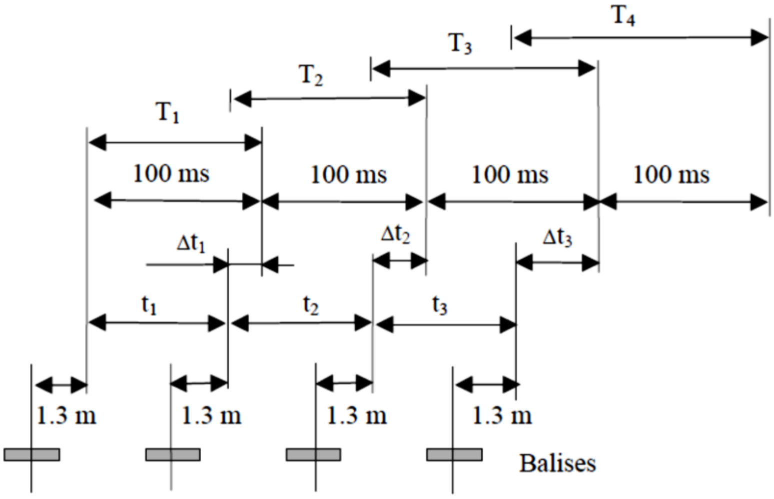

Fig. 4. Example of a passage of a cluster of four eurobalises

$$T_n = \Delta t_n - 1 \text{ ms, where } \Delta t_0 = 0 \text{ and } t_0 = 0 \quad (1)$$

$$\Delta t_{n-1} = \begin{cases} 0 \quad \text{if} \quad t_{n-1} \geq 100 + \Delta t_{n-2} \text{ ms} \\ 100 + \Delta t_{n-2} - \Delta t_{n-1} \text{ ms otherwise} \end{cases} \quad (2)$$

T_n = maximum delay from 1.3 m after the centre of the eurobalise until the Up-link data is available at the ERTMS/ETCS Kernel,

n = the number of the eurobalise in the cluster,

Δt_n = the time that the data is FIFO queued,

t_n = the elapsed time when the train moves from 1.3 m after the centre of eurobalise n to 1.3 m after the centre of eurobalise n+1.

The distance between two clusters of eurobalises shall be at least dc

$$dc = TN * vline \; [m] \quad (3)$$

dc = the distance between two clusters of eurobalises, i.e., from 1.3 m after the last eurobalise in the first cluster to 1.3 m before the first eurobalise in the second cluster,

vline = the maximum permitted speed in m/ms,

N = the last eurobalise in a cluster of eurobalises.

At low speeds of the train, an estimated location reference (with lower confidence than the location reference information delivered after the eurobalise passage) should be given in relation with the Up-link data after the maxi-mum time delay (a time-out).

4. Results

During the tests certain parameters via telegrams were sent to the ETCS on-board devices (various operating modes, speed, direction of travel, etc.) while the DMI (Driver Machine Interface) monitor indications were observed in order to verify the correct cooperation with the tested eurobalise prototypes. The adopted list of checks performed for the needs of functional tests of eurobalises carried out Test Track Centre is presented in Table 3.

Table 3. List of functional tests of eurobalise prototypes (own elaboration)

Test No.	Telegram in non-switchable eurobalise	TD2 signal indication transmitted in switchable eurobalise	Indication transmitted from switchable eurobalise – infill of information for TD2 signal
1.	Fixed telegram as described in Table 1	S6 (driving at a speed not exceeding 100 km/ h within the distance covered by signal)	S6 (driving at a speed not exceeding 100 km/ h within the distance covered by signal)
2.		S2 (driving with the highest permitted speed)	S2 (driving with the highest permitted speed)
3.		S1 (stop)	S1 (stop)
4.		Doubtful signal	Doubtful signal
5.		S1 (after the vehicle has passed the infill switchable eurobalise)	S2 (driving with the highest permitted speed)
6.		Doubtful signal (after the vehicle has passed the infill switchable eurobalise)	S2 (driving with the highest permitted speed)
7.		No indication - signal fade-out	No indication - signal fade-out

Malfunctions in the operation of the eurobalise result in the occurrence of system malfunctions, which would be displayed on the DMI, e.g. error message of the trackside equipment, or the implementation of service braking by the tested vehicle due to the lack of eurobalise in the assumed distance criterion (so-called linking error) etc. Additionally during the tests, indications from the DMI were recorded using cameras. For a detailed analysis and evaluation of the obtained results records from the JRU (Juridical Recording Unit) on-board recorder and logs from a EVC secure computer (European Vital Computer) were also took into consideration [2].

