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AIRCRAFT MONITORING IN REMOTE AREAS VIA THE LOW-ORBIT SATELLITE COMMUNICATIONS SYSTEM "IRIDIUM" ALONG WITH THE GSM DATA TRANSMISSION THROUGH ASC-6 TELEMETRY TERMINAL

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One of the most important aims of air traffic control is continuous positioning of aircraft, which makes it possible to control a given flight plan and record deviations from the route, along with organizing search and rescue operations in case of an accident or a disaster. Great difficulties arise when performing this task in areas where there is no radar station in the mountains, forests, at high latitudes or at extremely low altitudes. This problem can be solved by using satellite navigation systems, satellite communication systems and automatic vehicle monitoring.

In order to communicate with the control center, it is advisable to transmit data packets of up to 340 bytes containing information about the location of the aircraft and its status. This can be done via GSM mobile networks, and in areas where there is no communication of this kind, via the satellite communications system "Iridium". To put these two possible ways of communication into practice, the aircraft must have on board an ASC-6 GLONASS / GPS terminal (a vehicle-compatible modification), which determines location, speed and heading of the aircraft. It is also able to register a number of other parameters, such as the status of the analog / discrete inputs, and RS-232 connected sensors indications. This makes it possible to transmit to the control center not only the geographical position data, but also the speed of the aircraft and other operational data. A special communication module SM-1 can be used to support the satellite communication, as it is ASC-6 compatible through RS-232 interface.

Keywords: GPS, GLONASS, Iridium, monitoring device, GSM, telemetry data, transmission.

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МОНИТОРИНГ ВОЗДУШНЫХ СУДОВ В ВЫСОКИХ ШИРОТАХ ПОСРЕДСТВОМ ИСПОЛЬЗОВАНИЯ СПУТНИКОВОЙ СВЯЗИ «ИРИДИУМ» НА ОСНОВЕ ТЕЛЕМЕТРИЧЕСКОГО ТЕРМИНАЛА ASC-6

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Одной из важнейших задач в обеспечении воздушного движения является непрерывное определение местоположения воздушных судов (ВС), что дает возможность контролировать выполнение заданного плана полета и фиксировать отклонения от маршрута, а также в случае аварии или катастрофы незамедлительно проводить поиск, обнаружение и спасение воздушных судов. Большие трудности возникают при выполнении данной задачи в районах, где отсутствуют радиолокационные станции, в горных местностях, лесных массивах, в высоких широтах и на малых и предельно малых высотах. Целесообразно решать данную проблему с использованием спутниковых навигационных систем, спутниковых систем связи и систем автоматического мониторинга транспортных средств.

Для обеспечения связи ВС с диспетчерским центром предлагается передавать пакеты данных, содержащие информацию о местоположении ВС и его состоянии, объемом до 340 байт, для этого будут использоваться мобильные сети GSM, а в районах, где отсутствует данный вид связи, будут использовать спутниковую связь «Иридиум». Для решения поставленных задач предложено использовать на борту воздушного судна терминал ASC-6 ГЛОНАСС/GPS, предназначенный для установки на транспортное средство, регистрирующий местоположение, скорость, направление движения ВС. Также дополнительно он способен регистрировать ряд других параметров, таких как состояния аналоговых/дискретных входов и показания датчиков, подключенных по интерфейсу RS-232, что позволит передавать в диспетчерский пункт данные не только о географическом положении и скорости воздушного судна, но и данные о состоянии его работы. Для обеспечения спутниковой связи будет использован модуль спутниковой связи SM-1, который будет интегрироваться по интерфейсу RS-232 с терминальным оборудованием ASC-6.

Ключевые слова: GPS, ГЛОНАСС, Iridium, устройство мониторинга, GSM, передача телеметрических данных.

Introduction. Every year new and more advanced technologies come into different spheres of human activities. At the beginning of the 21st century the global positioning system GPS, and its Russian analog, the Global navigation satellite system (GLONASS) [1; 2] found wide application in many ways, especially in the sphere of transportation. They are widely used in satellite monitoring, which provides determination of mobile objects geographical position, and of their status. To improve transport operations, different remote control devices installed in vehicles perform functions of collecting and transmitting data to the control center [3]. For transmission of packet data, GSM communication system is generally used, as it is not expensive and easily accessible (in most cases frequencies 890-915 MHz are used [4]). However, for aircraft monitoring in remote regions there may be certain technical limits in the use of GSM. To solve this problem, the preference was given to the satellite communication system "Iridium"(the choice was based on the analysis of different satellite systems).

Iridium. To provide reliable data transmission in air-ground communication, the Iridium satellite system is a better choice among other similar systems. Compared to high-orbital and medium-orbital satellite communication systems, low-orbital systems have a number of advantages: low minimum delay (~ 250 mps), small-size antennae, simultaneous communication via several satellites, low-costs equipment [5].

