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ANALYSIS OF THE ANALOGUE AND DIGITAL COOPERATION OF THE RAILWAY RADIO COMMUNICATIONS IN THE CONTEXT OF THE EMERGENCY CALL

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Abstract

The paper presents the selected issues concerning the migration between the VHF 150 MHz communication and the GSM-R standard, which will be operated in the Polish railway industry at the same time. The analysis of the RADIOSTOP railway alarm signals in the VHF 150 MHz radio communication network was conducted. The service of the REC emergency call in the GSM-R system was characterised. Then, the technical problems related to the generation of alarm signals in the migration period were described. In addition to the problems associated with the technical aspect of connection of both alarm signals, the issues resulted from their radio range were analysed.

Emergency call service REC / e-REC in the GSM-R system, analysis and assessment of the implementation of the emergency call function during the migration period, phases of the REC emergency call, railway emergency call service, generation of the alarm signals during the migration of systems, differences in the range of the GSM-R and VHF 150 MHz systems, implementation of GSM-R on the entire railway line are presented in the paper

Keywords: *railway, radio connection, alarm call, GSM-R system*

1. Introduction

After the Polish accession to the European Union, and on the basis of the Treaty of Association of the European Union (EU) as well as the necessity to use and implement the EU legislation, the Republic of Poland adopted, among others, the policy of opening the market for products and services in the area of rail transport. Thus, Poland committed itself to the implementation of the interoperability requirements that is the harmonisation of the following conditions: legal, technical and organisational ones in the European rail system. These requirements were specified in Directive 2008/57/EC [1].

The system interoperability means the ability to provide the safe and uninterrupted movement of trains, which meet the required level of performance for these lines. The adoption of the standardised rail traffic management system was necessary to ensure the interoperability. The supported by the European Union project of the standardised rail traffic management system is called ERTMS (*European Rail Traffic Management System).* The European Rail Traffic Management System (ERTMS) guarantees the possibility of free movement of trains in the rail networks of individual countries without the necessity to stop at borders. ERTMS consists of the European train control system (ETCS) and railway communication system (GSM-R). Thanks to ERTMS, the driver receives the detailed information on acceptable parameters of traffic on a given section of the railway, and the system passes on all the messages to the driver desk. GSM-R is a transmission medium for the ETCS system (level 2 and 3), by the means of which, among others, the authorisations for train movement issued by RBC (*Radio Block Centre*) are sent. GSM-R replaces a series of national railway radio communication systems, and its implementation results not only in the improvement of the quality of radio communication, but it also allows to eliminate the barriers stemming from different standards of the voice communication and data transmission operated in Europe [3, 4].

Currently, the railway network in Poland operates in the 150 MHz band, and the system is a base for the implementation of the GSM-R and ETCS systems. After the successful introduction of the systems to operation, the 150 MHz radio will be disabled in the provided time windows. However, the replacement of the 150 MHz radio with the GSM-R standard requires simultaneous operation of these networks during the migration. It should be noted that there are certain problems associated with the connection of the RADIOSTOP alarm signals of the VHF 150 MHz and REC radio communications and the GSM-R system.

The problem of organisation of the radio network operation, taking into account both the requirements for the continuity of the telecommunication service provision and secure transmission as well as cooperation with the recently operated analogue radio communication network VHF 150 MHz is one of the key issues in the implementation of the GSM-R system.

2. RADIOSTOP signal analysis

According to Directive 2012/88/EU, the B class systems include a limited set of the existing national communication and train control systems, which were in operation before 20 April 2001. The overview of these systems is in the published by the European Railway Agency technical document called "List of CCS Class B systems" (ERA/TD/2011-11, version 2.0). These systems significantly impede the interoperability of locomotives and rail traction vehicles, but they play an important role in maintaining a high level of security on the trans-European rail network. According to the ERA/TD/2011-11 document, the system defined as "*SHP PKP radio system with Radiostop function*" was one of the indicated B class communication systems. Thus, the analogue VHF 150 MHz system with the RADIOSTOP function constitutes the B class railway communication in Poland. In order to prevent the creation of additional obstacles to the interoperability, the Member States should ensure the further functioning of the existing B class systems as well as their interfaces in accordance with the current specifications, unless the modifications aimed at removal of the defects, which relate to the security of these systems, are necessary [16].

