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Difficulties in TETRA operation with moving block in Kazakhstan

Abstract*. The importance of the research described in this article arises from the problem of adapting the digital TETRA radio standard as an information exchange channel between track-side and on-board SIRDP-E (block system). The aim was to define the characteristics of the use of base stations and radio modem modules from different manufacturers. Of the proposed applications for digital radio equipment, the best result was achieved for the equipment of the manufacturer Hytera Communications Corporation Limited as a base station and radio modem modules. The research showed the effectiveness of the proposed method of determining qualitative combinations of TETRA standard digital radio communication equipment in SIRDP-E system. The article may be useful for other manufacturers of digital radio communication equipment for railway signalling devices and railway operators in post-Soviet countries.*

Streszczenie. *Znaczenie badania opisanego w niniejszym artykule wynika z problemu dostosowania standardu cyfrowego radia TETRA jako kanału wymiany informacji między urządzeniami przytorowymi i pokładowymi SIRDP-E (system blokowy). Celem było określenie cech wykorzystania stacji bazowych i modułów radiomodemu różnych producentów. Spośród proponowanych zastosowań cyfrowego sprzętu radiokomunikacyjnego najlepszy wynik osiągnięto dla wyposażenie producenta Hytera Communications Corporation Limited jako stacji bazowej i modułów modemu radiowego. Badania wykazały skuteczność proponowanej metody określania jakościowych kombinacji urządzeń do organizacji cyfrowej komunikacji radiowej standardu TETRA w systemie SIRDP-E. Artykuł może być przydatny dla innych producentów sprzętu do cyfrowej komunikacji radiowej dla sygnalizatorów kolejowych i operatorów kolejowych w krajach poradzieckich. (****Trudności w działaniu systemu TETRA z blokiem ruchomym w Kazachstanie****).*

Keywords: SIRDP-E, TETRA, base station, radio modem module, comm refuses, laboratory testing.
Słowa kluczowe: SIRDP-E, TETRA, stacja bazowa, moduł modemu radiowego, odmowy połączenia, badania laboratoryjne.

Introduction

Increasing the railway capacity, improving reliability and introducing innovative technologies are challenges of the topmost importance for most countries of the world. Often, the most advantageous way to solve these problems is to improve the signalling system, as it has a significant role in traffic capacity, and its modernization is much simpler and cheaper than improving infrastructure by building additional paths and platforms. In view of the above, Joint-Stock Company "National Company "Kazakhstan Temir Zholy", striving to modernize the infrastructure and renew the rolling stock to reduce operating and maintenance costs and to bring the railway network to a qualitatively higher level, work closely with the world's leading manufacturers of railway equipment.

The backbone network of JSC "NC" KTZh" is actively expanding - new lines are being built, which have become part of the international corridors connecting Kazakhstan with China, Russia, Turkmenistan and Iran, which, in turn, has significantly increased the transit and export potential of Kazakhstan as a country, through which, cargo flows between the East and the West along the northern route (with access to Russia and further to Europe) and the southern route through Turkmenistan, Iran and Turkey.

Table 1. Railway automation and telemechanics device readings

Technical equipment	Units	Total capacity of technical equipment
Automatic Block	km	11 346
Radio Block (SIRDP-E)	km	1677
Semi-automatic block	km	2777
Relay Interlocking	point	14189
Electronic interlocking	point	1 216
Key interlocking	point	412
Centralized Traffic Control	km	4355
Electronic Centralized Traffic Control	km	7702
Hump interlocking	point	361

At the moment, devices of railway automation and telemechanics (RAT) of the railway backbone network of Kazakhstan are served by 35 division signalling and communication. Table 1 lists the systems of railway automation and telemechanics, providing control and monitoring of train traffic and the safety of the transportation process [1].

On the basis of the data presented, given the total length of the railway network of 15.8 thousand km, the railways of Kazakhstan, are equipped with RAT systems: centralized traffic control system – 12,057 km; it includes 15,817 points and interval train traffic control system – Automatic Block – 11,346km, Radio Block (SIRDP-E) – 1677km, Semi-automatic block – 2777km (see Fig. 1).

