Testing of Autonomous Onboard Device for Small Aircraft Flight Safety Improving in Central Asia countries

A Aitmagambetov¹, D Yeryomin¹, N Saterov¹, D Zhaxygulova¹² and R Kaliyeva¹,*

¹Institute of Space Technique and Technology, Almaty, Kazakhstan
²Al-Farabi Kazakh National University, Almaty, Kazakhstan

*Corresponding author: keshrim95@gmail.com

Abstract. This article is devoted to the issue of ensuring the safety of small aircraft flights in the airspace of the Central Asian countries. In this regard an analysis of known technical solutions has been carried out. The results of the analysis are presented in the article used as the basis for an automated system of the small aircraft flight path monitoring using global navigation satellite systems and low-Earth orbit satellite communication systems developing. This automated system aims to increase the efficiency of an organization of search and rescue efforts. One of the elements of the automated system is an onboard terminal, which is a remote technical mean installed on the aircraft. To this end during operation, the onboard terminal is vulnerable to environmental factors. So, this article discusses the developed methodology and results of conducted experiments on checking the execution of the functions and resistance to external climatic and mechanical influences.

1. Introduction

The small aircraft is light and ultra-light aeroplanes and helicopters that provide flights for various purposes, for example, transport and communication flights, agricultural work, forestry and aviation work, flights to provide medical assistance to the population, emergency rescue flights, search and rescue flights, sightseeing flights, search and survey flights at the altitudes of up to 2000 m with the speeds of 200-300 km/h at the distances of up to 500-1000 km. So, for example, in Kazakhstan, the above-mentioned flights according to the Kazakhstan Small Aviation Association, is performed by such aeroplanes and helicopters of light category as Yakovlev Yak-12A, Yakovlev Yak-18T, Antonov An-2, Myasishchev M101T, Partenavia 68 B, Cessna A188B and Bo.105 CBS4, as well as ultra-light aircraft (Sila 450C, Aero AT-3 R100, Cicada-M) and various models of ultralight trike.

Nowadays, the share of small aircraft in the world is approximately 90% of the total number of aircraft, noting that the global small aircraft market continues to grow [1, 2]. As of the beginning of 2020, Kazakhstan's small aviation fleet consists of just about 500 units of aircraft [3], and one of the main problems causing difficulties in the development of small aviation in Kazakhstan is low flight safety of small aircraft [3, 4]. From this, it follows that the urgent task is to improve the safety of small aircraft in Kazakhstan.

One of the elements that characterize aircraft flight safety is ensuring a high efficiency of search and rescue operations in case of an aircraft accident. This element is responsible for the reduction of the risk of aircraft crew and passenger death. Currently, search and rescue operations are performed in Kazakhstan in case of an aircraft accident per the Regulations on the organization of search and rescue support of flights in the Republic of Kazakhstan [5]. As stated in the Regulations, search and rescue operations are organized when the coordination centre receiving a distress signal transmitted from an aircraft and carried out within the plan for the established search and rescue area.
The transmission of the distress signal from the aircraft is carried out using the communication, warning and direction-finding equipment available on board, namely, ultra-high frequency (UHF) and high frequency (HF) radio stations, identification equipment and secondary radar equipment. UHF and HF radio communication is used onboard the aircraft to transmit distress signals and flight information (course, speed, altitude) in telephone and telegraph modes [5]. The main disadvantages of UHF and HF radio communication are low quality of communication in voice data transmission and the time required to dial and transmit data in the form of a message (code). Both identification equipment and secondary radar equipment require installation of a transceiver onboard and operate on a request-response principle, when the onboard radar responder sends a certain set of information, including a distress signal, to a ground station request. Thus, there is a system of identification as "one's own" or "another's" aviation, which was developed to determine whether an object belongs to "one's" or "another's" aviation, which is most relevant for military purposes [6, 7], as well as a secondary radar system and an automatic dependent surveillance-broadcast system (ADS-B), which are widely used in civil aviation. The secondary radar system makes it possible to determine the position of an aircraft by azimuth and range, as well as to transmit to the dispatcher service a four-digit code, or respondent code (squawk code), and the barometric height of an aircraft with the frequency once in 4-12 s depending on the antenna rotation speed [8, 9]. The more advanced is the ADS-B system, which uses global navigation satellite systems (GNSS) and transmits to ground stations the coordinates of the aircraft, altitude, velocity vector, as well as additional flight information every half-second [10]. Such systems make it possible to significantly improve the efficiency of searching for an aircraft in distress and rescuing crew and passengers.