In the currently operated VHF 150 MHz analogue system, in order to improve the safety of the rail traction vehicle traffic, the RADIOSTOP system, which is combined with the train radiotelephone, is applied. Activation of the RADIOSTOP signal by the driver is conducted by pressing the "Alarm" button on the radiotelephone keypad, which results in sending a special sound signal via radio. The "Alarm" signal is a combination consisting of three consecutive short tones, which vary in frequency and periodic repetition [8, 9]. As a result, the carrier signal is modulated by a defined sequence (3x100 ms) of three acoustic signals f_1 = 1 160 Hz, f_2 = 1 400 Hz and f_3 = 1 670 Hz followed by the interval of 500 ms. The signal is continuously transmitted until it is switched off. An employee, who transmitted the "Alarm" signal, should immediately inform via the radiotelephone on the emergency channel the nearest signaller about the reason of the signal transmission. It does not apply to the employees who must leave the control cabin in an emergency. The signaller should immediately inform a dispatcher about this fact [6]. Activation of the RADIOSTOP function is conducted by pressing the ALARM button and it results in immediate automatic braking of the trains, which are in the area of a given radiotelephone. The automatic braking is implemented if the radiotelephone at the rail traction vehicle is connected with the SHP devices – the automatic train braking devices. The devices used in PKP (Polish railways) are not dependent on the indications of the railway signals.

The RADIOSTOP signal receivers unlock the radiotelephone frequency modulation path, allowing the speaker emits the acoustic signal. If the on-board radiotelephone is connected to the SHP devices, then the automatic braking of trains, which are in the area of the generated signal, takes place.

The button, which activates the alarm signal, should be red and ergonomically shaped. Its design and location should ensure an easy access for the user, as well as protect against the accidental use of the button. The ALARM signal itself is a combination consisting of three consecutive short tones, which vary in frequency and periodic repetition. The RADIOSTOP function working on the lines covered by the GSM-R development will be used until the dismantling of the 150 MHz radio system on these lines and was included in the Specific Transmission Modules (STM) for the SHP system.

3. Emergency call service REC / e-REC in the GSM-R system

The railway emergency calls are used to transfer information about the dangers, which require taking specific actions or in a given area that require action or stoppage of the train movement, to the railway personnel. The REC (*Railway Emergency Call*) service is one of the most crucial GSM-R services and it can be activated by pressing the alarm button in radiotelephones and cabin radios in case of noticing any danger. There are two types of railway emergency calls:

– the emergency calls for trains unrelated to the shunting operations,
– emergency calls related to the shunting operations.

The connection type is determined automatically on the basis of the terminal operational mode that initiated the call. It is necessary that the railway emergency call be transmitted to all drivers and signallers within the operating area, in which the danger occurred.

The REC service is one of the most important GSM-R services. The emergency call has a high priority for the calls informing about the stoppage of movement due to the dangers for the train drivers, dispatchers and other people in a given area. It is activated by pressing a special and distinctive alarm button in radiotelephones and cabin radios. The emergency call is compiled in time to 2 seconds after pressing the button and the REC reception is automatically confirmed (confirmation message contains the locomotive number or the train number).
This connection is defined for the three phases and presented in the following diagram [3]:

– phase 1: warning,
– phase 2: information,
– Phase 3: alarm ending.

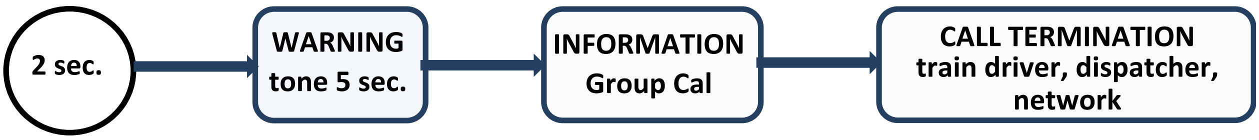

Fig. 1. Phases of the REC emergency call. The development based on [3]

The alarm signal is sent to all users in a specific area with the use of the voice group call service (VGCS). REC has the highest priority (according to the eMLPP priority: 0), and its initiation causes the breakdown of other connections. The service does not stop trains (such as the RADIOSTOP system), but it only sends the information about the danger. After receiving the alarm signal, the train driver must immediately stop the train. The further drive can be started again only after obtaining the authorisation from the employee entitled to control the traffic on the section with the use of the point-point connection with a train. The manner of the service functioning is shown in Fig. 2.

