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rmRailProtector 4.0 – the innovative Rail-Mil components based family for the ERTMS/ETCS L1 functionality

Abstract: The article presents a family of innovative products rmRailProtector 4.0, which are a comprehensive solution for the ERTMS / ETCS functionality on L1 level. The presented system was developed in Poland using Polish technical thought and the potential and many years of experience of Rail-Mil in the design, production, implementation and operation of train traffic control systems. The rmRailProtector 4.0 system thanks to cooperation with the experts of KOMBUD S.A. Automation Group as a comprehensive solution, it is adapted to work with the MOR-3 – multi-computer interlocking system used to control of railway traffic. The first planned implementations of rmRailProtector 4.0 systems assume a configuration consisting of MOR-3 interlocking system and rmRailProtector 4.0 system with ERTMS / ETCS level L1 functionality. rmRailProtector 4.0 covers devices, including: Eurobalises in the fixed and programmable version, an innovative fiber interface in the LEU-Eurobalise relation, standard and centralized LEU encoders as well as programming and diagnostic tools, according to the CCS TSI requirements (Technical Specifications for Interoperability, Control-Command and Signaling). The article synthetically summarizes the basic functional, formal and legal aspects of the proposed solutions, with reference to the requirements for the interoperability of the rail system. An innovative approach to the design of the ERTMS / ETCS L1 system was presented in detail, including the wide application of fiber optics in the connection of Eurobalise with LEU and the innovative supply of Eurobalise using optical interface. The article intentionally omits the presentation of centralized LEU, including innovative LEU with an optical interface, which will be presented in subsequent publications. The approach presented above is a new quality in the area of extensive network design at large railway stations. The innovation of the presented solutions found expression in the complex to Patent Office of the Republic of Poland with the patent application identification number: P.430674.

Keywords: Eurobalise; ERTMS/ETCS; fiber-optic interface

Introduction

Innovative components of the rmRailProtector 4.0 system manufactured by Rail-Mil are a response to market needs expressed by rail infrastructure managers [8], [9]. The presented solution is developed in Poland and based on the company's many years of experience in implementing research and development projects and its production potential.

The National Plan for the Implementation of the Technical Control Interoperability "CONTROL" [1], adopted for implementation by the Ministry of Infrastructure and Construction of the Republic of Poland in 2017, provides for the equipment of railway lines covered by the plan according to the numerical values listed in Table **1**.

Table **1**. Costs of building the ERTMS.ETCS system on railway lines covered by the plan

	ETCS level L1	**ETCS level L2**	**GSM-R**
Line length	3 555 km	4 678 km	13 680 km
Unit cost	PLN 260 000 /km	PLN 485 000/km	PLN 205 000/km
In total	PLN 0,924 bn	PLN 2,26 bn	PLN 2,80 bn
In total, the whole plan	PLN 5,894 bn		

Source: [1]

The potential implementation area indicated above, which includes railway lines that will be equipped by the TSI CCS implementation plan and the fact that by introducing the presented solutions Rail-Mil will be the only Polish supplier of ERTMS/ETCS components allows to state that this is a strategic and economically justified direction of development.

The rmRailProtector 4.0 system thanks to cooperation with the experts of Zakłady Automatyki KOMBUD S.A. as a comprehensive solution, it is adapted to cooperate with a multi-computer station dependency system used to control railway traffic of the MOR 3 type. The first planned implementations of the rmRailProtector 4.0 systems assume a configuration consisting of a station type MOR-3 dependency system and the rmRailProtector 4.0 system with ERTMS/ETCS level L1 functionality.

rmRailProtector 4.0 – ERTMS / ETCS components from Rail-Mil

The rmRailProtector 4.0 system is based on the following components of the Q7 family produced by Rail Mil.

Q7-BL-FX –fixed Eurobalise

Compliant with the specification of requirements for ERTMS / ETCS system components assembled in SUBSET-036 [2] reduced type balise. Programming takes place through an air gap, using dedicated balise Q7-UPKE or Q7-UPKE-HAND programmers.

An innovative solution is an option of deactivating the lineside track from the programming device without the need for a metal cover (shutter) to turn off. The color of the cover is always determined by the Purchaser. Fig. **1** shows the fixed Eurobalise in RAL 1016.

The basic technical parameters of the Eurobalise non-switchable type: Q7-BL-FX are presented in Table **2**.