CONCLUSIONS

The example of the research presented in the article is only a small part of the research capabilities of the Railway Research Institute Test Track Center in Żmigród in terms of design, testing and, as a result, certification of ETCS components (both on-board and trackside). High availability and relatively simple formal and organizational conditions in the object separated from the structures of PKP PLK S.A. make the Test Track Center optimal testing ground for the above-mentioned projects. Thanks to the applied technical solutions wide range of research possibilities of the IK facility allows for checking selected interoperability constituents as well as entire subsystems in real environmental conditions and for atypical test cases.

Tests showed that all telegrams were sent correctly from examined prototypes and also vehicle properly received information transmitted from the eurobalises under research. There were no systemic errors or doubtful events that would require further explanation and analysis. Described checks are an important element in the process of assessing compliance with specific requirements and allow for the elimination of design errors that were not detected in the laboratory testing phase.

WYBRANE MOŻLIWOŚCI BADAWCZE OKRĘGU DOŚWIADCZALNEGO INSTYTUTU KOLEJNICTWA W ŻMIGRODZIE NA PRZYKŁADZIE EUROBALISY

W artykule scharakteryzowano część przytorową systemu ERTMS/ETCS zainstalowaną na Okręgu Doświadczalnym Instytutu Kolejnictwa w Żmigrodzie, na której przeprowadzono testy funkcjonalne prototypów składników interoperacyjności podsystemu "Sterowanie-urządzenia przytorowe" tzw. eurobalis w oparciu o autorski harmonogram sprawdzeń oraz warunki zawarte w specyfikacjach Subset 040 oraz Subset 036. Ponadto przedstawiono strukturę przykładowego telegramu wysyłanego z eurobalisy do pojazdu trakcyjnego za pośrednictwem szczeliny powietrznej tzw. Intefejsu A1 oraz wybrane wymagania dla parametrów czasowych i odległościowych stawiane eurobalisom podczas projektowania części przytorowej systemu ERTMS/ETCS. Dodatkowo scharakteryzowano metodykę przyjętą podczas badań oraz wyszczególniono wykaz testów funkcjonalnych przeprowadzonych na wybranym poligonie badawczym. W podsumowaniu opisano wnioski z przeprowadzonych testów oraz główne cechy infrastruktury badawczej Instytutu Kolejnictwa.

Słowa kluczowe: ocena zgodności, ETCS, eurobalisa, składnik interoperacyjności, transmisja danych, testy funkcjonalne

REFERENCES

[1] Massel A. (2021). Rola Okręgu Doświadczalnego Instytutu Kolejnictwa w Badaniach Taboru i Infrastruktury Kolejowej. Warszawa, Żmigród, ISBN 978-83-943246-5-0

[2] Młyńczak, J., Toruń, A., Bester, L. (2016). "European Rail Traffic Management System (ERTMS)". In: Sładkowski, A., Pamuła, W. (eds) Intelligent Transportation Systems – Problems and Perspectives. Studies in Systems, Decision and Control, vol 32. Springer, Cham. pp 217-242. https://doi.org/10.1007/978-3-319-19150-8_7

[3] Pawlik M. (2015). Europejski System Zarządzania Ruchem Kolejowym. Przegląd funkcji i rozwiązań technicznych - od idei do wdrożeń i eksploatacji. KOW, Warszawa, ISBN 978-83-943085-1-3

[4] Toruń A., Zakrzewski K. (2016). "Instalacja badawcza systemu ERTMS/ETCS poziomu 1 na okręgu doświadczalnym Instytutu Kolejnictwa w Żmigrodzie". V Międzynarodowa Konferencja Naukowa "Najnowsze technologie w transporcie szynowym".

[5] Praca Instytutu Kolejnictwa nr 000633/10 X 2019

[6] Rozporządzenie Komisji (UE) 2016/919 z dnia 27 maja 2016r. zmienione przez Rozporządzenie wykonawcze Komisji (UE) 2019/776 z dnia 16 maja 2019 r.

[7] Subset-036, FFFIS for Eurobalise, Issue 3.1.0, December 2015

[8] Subset-040, Dimensioning and Engineering rules, Issue 3.4.0, December 2015