In accordance with the EIRENE requirements, the emergency call is automatically received. It is a duplex connection. The user initiating the REC connection is marked in order to distinguish it from other members of the railway emergency in the dispatcher terminal. The procedure for handling the trains is to stop the train after receiving the REC signal – the travel can be started again only after obtaining the authorisation from the employee entitled to control the traffic on the section with the use of the point-point connection with a train. The initiation of the REC connection should be confirmed by the base station with a return code No. 1612 – this confirmation is to prevent making an emergency call with the use of an unauthorised radiotelephone.

The eREC service is an advanced emergency call service. As is the case of the eLDA service, in order to determine the train location, GPS data as well as data of the track-side detection equipment are used. It prevents the situations, in which the train being on the border of two sections is connected to a wrong dispatcher, and it consequently sends an alarm message to the wrong trains.

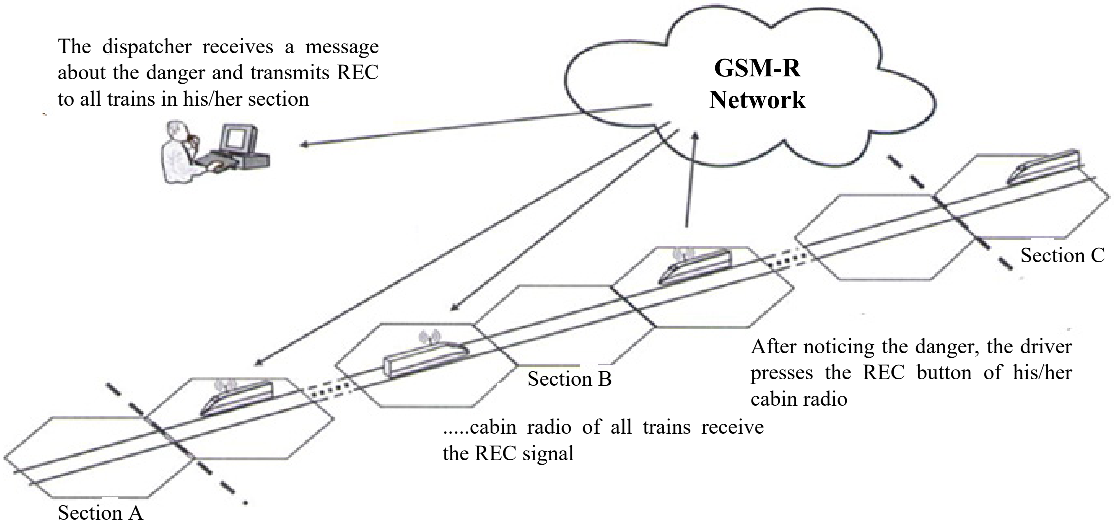

Fig. 2. Railway emergency call service. The development based on [11]

4. Analysis and assessment of the implementation of the emergency call function during the migration period

The analogue VHF system is a local, practically one-service system, i.e. there is only the voice transmission, whereas the GSM-R digital system is a multiservice network system – data transmission, voice transmission – centrally managed. In the context of the operation, these systems must cooperate in the scope of the exchange of the "Radiostop" and "REC" signals, i.e. the Radiostop signal, which is sent via the VHF system, must be received by the GSM-R system and shown at the relevant section of the railway line, and the other way around, the REC signal, which is sent via the GSM-R system, must be interpreted by the VHF system devices as the Radiostop signal in the area of the VHF radio station that received this signal. The common element of both systems consists of the SDH system, which are necessary in the GSM-R system for transmission of signals between the parts of the GSM-R system (BSS, NSS, OMC, etc.), however, in case of the SZS systems for the transmission of control data between individual radio stations and the signaller of a given section.