Fig. **1**. Non-switchable type type Q7-BL-FX [4]
Source: internal materials of Rail-Mil [4]

Tab. **2** Fixed eurobalise type Q7-BL-FX - list of basic parameters

track-side balise type	reduced type balise
resistance to pollution	class A
programming method	using an air gap
special features	option to deactivate balise
the method of attachment	from the programmer level
physical dimensions	drilling in 200mm spacing,
housing color	M12 screws, recommended version made of A04 or A02 steel

Q7-BL-TR – transparent Eurobalise

Compliant with the specification of requirements for ERTMS/ETCS system components assembled in SUBSET-036 [2] Reduced type balise, supporting standardized by specifications C1, C6 interfaces without C4 interface.

Programming, similarly as in the case of non-switchable balises, takes place through an air gap, using dedicated balise programmers. An innovative solution, as in the case of non-switchable balances, is the option to deactivate the trackside balancing from the level of the programming device Q7-UPKE-HAND or Q7-UPKE.

Basic technical parameters of fixed Eurobalise type: Q7-BL-TR, is summarized in Tab. **3**.

Fig.**2**.Transparent Eurobalise type Q7-BL-TR
Source: internal materials of Rail-Mil [4]

Tabl.**3**. Transparent Eurobalise type Q7-BL-TR - list of basic parameters

track-side balise type	reduced type balise
resistance to pollution	class A
programming method	using an air gap
special features	- option to deactivate the balise
the method of attachment	from the programmer level,
physical dimensions	drilling in 200mm spacing,
housing color	M12 screws, recommended version made of A04 or A02 steel
supported interfaces	440x250x55 [mm]
maximum installation distance from LEU	RAL1016 for PKP PLK

Q7-BL-FO – Transparent Eurobalise with an innovative fiber interface

Compliant with the specification of requirements for ERTMS / ETCS system components assembled in SUBSET-036 [2] reduced type balise with an innovative fiber optic interface, supporting C1, C6 interfaces, and C4 interface as well as full internal diagnostics according to its standard. Programming, similarly as in the case of fixed balises, takes place through an air gap, using the dedicated baler programmer Q7-UPKE.

Tab. **4**. Transparent Eurobalise with an innovative fiber optic interface type Q7-BL-FO - list of basic parameters

track-side balise type	reduced type balise
resistance to pollution	class A
programming method	using an air gap
special features	- option to deactivate the balise
the method of attachment	from the programmer level,
the method of attachment	- fiber interface based on MM (Multi Mode) transmission;
physical dimensions	- full on-line diagnostics of the state of Eurobalises
housing color	drilling in 200mm spacing,
supported interfaces	M12 screws, recommended version made of A04 or A02 steel
maximum installation distance	drilling in 200mm spacing,

A detailed description of the innovative fiber interface is presented later in the article.

Q7-UPKE– Eurobalise programmer

Programmers dedicated to those produced by Rail-Mil Eurobalise are available in standard and handy versions. Figure **3** shows the programmer in the standard version.

Fig. **3**. Eurobalise type Q7-UPKE programmer - standard version
Source: internal materials of Rail-Mil [4]

Programmers in both versions use interface A in balises reading. Programming takes place through the air gap. Integrated batteries allow for not less than 20 hours of continuous operation of Q7-UPKE and 50h of Q7-UPKE-HAND after full charging. The housing is made of the IP65 protection class. The device can access via WiFi network used for diagnostic purposes and read data for dedicated software.

The programmer is synchronized in terms of location and time synchronization with the integrated GPS transmitter.

Q7-UPKE and Q7-UPKE-HAND

The programmers have the unique functionality of deactivating the trackside balancing from the programmer level. This process includes the steps listed below (in order of realization):

in the scope of checking the status of Eurobalises:

- place the programmer above the center of the balise;
- activate the programmer;
- the programmer automatically after examining the status of the checked balances, active/inactive, displays it on the information panel in the form of an LED indicator;

in the scope of deactivating Eurobalises:

- place the programmer above the center of the balise;
- press the LOCK button (deactivation)
- after receiving feedback on the change of the bale status from active to deactivated status, it will no longer be detected by vehicles equipped with functional vehicle ERTMS/ETCS devices;

The activation process is analogous to the above, and after it is carried out, the activated balise is again detected by vehicles passing over it equipped with functional vehicle ERTMS/ETCS devices.

Thanks to the built-in GNSS (modern GPS version), the programmers have the additional functionality of line diagnostics, it is possible to quickly jump over the line to rip and remove the following diagnostic information:

- telegrams
- serial number data
- diagnostic data

- the position of balises
- time and moment of reading
- locked/unlocked status

Q7-PROG – dedicated Eurobalise programming software

The Q7-PROG software is compatible with the Eurobalise dedicated to programming the Q-UPKE programmer, whose characteristics are presented above.