At the same time, in practice, secondary radar or ADS-B systems are often not available for small aircraft, for example, due to the lack of appropriate transceivers, so their observation is only possible using the simplest primary radar. Primary radiolocation is the determination of the position of an aircraft using range and azimuth by receiving the signal sent by the radar station and reflected from the object. At the same time, primary radar does not allow transmitting additional information about the aircraft's flight characteristics. In this case, it is possible to improve the efficiency of search and rescue operations by using modern rescue equipment, such as Cospas-Sarsat beacons or personal satellite communicators activated by the AOPA Tracker service.

The Cospas-Sarsat System (Search And Rescue Satellite-Aided Tracking) is an international satellite system designed to detect emergency beacons transmitting signals at 406 MHz. The Cospas-Sarsat system uses the space segment (geostationary and subpolar low-orbit satellites), a network of receiving and processing stations, a network of coordination centres and emergency beacons. When the space segment receives a signal from an emergency radio beacon, the information about the disaster is transmitted to the receiving and processing station and then to the coordination centre, which organizes search and rescue operations and provides feedback from the radio beacon via the space segment [11]. In the Cospas-Sarsat system, three types of emergency beacons are used depending on operating conditions: sea vessels beacon, aircraft beacon and personal beacon. Aviation beacons send a distress signal manually or automatically when an accident sensor is triggered [11]. By the end of 2019, 45 countries had joined the Cospas-Sarsat system, but Central Asian countries, including Kazakhstan, were not included [12].

AOPA Tracker is a service that enables the automatic tracking of aircraft by using a satellite communicator such as IRIDIUM360° RockSTAR Pro or Garmin inReach SE+ [13]. The principle of the service consists in the interaction of the AOPA Tracker service with the aircraft crew, to whom SMS requests are sent to confirm the change in flight status (start of a flight, end of flight, emergency); the crew also has the opportunity to notify the service of the emergency by SMS. When receiving an SMS about an emergency, as well as in case of loss or absence of communication with the crew, the system assigns the flight an alarm status and notifies to the dispatcher (with additional payment for the service) and trusted contacts of the crew, who decide to start the search and rescue operation. Thus, the effectiveness of such a service largely depends on the human factor, which often does not guarantee timely notification of the coordination centre of the need to search for aircraft in distress and rescue its crew and passengers.
After the coordination centre, per Regulations [5], receives a distress signal, the search area is established and a radio or visual search is carried out. A radio-technical search is the main method of searching for an aircraft that has made an emergency landing and possible when an emergency beacon is activated on board an aircraft requiring rescue. If the radio technical search is unsuccessful, ground search and rescue teams and aircraft perform it visually. At the same time, the efficiency of search and rescue operations is negatively affected by adverse weather conditions and difficult terrain (rough terrain, forest). Thus, for example, to search for small aircraft by visual observation from the air after the observation flight at a high altitude above the search area, the flight is performed at an altitude of 100-300 m above the terrain. As a result, a large amount of time, human and material resources are spent and the probability of rescue of the crew and passengers of the aircraft in distress is reduced.

From the above, we can conclude that the effectiveness of search and rescue work depends on such factors as:

– availability on board the aircraft of means of alarm transmission;
– time in which a coordination centre receives a distress signal;
– the content of additional information about the aircraft and the flight transmitted to the coordination centre;
– human factor.

Following the factors identified above and taking into account the need to improve the efficiency of aeronautical search and rescue work in the territory of the Central Asian countries, an automated system of the small aircraft flight path monitoring has been developed. The automated system of the small aircraft flight path monitoring uses autonomous onboard terminal with low Earth orbit satellite communication system (LEO-SCS) and GNSS modules, continuously processes onboard terminals data in the data centre and displaces information to users in the control centre or directly in coordination centre. Operating algorithm of the automated system of the small aircraft flight path monitoring is described in details described in [14].

The implementation of such a system provides the following:

– the rapid transmission of data to the coordination centre by decreasing the number of steps of distress signal transfer;
– providing the coordination centre with a wide spectrum of information on current flight and previously conducted flights, general information on aircraft and its owner;
– reduction of the influence of the human factor by data analysing in the data centre.