It also should be noted that the Radiostop and REC signals are alarm signals, but their operation is different. The reception of the Radiostop signal by cabin radios in the rail traction vehicles results in the emergency stop of trains, whereas the REC signal received by the cabin radios is only a piece of information for drivers that from that moment, different driving rules are applicable, i.e. in accordance with the rules defined by the Manager of the procedure infrastructure, e.g. driving on sight, driving to the first signal, according to the orders of the signaller, etc.

According to the provision of the National Implementation Plan (NPW) of the European Rail

Traffic Management System (ERTMS) in Poland, the RADIOSTOP function working on the lines covered by the GSM-R development will be used until the dismantling of the VHF 150 MHz system on these lines. This function was included in the Specific Transmission Module (STM) for the SHP system and it has to ensure proper interaction of the RADIOSTOP signal by the rail traction vehicles equipped with ECTS and SHP STM while driving on the lines equipped with the SHP and 150 MHZ radio. Thus, during the migration, the vehicles running on the lines equipped with the 150 MHz and GSM-R standards are required to receive and correctly interpret the RADIOSTOP signal. Therefore, there will be some inconvenience associated with the operation of the two systems. It will be felt by both drivers, signallers and maintenance services. It is connected, among others, with the need to achieve proficiency in the use of two types of devices of the various radiotelephony systems as well as equipping workshop with a larger number of specialised testers and measuring instruments. It will also lead to an increase in the range of spare parts and device reserves. Furthermore, the drivers should switch from the analogue network to the GSM-R network in the places marked with the W33 indicator, and in case of the places marked with the W34 indicator; they should switch from the digital network to the VHF 150 MHz network.

In addition, in case of each railway line equipped with GSM-R as long as it is equipped with the 150 MHz radio, the track-side equipment must guarantee [3]:

- the automatic generation of the GSM-R alarm signal will accompany the generation of the RADIOSTOP signal from the track-side equipment (stage 1),
- the RADIOSTOP signal received by the track-side equipment (e.g. generated by the driver) will automatically result in the generation of the GSM-R alarm signal (stage 2),
- the automatic generation of the RADIOSTOP signal will accompany the generation of the GSM-R alarm signal from the track-side equipment (stage 3),
- the GSM-R alarm signal received by the track-side equipment (e.g. generated by the driver or the employee driving on tracks) will automatically result in the generation of the RADIOSTOP signal (stage 4).

The picture of generating the alarm signals during the migration of VHF 150 MHz railway radio communication systems and the GSM-R system was presented in Fig. 3.

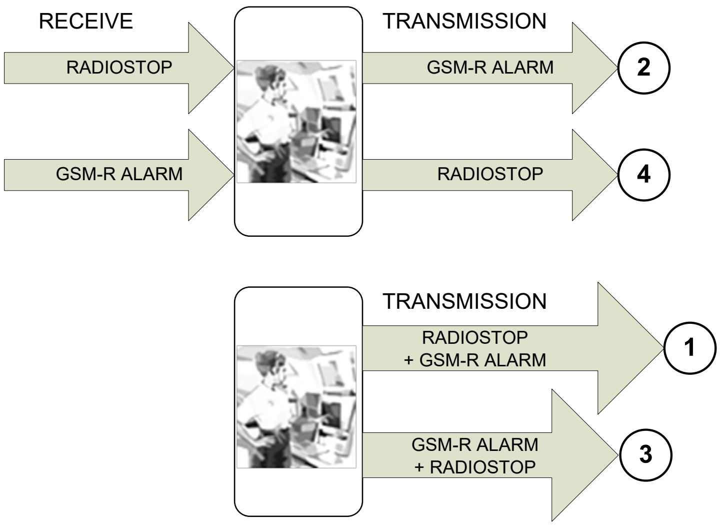

Fig. 3. Generation of the alarm signals during the migration of systems. The development based on [12]

In relation to the above information, it is assumed that the signaller will have an integrated terminal, which will send the RADIOSTOP and REC signals at the same time. Integrating the terminal in this manner is possible by adding the appropriate interfaces between the signaller's part, which supports the 150 MHz radio, and the signaller's part of the GSM-R standard.

In addition to the problem related to the technical aspect of connection of both alarm signals, it is important to remember about the differences resulting from their range. There is no possibility of such programming of the GSM-R network that makes the REC signal cover exactly the same area as RADIOSTOP. In Fig. 4, the range of both systems in relation to the Local Control Centre (LCS) was presented.