Figure **4** presents the graphical user interface of specialized software. The most important characteristic features should be indicated:

- compatibility with Rail-Mil Eurobalise programmers;
- Eurobalise programming functionality;
- balise reading via interface A using an air gap;
- decoding the telegram to the ETCS language;

As innovative features in relation to Q7-PROG software should be indicated:

- the ability to easily copy telegrams from one balise to the next;
- the possibility of activating and deactivating the balises using the programmer;

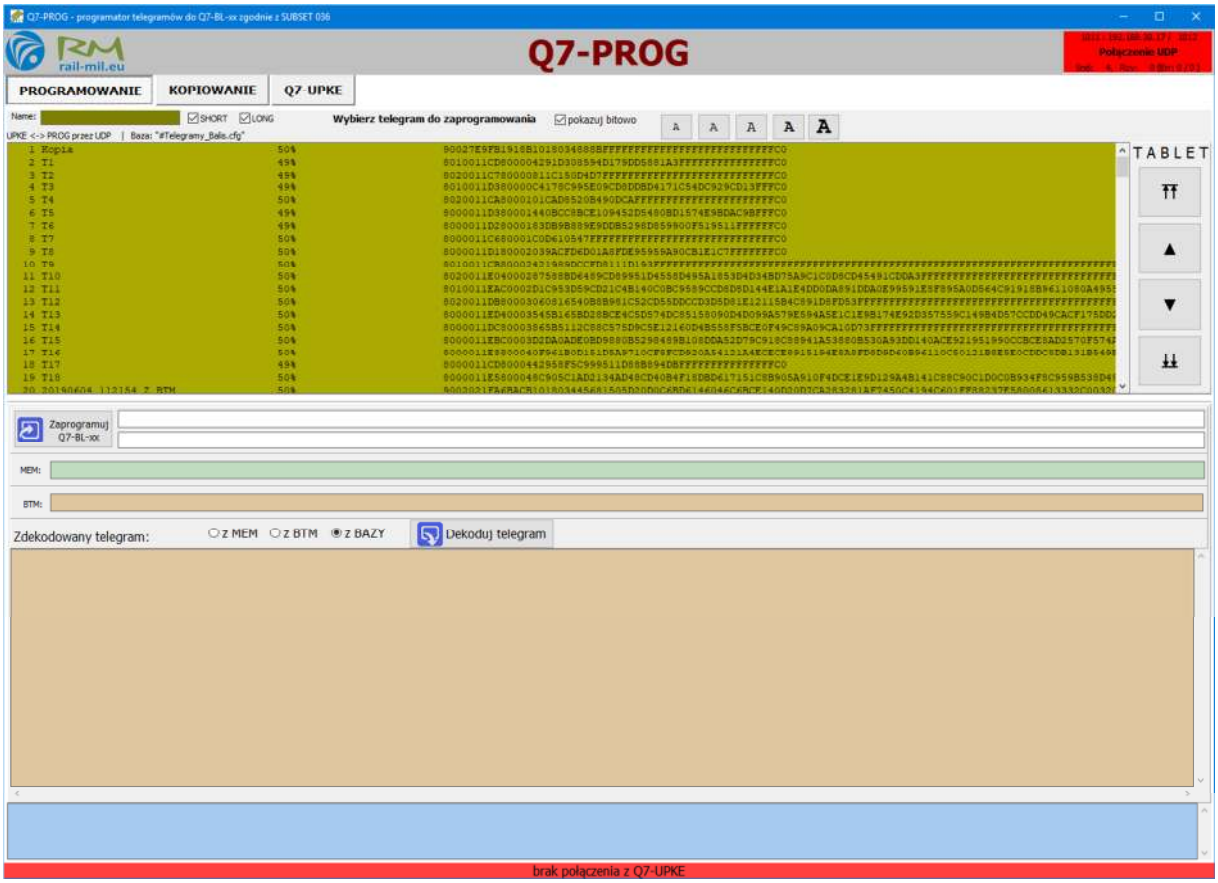

Fig. **4**. Eurobalise programming software - graphical user interface
Source: internal materials of Rail-Mil. [4]

Programming of Eurobalises is carried out according to the steps listed below (upon the correct sequence), for the received telegram package:

- conversion/import to Q7-CREATOR software or developing them in software;
- generating the final telegram for Eurobalises;

- defining the required telegram format (short/long);
- placing the Q7-UPKE/Q7-UPKE-HAND programmer over the center of the balise;
- software connection with the programmer using a transmission cable or in a wireless form via Wi-Fi;
- releasing available commands for:
    - balise programming;
    - content verification (telegram).