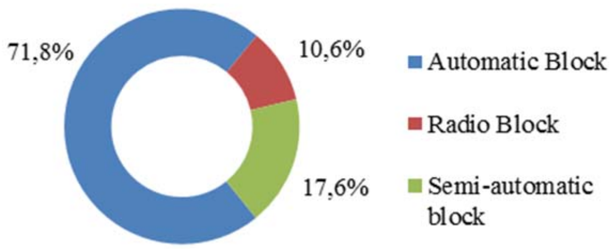

Fig.1. Percentage of interval train traffic control equipment in the Republic of Kazakhstan

JSC "NC "KTZh" pays great attention to the implementation of modern radio channel based train traffic control systems, primarily in cooperation with Bombardier Transportation, as the automatic block systems built on the basis of relay elements do not meet the growing requirements for ensuring train traffic safety.

From 2012, JSC "NC "KTZh" has been operating the interval train traffic control system using the SIRDP-E radio channel as part of INTERFLO 550 of Bombardier Transportation on its backbone networks, based on the ERTMS/ETCS level 3 concept, on 146km in length Uzen-Bolashak line, adjacent to the border with Turkmenistan and from the border with China, is a new line Zhetygen-Altynkol - 298km [2].

In addition, SIRDP-E with moving blocks is being introduced on three new lines - Beyneu-Shalkar (471km), Saksaulskaya-Zhezkazgan (517km), Arkalyk-Shubarkol (214km) [2].

Table 2. The geography of the implementation of the SIRDP-E system based on the INTERFLO 550 of Bombardier Transportation for railway control systems in signalling

Project title	Location
INTERFLO 550 - Arkalyk – Shubarkol, Zhezkazgan – Saksaulskaya and Shalkar – Beyneu lines	Kazakhstan
INTERFLO 550 - Khoit – Zamynuud line (Trans-Mongolian Railway), Mongolia	Mongolia
INTERFLO 550 - OPTIFLO - Repbäcken - Malung (Västerdalsbanan), Sweden	Sweden
INTERFLO 550 - Transport corridor between stations Zhetygen and Altynkol	Kazakhstan
INTERFLO 550 - Uzen-Bolashak, Kazakhstan	Kazakhstan
INTERFLO 550 - Regional passenger line operation, Sweden	Sweden

As shown in Table 2, the main share of the interval traffic control system of trains with moving blocks, which is being used in Kazakhstan, is based on INTERFLO 550 of Bombardier Transportation.

During the operation of SIRDP-E in Kazakhstan, the task of paramount priority was to test the interaction of the system with the digital radio network of the TETRA standard. All the above sections are single track, i.e. the effectiveness of the usage of the system with moving blocks. However, this system has a number of problems, mainly due to the provision of high-quality radio communication using the TETRA digital radio communication standard and the results of refuses of Uzen-Bolashak and Zhetygen-Altynkol over the past 4 years are given in Table 3.

During the operation of SIRDP-E in Kazakhstan, the task of paramount priority was to test the interaction of the system with the digital radio network of the TETRA standard. All the above sections are single track, i.e. the effectiveness of the usage of the system with moving blocks. Figure 2 shows the structure of the radio communication organization of the TETRA standard, where the distance of the radio tower does not exceed 15 km, thereby providing double radio coverage. However, this system has a number of problems, mainly due to the provision of high-quality radio communication using the TETRA digital radio communication standard.

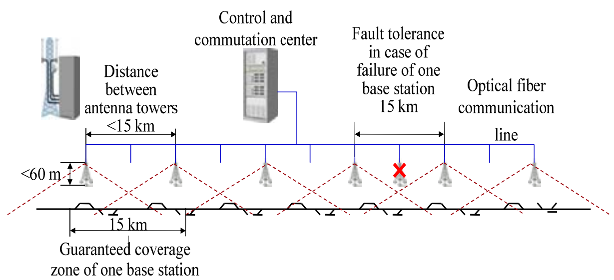

Fig.2. Radio communication organization of the TETRA standard

In the EU, the GSM-R is used as the radio communication standard for the ETCS system and at the moment, this standard is already adapted to the operating conditions and has a fairly large polygon throughout Europe [3]. In Kazakhstan, TETRA, based on the NEBULA TETRA infrastructure of Teltronic S.A.U. Headquarters was used as a radio communication standard, as the frequency bands used in the GSM-R standard are occupied by the security forces of the Republic [4].