Two cases can be considered:

1) activation of the RADIOSTOP signal within the LCS area,
2) activation of the REC signal within the LCS area.

In the first case, if the RADIOSTOP signal in the LCS area is transmitted, the immediate braking of the trains, which use the VHF 150 MHz standard, will take place. In contrast, the interoperable trains that use the GSM-R radio communication will not be stopped, and only the automatic setting up the REC channel for all the trains covered by the range of the RADIOSTOP signal.

In the second case, the transmission of the REC signal will result in the minimal delayed braking of the B class trains (using the analogue standard) within the LCS area, and in case of the A class trains, the automatic setting up of the REC channel will occur. Both of the above cases are not conducive to the efficient operation of the trains and cause ambiguities, which impede the safety of the train traffic. Perhaps, adding the interface in radio communication terminals, which enables processing of the REC signals to the RADIOSTOP ones, and the other way around, providing the breaking of all trains or setting up the talk channel in all trains within the LCS area, would be a more favourable option.

Analysing the ranges of two systems, it should be noted that the RADIOSTOP signal covers the entire infrastructure within a radius of about 10 km, while the REC one covers mainly the infrastructure subject to a given base station. Thus, in order to prevent the uncontrolled emissions of the RADIOSTOP signal, a new network of the railway radio communication channels in the 150 MHz band allowing for the implementation of the Local Control Centres for Polish railways should be developed. The picture of implementation of Local Control Centres (LCS) with regards to the current railway radio communication 150 MHz in Fig. 4.

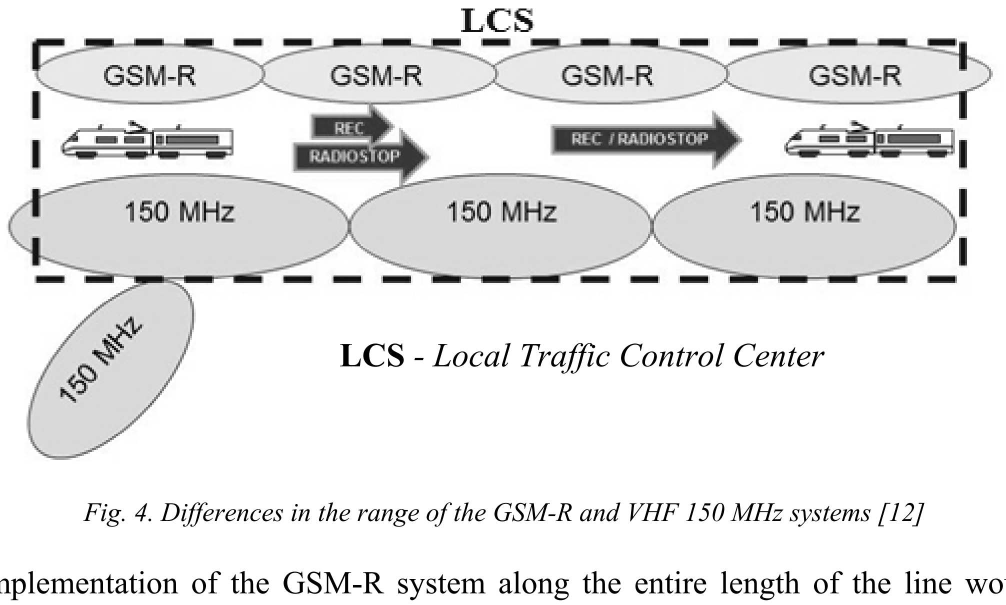

Fig. 4. Differences in the range of the GSM-R and VHF 150 MHz systems [12]

The implementation of the GSM-R system along the entire length of the line would be the easiest solution to the problem arising out of the range of both systems. Such a concept would ensure the avoidance of perturbations related to the operation of these two systems during the migration period. The picture of the GSM-R radio communication network along the entire line was presented in Fig. 6.

The use of two alarm signals on one line requires the development of special procedures and rules of operating the train traffic in the emergency situations due to the fact that the RADIOSTOP signal reception by the analogue cabin radio in a train results in the emergency stop of all the trains equipped with the analogue communication system, which receive this signal, whereas, the REC signal reception by the GSM-R digital cabin radio should result in the driver's reaction, which is described in the appropriate procedure [2].