Since the proposed decision does not create any obstacles for operating of other onboard devices, including distress signal transmission devices, the availability of onboard terminals on small aircraft can be allowed by decision at different levels. In particular, the decision to apply the automated system of the small aircraft flight path monitoring can be adopted as a small aircraft flight requirement at the state level. Private companies also can voluntarily use the considered automated system.

Thus, the automated system of the small aircraft flight path monitoring reduces of the time spent on searching for the aircraft that has made an emergency landing by early warning and narrows down the search area by transmitting information on the geographical coordinates of the aircraft in distress to the coordination centre. In addition to the social effect and improvement of the safety of small aircraft flight path monitoring, the automated system of the small aircraft flight path monitoring also contributes to the technical control of the small aircraft fleet, to the detection of unauthorized (illegal) flights, to the control of the activity (frequency of the flights) of public and private owners of small aircraft.

The automated system of the small aircraft flight path monitoring consists of three parts: onboard terminal, data centre and control centre. The onboard terminal is an autonomous remote technical device of the automated system of the small aircraft flight path monitoring, which contains locking and sealing device (LSD) of single-use and the electronic unit, which consists of hardware and software module (HSM) with embedded software and electronic scheme of LSD cable and onboard terminal body integrity control (ECS). The onboard terminal is installed on aircraft using LSD, controls the presence of onboard terminal on aircraft by ECS, records and transmits navigation and telecommunication data using navigation and communication modules. The general structure of the
onboard terminal is shown in figure 1. Detailed information on the technical means of the onboard terminal is provided in [15].

![Diagram](image)

**Figure 1.** Onboard terminal structure

Algorithm of onboard terminal software performing is shown in figure 2. At the initial state, when aircraft is on the ground, onboard terminal records control sensors and atmospheric air pressure sensor data, but navigation and communication modules are in the offline state to save the battery power. In regular operation mode, navigation and communication modules activated responsive to changes in pressure during takeoff. After that navigation and telemetry data are recorded every second, stored in the built-in memory card and sent to the data centre as a data package every 15 seconds. The structure of the package data and the volume of transmitted data is shown in table 1.

![Table](image)

**Table 1.** Data package structure

| Byte number | Byte length | Type     | Description                        |
|-------------|-------------|----------|------------------------------------|
| 1           | 1           | Uint8    | preamble (protocol version) (0xE6) |
| 2           | 4           | Uint32   | data recording time UnixTime       |
| 6           | 2           | Uint16   | onboard terminal ID                |
| 8           | 4           | Float4   | latitude                           |
| 12          | 4           | Float4   | longitude                          |
| 16          | 2           | Uint16   | air pressure                       |
| 18          | 1           | Uint8    | bit 1 body integrity              |
|             |             |          | bit 2 cable integrity             |
| 19          | 1           | Uint8    | battery level                      |
| 20          | 1           | Uint8    | CRC8                               |
| Total:      | 20          |          |                                    |

Onboard terminal attempts to transmit data packages via cellular channels (by default) and satellite channels if is not available. During a communication session (data transmission) onboard terminal can receive new configurations from the data centre. The flight is considered as complete, if navigation module records the same (with an acceptable error) coordinates of aircraft for 15 minutes, after which the navigation and communication modules are disabled. In case of emergency, such as cable disruption and/or body integrity disruption, and/or reduction of battery charge to critical, while aircraft is on the ground, navigation and communication modules activated and data package with warning message is formed. The failure during the flight is determined by the data centre based on the changes in aircraft speed and pressure (as flight altitude characteristics).
The onboard terminal is designed to operate in the conditions of moving aircraft and affected by external mechanical and climatic factors both during the flight and when the aircraft is on the ground.

Thus, the onboard terminal should provide the following characteristics:
- automatic notification in data centre regarding onboard terminal body integrity disruption;
- automatic notification in data centre regarding onboard cable integrity disruption;
- atmospheric air pressure recording;
- automatic activation of mobile satellite communication channel Iridium, mobile cellular communication channel GSM and GNSS GPS/GLONASS modules after registration of changes in atmospheric air pressure by the barometric sensor to the corresponding aircraft flight height;

**Figure 2.** Onboard terminal working algorithm
– automatic deactivation of mobile satellite communication channel Iridium, mobile cellular communication channel GSM and GNSS GPS/GLONASS modules after 15 minutes of no change in coordinates of aircraft;
– satellite navigation using GNSS GLONASS/GPS signals with a standard deviation of 15 m;
– data storage in built-in memory;
– data transmission to the data centre via GSM cellular communication channels;
– data transmission to the data centre via LEO-SCS Iridium;
– data integrity control;
– water-resistant body;
– resistance to mechanical impacts;
– resistance to climatic impacts.