Table 3. Average yearly number of refuses of Uzen-Bolashak and Zhetygen-Altynkol

Reason/location	Uzen-Bolashak		Zhetygen-Altynkol	
	2015 2017	2018	2015 2017	2018
Communication refuses between OSS (Onboard Safety System) and RBC (Radio Block Center) in transit	56	0	134	0
Lack of communication between OSS and RBC during train registration	148	3	84	0
Malfunction of OSS of locomotive	206	145	25	0
Malfunction of distance and speed sensor	133	30	20	0
Incorrect actions of an engineer	2	0	6	0
Malfunction of OSS through engineer's fault		0	0	0
Switching to protection mode	2	0	1	0
Malfunction of Tail half-set of the train integrity monitoring system	3	0	7	0
Lack of Tail half-set of the train integrity monitoring system	0	0	14	0
Malfunction of axle counter sensor	0	0	0	0
Reboot of CPU RBC	0	0	1	0
Equipment malfunctions	0	0	0	0
Incorrect actions of Train dispatcher	0	0	18	0
Incorrect actions of Train director	0	0	0	0
Due to accident	0	0	0	0
Improper location of the balise in relation with the repair of track elements	0	0	0	0
Total	553	178	309	0

Trackside equipment SIRDP-E includes a balise-based point-to-point data transmission system and a radio block centre connected to the TETRA digital radio communication system, through which, data is exchanged with SIRDP-E mobile objects – locomotives, equipped with onboard security systems (OSS). Information on the state of control and monitoring objects (electric point machines, signals, axle counting systems and level crossings) are sent to the RBC from the EBILock 950 R4 electronic interlocking, control commands are set and train traffic is controlled through centralized traffic control and reserve Human Machine Interface of train directors.

During the operation of the SIRDP-E system, information is exchanged between trackside equipment of the radio blocking system and onboard security systems through the TETRA (GSM-R) digital radio communication network, in accordance with the ERTMS/ETCS L3 System Requirements Specification [5–9].

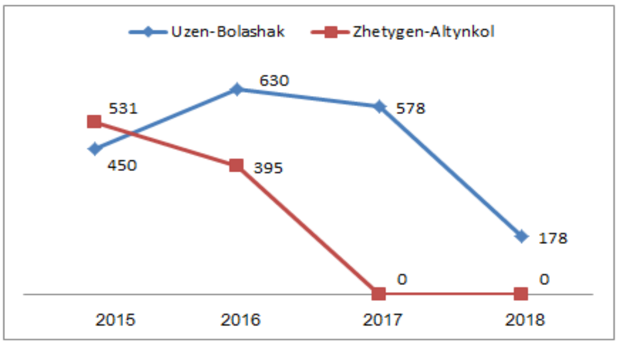

Fig.3. Chart of change in the number of refuses on lines Uzen-Bolashak and Zhetygen-Altynkol

As can be seen from Fig. 3, most of the refuses appeared at the beginning of the implementation and operation of the SIRDP-E system, and this is due to refuses and the lack of high-quality communication between trackside equipment of the radio blocking system and onboard security systems in transit and during train registration [9].

There are no refuses in the Zhetygen-Altynkol line in 2017 and 2018 (see Fig. 3), as at present instead of SIRDP-E the semi-automatic blocking is functioning, thereby negatively affecting the traffic and transporting capacity of the track and not providing the required growth in cargo traffic from China to Central Asia, Iran, Western Europe and the Transcaucasian republics.

Material and methods

During the operation of this system, it was revealed that the quality of radio communication is affected by refuses of the base station equipment in use (SAS, Teltronic S.A.U.) and radio modem module (PTP-603, Teltronic S.A.U.). To solve the above problem, laboratory and field tests were carried out using digital communication radio equipment from Motorola Solutions and Hytera Communications Corporation Limited, in order to determine the optimal combination of a digital radio communication equipment of TETRA standard.

In accordance with the adopted technical solutions, laboratory tests of base stations and radio modem module were carried out in 4 stages (see Fig. 4.).