The pilot project is the first installation of the ERTMS devices adapted to the Polish conditions. It includes the E30 railway line E30 on the Legnica – Węgliniec – Bielawa Dolna section. Moreover, the implemented GSM-R system obtained a permit No. PL 63 2014 0001 for operation of the structural subsystem Control – track-side equipment in the scope of the ERTMS/GSM-R system. Apart from providing the ERTMS on-board and track-side equipment as well as the STM modules of the SHP systems, a mutual dependence of the RADIOSTOP and REC alarms will be performed.

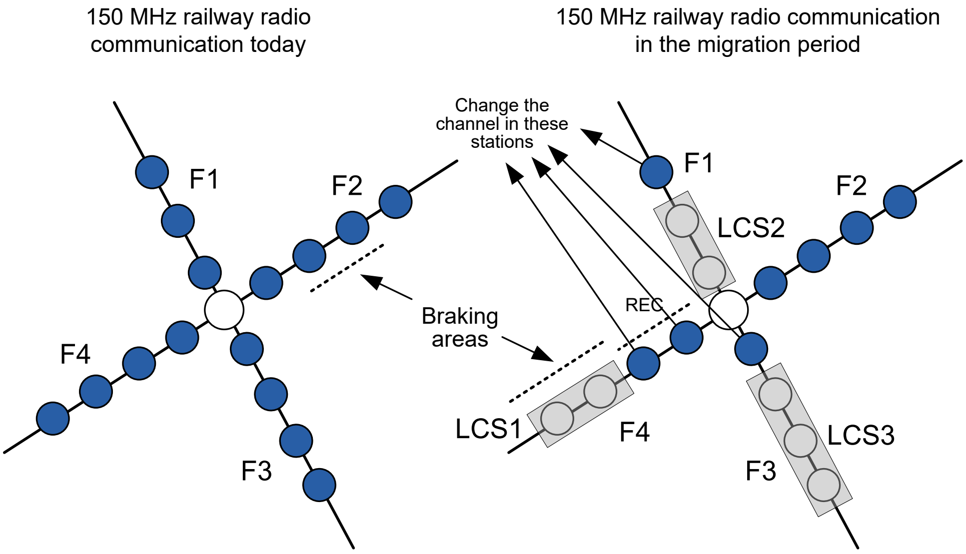

Fig. 5. Implementation of GSM-R on the entire railway line

5. Conclusion

The effective and seamless communication, thanks to which the information necessary to manage and control the train traffic and also essential for the passenger service can smoothly flow, is a very important factor affecting the safety of the rail transport. In Poland, the current system of the VHF 150 MHz radio communication ceased to be developmental. However, the most serious drawback, in the context of the European Union, includes the inability to provide the required interoperability in the community. Thus, the safe and uninterrupted train traffic in the area of the Member States of the European Union is impossible. Therefore, it is necessary to modernise immediately the current railway network according to the European standards and to replace of the VHF 150 MHz radio with the GSM-R standard.

The migration period between the 150 MHz radio and the GSM-R standard, which will be operated at the same time, will be the biggest challenge for infrastructure managers associated with the construction of a new system. Therefore, there will be some inconvenience associated with the operation of the two systems. Unfortunately, there is a problem with the connection of the RADIOSTOP and REC alarm signals and the VHF-150 MHz and GSM-R radio communication systems. This problem applies both to the aspect related to the technical connection of both alarm signals as well as the difference resulting from their range. In accordance with the decision of the infrastructure manager, during the migration, the rail traction vehicles must be equipped with the 150 MHz/GSM-R dual-system radio, which will allow to support two system. In addition, it is necessary to develop appropriate procedures for the transmission of the RADIOSTOP or REC signals on the line sections equipped with both facilities.

To sum up, the GSM-R standard is replaced by a number of national systems of radio communication. Its implementation results in an increase in the quality of railway radio communication, and allows eliminating the barriers stemming from the different communication standards operated in Europe. In Poland, the replacement of the VHF 150 MHz current analogue system with the GSM-R standard as well as the smooth "transition" through the migration period is therefore so essential.

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