2. Testing Methodology

To confirm the compliance of the onboard terminal to the required technical and operational characteristics and sustainability and resistance to external climatic and mechanical impacts the following tests are decided to carry out:
– functions tests;
– external impacts.

Verification of onboard terminal functions begins with the onboard terminal body and LSD cable integrity tests. The test on the LSD cable integrity is carried out with an active onboard terminal by deliberate breaking (cutting) the cable resulting in the formation of the warning message, which is along with navigation and telemetry data immediately transmitted to the data centre via cellular or satellite communication channel. Then the LSD (of single-use) is changed and the onboard terminal is restarted. The test is performed five times and considered successful if the warning message is displayed in the control centre at each break of the cable. The test on the onboard terminal body integrity is carried out with an active onboard terminal by intentional opening (integrity violation) of the body. Then the body integrity is restored and the onboard terminal is restarted. The test is performed five times and considered successful if the warning message is displayed in the control centre at each body opening.

The function of switching the communication and navigation modules on and off when the value of atmospheric air pressure changes is tested by raising and lowering the onboard terminal within a section of 6 m (3 floors) height, on which the baseline height is established, as shown in figure 3. Before starting the test with the barometric sensor determine the pressure at the height taken as the baseline and set the resulting pressure value with an error of ± 0.16 Pa as the limit value.

As a result of raising the onboard terminal to an altitude higher than the base, the barometric sensor registers a pressure drop below the limit value, which will lead to the activation of the navigation and
communication modules. Navigational and telemetry data on the aircraft will be displayed in the control centre. After receiving the data from the onboard terminal, in the control centre, the onboard terminal shall be descended below the baseline, as a result of which the barometric sensor shall record the pressure rise above the limit value. The navigation and communication modules are deactivated 15 minutes after the pressure has not changed within the specified range.

Testing the function of satellite navigation is performed by visual observation of a series (sequence) of location points (coordinate marks) of the onboard terminal, placed on Falcon Avia Festival R40F aircraft, travelling by route Burundai airfield – Karasai region - Burundai airfield, on the screen of the control centre dispatcher’s workstation, against the background of an electronic map of the area, when moving the onboard terminal in any way. The measurement of the accuracy of satellite navigation is conducted by placing the onboard terminal at a point with known “true” coordinates measured by the Trimble BD930 dual-frequency receiver. The onboard terminal is kept at a given point motionless for 30 minutes. Then a visual assessment is performed on the dispatcher’s screen by counting the number of points inside a circle with a radius of 15 meters and centred at the “true” coordinates. At least 68% of the total number of measured points should be placed inside this circle. In case of cohesion of points on the map, one should calculate the number of points outside the circle; their number should be less than 32% of the total number of measured points.

Checking the function of transmitting data from the onboard terminal to the data centre via cellular and satellite communication channels and channel switching and verification of built-in memory are performed according to the scheme given in figure 4. When the cellular communication channel is available, data are transmitted in standard mode: data packets are transmitted one by one at regular interval from the onboard terminal to the data centre, via GSM communication channel (▲). After receiving several packets of data by GSM/ GPRS, the cellular module is turned off manually, and the satellite communication channel is automatically turned on. After receiving several data packets by Iridium SBD (■), the satellite module is turned off manually. Without any available communication channels, the onboard terminal saves data in built-in memory (○), and after turning on both cellular and satellite communication modules all stored data packets are transmitted via GSM channel (▲*). After that, the standard data transmission mode resumes (▲).

![Figure 4. Communication channels and built-in memory testing scheme](image)

The data integrity test is based on monitoring the data integrity of the onboard terminal using the CRC (cyclic redundancy check) code. After the data package is checked for integrity by the server, the server sends the corresponding information to the onboard terminal. If the onboard terminal does not receive such information within 5 minutes, it sends this data package again during the next communication session. But if the onboard terminal does not receive information from the server about the validity of the data packet containing information about an emergency (cable break and/or body opening), then such packet is sent again immediately. Thus, the server response must be verified during the test.