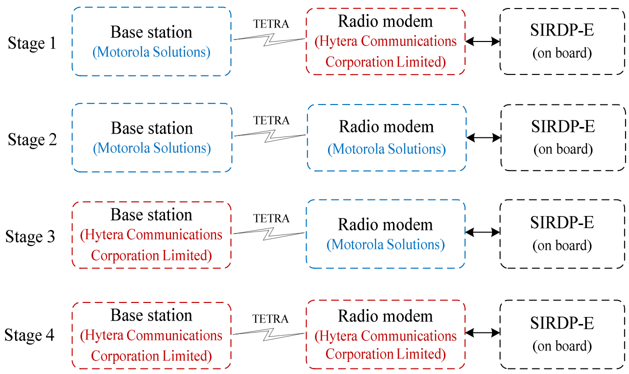

Fig.4. TETRA radio quality test options

Stage 1: Motorola Solutions base station testing with Hytera Communications Corporation Limited radio modem module and SIRDP-E onboard equipment.

Stage 2: Motorola Solutions base station testing with Motorola Solutions radio modem module and SIRDP-E onboard equipment.

Stage 3: Hytera Communications Corporation Limited base station testing with Motorola Solutions radio modem module and SIRDP-E onboard equipment.

Stage 4: Hytera Communications Corporation Limited base station testing with Hytera Communications Corporation Limited radio modem module and SIRDP-E onboard equipment.

In addition, the operational tests of the TETRA equipment of Hytera Communications Corporation Limited infrastructure and SIRDP-E equipment in the Zhetygen-Shelek track were carried out in accordance with [6].

Results

During the test (Stage 1), a combination of the radio modem module of the manufacturer Hytera Communications Corporation Limited with the base station of the manufacturer Motorola Solutions, 2 short-term (~ 1 s and ~ 15 s) communication losses were detected at the time of establishing the connection, which did not affect the operation of SIRDP-E. Testing time was 15 hours and 21 minutes.

The test (Stage 2) combination of the radio modem module of the manufacturer Motorola Solutions with the base station of the manufacturer Motorola Solutions, 7 long (> 60 s) communication losses were detected, which caused the train to stop. Testing time was 10 hours and 20 minutes. After eliminating the error in the modem configuration, the test was repeated for 4 hours and 40 minutes, the test showed no communication errors.

The test (Stage 3) combination of the radio modem module of the manufacturer Motorola Solutions with the base station of the manufacturer Hytera Communications Corporation Limited showed a complete absence of communication losses, the testing time was 16 hours 17 minutes.

The test (Stage 4) combination of the radio modem module of the manufacturer Hytera Communications Corporation Limited with the base station of the manufacturer Hytera Communications Corporation Limited showed a complete absence of loss of communication, the testing time was 14 hours and 17 minutes.

The results of the study in accordance with Fig. 4 are given in Table 4. They showed that the errors occur at random and the optimal combination of using the base station equipment and the TETRA digital communication modem module was determined.

Table 4. Test results

Test stage	Test time	Communication error detection
1st Stage	15 hours 21 min.	2 errors
2nd Stage	10 hours 20 min.	7 errors
3rd Stage	16 hours 17 min.	No errors
4th Stage	14 hours 17 min.	No errors

Discussion and Conclusion

This research work shows the results obtained in order to achieve the goal of determining the appropriate types of onboard and trackside equipment of different manufacturers of digital radio communication of the TETRA standard of the SIRDP-E system, in order to prevent refuses, as shown in Table 3.

To overcome these problems, it is proposed to select the type and manufacturer of base station equipment and a radio modem module that performs the main information exchange between the RBC and the onboard equipment of the train, while the SIRDP-E system is functioning.

The results of the tests given in Table 4 show that the high-quality TETRA digital communication coverage in Kazakhstan provides the combinations of equipment, as shown in the 3rd and 4th stages of testing.

In Kazakhstan, the main share of the operated interval train traffic control systems, as shown in Fig. 1, use track circuits to determine the location of trains.

In accordance with the ERTMS / ETCS L3 System Requirements Specification, SIRDP-E does not allow usage of track circuits or axle counters for locating the train, i.e. the main channels for exchanging information on the location of the train are only digital radio communication and the issue of improving the quality of communication remains relevant [9-15].

The test results make it possible to reduce the duration and cost of field tests. In case of not achieving the goals set for the usage of equipment from different manufacturers, it is proposed to solve the issue of the location of the train and increase the reliability of the system by applying Distributed Acoustic Sensing (DAS) technology [10–17].

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