Fiber optic interface as an innovative solution for data transmission in the LEU-Eurobalise relation

The connection of the eurobalise with the dependency system is carried out through the LEU (Lineside Electronic Unit) encoder unit. The interface between Eurobalise and the LEU encoder is standardized and specified in [2] as the "C" interface. The "C" interface forwards telegrams generated by LEU to Eurobalises, which transmits them further to vehicle devices.

Since the cable is considered part of Eurobalise, the specification applies in particular to the connection to LEU. The solution preferred by the specification applies to cables up to 500 m (requirements for longer cables are not standardized). Signals transmitted via the "C" interface must be independent of polarity - which means that swapping two input wires will not affect the received bitstream.

The specification in [2] defines four different "C" interfaces:

- „C1” – up-link,
- „C4” – the output of blocking telegram switching in LEU (option),
- „C5” – Eurobalise programming input (no standardization),
- „C6” – power input.

The "C1" interface is used for telegram transmission from LEU to Eurobalises. The transmission medium should be transparent to the sent messages. The baud rate should be 564.48 kbit/s.

The "C4" interface is used to transmit to LEU information that Eurobalise is powered by on-board equipment of a vehicle passing over it, and then the change of the telegram sent by the LEU should be blocked.

The "C6" interface is used to supply the up-link Eurobalise input interface circuits. The signal should be a sine wave with a frequency of 8.820 kHz ± 0.1 kHz.

The Rail-Mil company proposes an innovative implementation of the "C" interface based on fiber optics. The solution includes interfaces "C1", "C4" and "C6", using fiber optic cable for both two-way digital data transmission as well as for supplying the Eurobalises logic system.

The technology of sending energy to the power supply, and not just (or instead) of digital PoF (power-over-fiber) data transmission, allows the resignation of separate metallic data transmission and power lines [6], [7]. It currently applies to power devices with the power of several watts, which in the case of eurobalise is fully sufficient. It is worth emphasizing, however, that fiber optic technology enables powering devices with many times higher power [10]. Multimode optical fiber is used in conjunction. Figure **5** shows the optical to electrical converter.

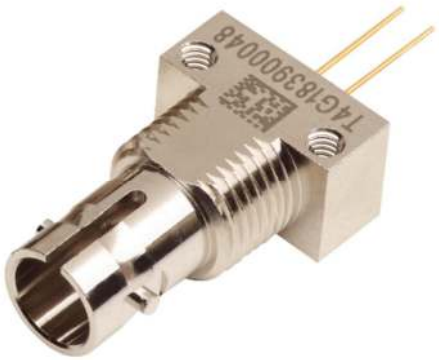

Fig. **5**. Optical to electrical energy converter in the 800-850nm band.
Source: [5]

Figure **6** shows a diagram of the relationship between LEU and Eurobalise using fiber optics based on the components of the rmRailProtector 4.0 family. Two solutions were created using four or five fibers. Logically, four interfaces can be distinguished:

- 1 – 2: power supply for Eurobalise's logic (interface "C6"),
- 2 – 7: transmission of telegrams (interface "C1"),
- 8 – 3: transmission of information on blocking telegrams from the LEU (interface "C4") and diagnostic data,
- 4 – 9 – 5: fiber optic line integrity check.