Checking onboard terminal sustainability and resistance to external influences included vibration, elevated temperature, and low atmospheric pressure and water immersion tests under the conditions presented in table 2.
Table 2. Characteristics and values of mechanical and climatic factors

| Impact factor                  | Factor characteristic         | Factor value |
|-------------------------------|-------------------------------|--------------|
| Vibration                     | frequency range, Hz           | 20-2000      |
|                               | root mean square acceleration, g | 10           |
| High temperature              | temperature, °C               | +40          |
|                               | holding time, h               | 2            |
| Low temperature               | temperature, °C               | -10          |
|                               | holding time, h               | 2            |
| Low atmospheric air pressure  | atmospheric air pressure, kPa | 70           |
|                               | holding time, h               | 30           |
| Water resistance              | immersion depth, m            | 0.5          |
|                               | holding time, min             | 60           |
|                               | water temperature, °C         | 20±10        |

For vibration resistance test the onboard terminal is installed on a vibration table and exposed to random broadband vibration in the frequency range of 20-2000 Hz.

To carry out climatic tests, the onboard terminal should be placed into designed in the Institute of Space Technique and Technologies thermal vacuum chamber shown in figure 5, where communication signals are disabled. In this case, the onboard terminal saves data in the built-in memory and transmits them to the data centre after being removed from the camera and restoring GSM or Iridium communication channel. The climatic tests begin with the low-temperature test, which is conducted to check the onboard terminal for resistance to the low temperature of minus 10°C (i.e. during transportation and operation). The high-temperature test is performed to check the onboard terminal for resistance to the effects of high working temperature of plus 40°C (i.e. during operation). The low atmospheric test is done to check the onboard terminal for resistance to the effects of low atmospheric air pressure of 70 kPa (i.e. during operation).

![Figure 5. Thermal vacuum chamber](image)

In order to check the water resistance of the body, a 13.5-litre water tank is required. The water resistance test is intended to check that the onboard terminal remains functional after being in the water.

Tests on mechanical and climatic factors are considered successful if the onboard terminal continues to work and performs the required functions after exposure.
3. Results and Discussion
An experimental sample of the onboard terminal shown in figure 6 was assembled for the tests. The electronic unit (HSM with embedded software and ECS) and LSD of experimental sample fully correspond to those of the utility model.

![Onboard terminal test sample](image)

**Figure 6.** Onboard terminal test sample

The onboard terminal body and LSD cable integrity tests were successful: as a result of all cables cuttings and body openings, warning messages were received in the control centre. Similarly, GNSS and LEO-SCS modules switching on and off test were successful. The testing result of the onboard terminal navigation function is shown in figure 7. Providing the Falcon Avia Festival R40F aircraft with the onboard terminal made it possible to reliably determine its position during a Burundai airfield – Karasai region – Burundai airfield flight.

![Result of dynamic recording of positioning of the aircraft using the onboard terminal](image)

**Figure 7.** Result of dynamic recording of positioning of the aircraft using the onboard terminal (red markers relate to navigation data registered and transmitted by the onboard terminal within 30 minutes, blue broken line shows the flight path, black arrows show the flight direction)

The navigation tests showed that the onboard terminal provides the object navigation with a standard deviation of 15 m. In figure 8, the result of the static recording of positioning accuracy is shown: 73 % of dots lie within a circle of 15 meters in radius and centred at the “true” coordinates.
The test of the function of data transmission from the onboard terminal to the data centre via cellular and satellite communication channels and channel switching and verification of built-in memory passed successfully. The onboard terminal enables data transmission via cellular and satellite channels without any failures. If there is no communication, the onboard terminal saves all data to the built-in memory and transmits them when the communication appears.

The data transmitted by the onboard terminal have been successfully verified for integrity by the cyclic redundancy code performed in the data centre. The following is installed:

- after checking the integrity of the data the onboard terminal receives the response from the server during the communication session;
- in case of absence of the response from the server, the onboard terminal retransmits the data package during the next communication sessions until receiving the response from the server.

The conducted mechanical and climatic tests showed that electronic components of the electronic unit assembled in body onboard terminal provide reliable operation in conditions close to the real ones. During the mechanical test, the onboard terminal continuously transmitted data packages to the data centre and information was displayed in the control centre.

During the climatic tests, the onboard terminal saved data from integrity control and air pressure sensors in the built-in memory and at the end of the tests, all archived data were displayed in the control centre. Navigation data were not recorded due to the unavailability of the signal into the chamber. At the same time, after each climatic test, the onboard terminal stayed functional, registered and transmitted data collected from the sensors to the data centre. It should be noted, that cold temperature test, leads to an increase in the discharge rate of the battery, which must be taken into account during operation.

The body's water resistance test was also successful, and at the end of the test the onboard terminal performed its functions as normal.

4. Conclusion

In accordance with the results of functional tests, the onboard terminal provides for autonomous operation and ensures reliable functioning:

- the onboard terminal provides control of the locking and sealing device body and cable;
- the function of switching on and off GNSS and communication modules depending on the air pressure value performs properly;
– navigation data are recorded with an acceptable error;
– data transmission via GSM and Iridium is uninterrupted;
– the function of switching between the data transmission channels depending on the conditions of their availability works well (the GSM cellular communication channel is duplicated by a satellite communication channel);
– all registered data are recorded on a memory card;
– the data integrity check algorithm is performed correctly.

The climatic and mechanical tests provide the verification of the onboard resistance to external influences. The onboard terminal is operable in a wide range of operating temperatures ranging from minus 10 to plus 40°C and low atmospheric air pressure (70 kPa), as well as if there are mechanical effects (vibrations) that are typical of objects mounted on aircraft.

Thus, the developed onboard terminal has technical capabilities to implement the continuous remote aircraft flight path monitoring and emergency warning.

Acknowledgment
This paper funded through the targeted programme BR05336383 of Aerospace committee of Ministry of Digital Development, Innovations and Aerospace Industry of the Republic of Kazakhstan.

References
[1] Badulina A V 2014 Russian Foreign Economic Journal 5 68-79
[2] Sobolev L B 2016 Economic Analysis: Theory and Practice 15(3) 4-16
[3] Press centre 2020 Rassmotreny voprosy maloy aviacii vliyayushchie na bezopasnost poletov Ministry of Industry and Infrastructural Development of the Republic of Kazakhstan 14 February 2020 https://www.gov.kz/memleket/entities/miid/press/news/details/rassmotre
[4] Press centre 2018 Nackompaniya po dushu maloj aviacii Sputnik Kazakhstan 23 January 2018 https://ru.sputniknews.kz/economy/20180123/4360849/nackompaniya-po-dushu-maloj-aviacii.html
[5] Pravila po organizacii poiskovo-spasatel’noho obespecheniya polyotov, utverzhdenny’e postanovleniem Pravitel’stva Respubliki Kazaxstan ot 4 noyabrya 2011 goda N 1296
[6] Koryakin O 2015 Kak sozdavals’ Sistema opoznavaniya “svoj-chuzhoj” Russkoe oruzhie 2 April 2015 https://rg.ru/2015/04/02/parol-site.html
[7] Alyoshin A, Gapotchenko O, Prokof’ev V and Solokin V 2009 Sistema identifikacii vmesto sistemy’ opoznavaniya Vozdushno-kosmicheskaya oborona 26 May 2009 http://www.vko.ru/koncepcii/sistema-identifikacii-vmesto-sistemy-opoznavaniya
[8] Arif T T 2010 Aerospace Technologies Advancements (London: InTech)
[9] Zhang X J and Zhang Q S 2001 Engineering 27 24-27
[10] Australian Civil Aviation Authorities CASA 2017 CNS/ATM resource guide (Canberra: Civil aviation Safety Authority)
[11] Levesque D 2016 The history and experience of the International Cospas-Sarsat Programme for search and rescue (Paris: International Astronautical Federation)
[12] Cospas-Sarsat System Data No. 45 2019 (Montreal: Secretariat of the International Cospas-Sarsat Programme)
[13] AOPA.RU 2014 APOA-Tracker AOPA-RUSSIA, 7 July 2020 https://aopa.ru/index.php?id=73
[14] Aitmagambetov A Z, Yeryomin D I, Zhaxygulova D G and Kaliyeva R A 2019 T-comm: Telecommunication and Transport 13(8) 36-41
[15] Aitmagambetov A, Yeryomin D, Zhaxygulova D and Kaliyeva R 2019 Vestnik KazNRTU 5 (135) 375-379