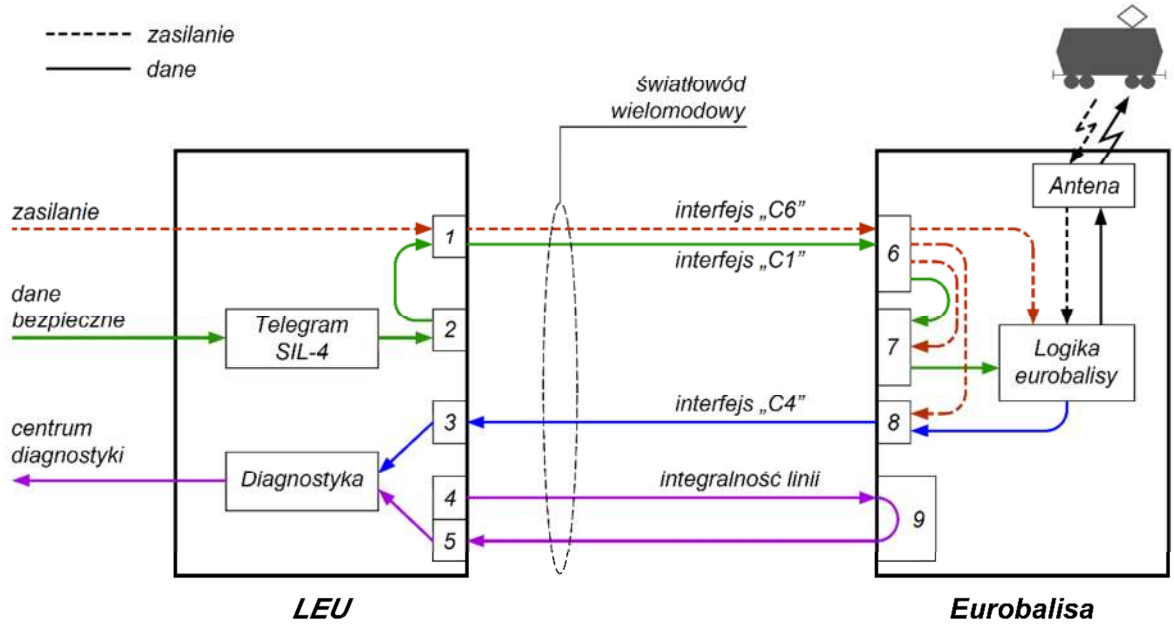

Fig. **6**. Connection diagram of LEU and Eurobalises with a fiber interface (description in the text).Source: Rail-Mil internal materials. [4]

The use of fiber optic connection for Balise-LEU cooperation is a legally protected solution for Rail-Mil (application number is P.430674)

The fiber interface is not explicitly defined in the TSI in terms of technical implementation. However, it is in the functional scope most compliant with the requirements specified in [3].

The use of fiber optic cable in the implementation of the "C" interface has several advantages that make this solution more advantageous than metallic connections:

- increasing the maximum distance between Eurobalise and LEU to 3000 m (which enables centralization of LEU even at very large railway stations),
- resistance to electromagnetic interference, surges, lightning,
- resistance to interference from the outside (cyber security),
- transmission of information from Eurobalises to LEU, including full diagnostic information,
- continuous control of fiber optic line integrity,
- simplification of cabling - direct connection of the optical fiber to the Eurobalise,
- galvanic separation of connected devices,
- reduction of theft risk due to the lack of a copper cable.

Eurobalise with fiber optic interface type Q7-BL-FO will be adapted to work with the LEU encoder equipped with the appropriate interface on its side. For Rail-Mil devices, this will be a Q7-LU-FO3 encoder. In this case, Eurobalise must be supplied with the LEU, so the grouping of interoperability constituents may be used following sections 4.2.7.4 and 5.2.2 [3]. A group defined by its functions and by other external interfaces is considered to be an interoperability constituent.

Conclusions

The concept of the innovative rmRailProtector 4.0 product line presented in the article is a response to the market demand for the highest quality solutions and with the best technical parameters, significantly exceeding the requirements specified as minimum for this class of devices.

The implementation of the ETCS system in Poland is and will be a long-term process involving very different sections of railway lines [8], [9]. Installing the ETCS L2 system is expensive [11] and will not be cost-effective everywhere. In such cases, an alternatively designed ETCS L1 system can be an alternative. Such a system should be based on fiber-optic technology enabling a significant extension of transmission lines, modern eurobalise programming tools, and centralized LEU and obtaining information from the interlocking that will allow better use of information processed in the base layer, improve operational results and ensure smooth traffic [12]. All the above-mentioned demands are met simultaneously by the Rail-Mil rmRailProtector 4.0 family of products.

The presented solution is adapted to work with a multi-computer station dependency system used to control railway traffic type MOR 3 produced by Zakłady Automatyki KOMBUD S.A. The first implementations of the rmRailProtector 4.0 system are planned as joint implementations in cooperation with the abovementioned companies.

The set direction can be successfully considered right because the conducted research and tests confirm the high reliability and effectiveness of the proposed solutions. The rmRailProtector 4.0 family sets a completely new quality in the design, installation, and operation of the ETCS L1 system. Soon, it will also be possible to check the system under actual application conditions. Further work will, therefore, focus not only on the improvement of the devices themselves but also on the principles of designing systems built from them. This is to make full use of the opportunities arising from the implementation of the ETCS system on the railway network.

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