Among the services provided by the Iridium Company, short SBD data packet service is the most appropriate and efficient. It gives an opportunity of short information message exchange between the terminating equipment and the central computing system. Mobile-originated SBD message may come up to 1960 bytes, Mobile-terminated SBD message may contain up to 1890 bytes [6]. As the SBD Iridium service uses only the access stage in case of regular interconnection, it does not pass through the entire channel from the Iridium gateway to the switchboard and thus has a shorter delay in establishing the connection [7]; this factor plays an important role in the choice of the particular service. High-speed connection and small amount of data makes it possible to transmit the necessary information within a short period, providing a continuous, reliable communication.

ASC-6. For collecting and transmitting data, such subscriber telemetry terminals as ASC-6 has also proved efficient (fig. 1). The ASC-6 GLONASS/GPS terminal is devised to be installed in vehicles. It registers the location, speed and direction of the vehicle [8]. A navigation problem can be solved by means of the global GLONASS navigation system, GPS global positioning system, or using both these systems simultaneously. The terminal can be used for any kind of stationary and mobile objects and vehicles. In addition, it is capable of registering some other parameters, such as status of the analog/discrete inputs and the indication of sensors connected through RS-232 interface. The terminal saves all recorded events and statuses in a non-volatile memory. The stored data are transmitted through a mobile operator network of the GSM 900/1800 standard, using the technology of GPRS packet data transference to the allocated server with a static IP address, from which they can be acquired through the Internet by control centers for further analysis and processing. To keep the communication reliable, the terminal supports the installation of two SIM cards of different mobile operators [9].

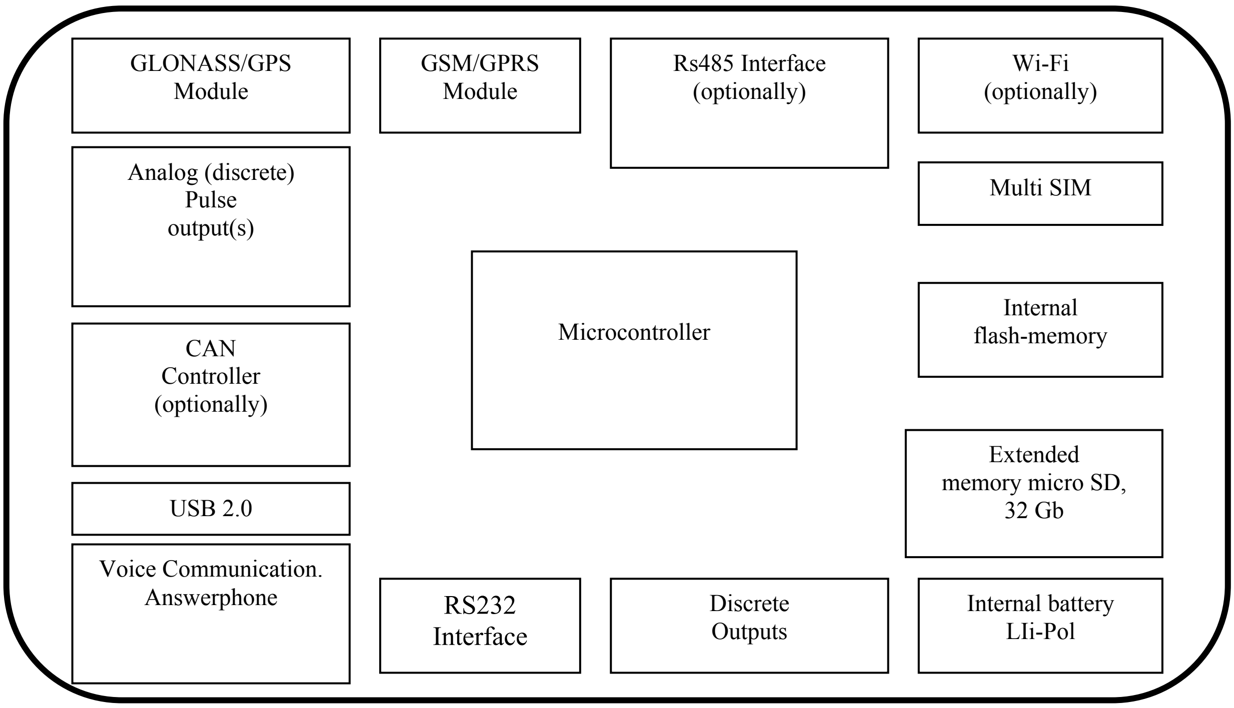

Fig. 1. Structure / operation diagram

Рис. 1. Структурно-функциональная схема терминала

When using GPRS, data are stored in packet form, and then transmitted over several radio channels at a time. These channels can also connect several users in sequence. As voice calls have higher priority than GPRS connection, the transfer of data packages is made only through radio channels free from voice calls, and that can affect the speed of connection. The speed also greatly depends on the quality of network coverage at the location where the connection is required.

GPRS billing depends on the amount of transferred/ obtained information, and not on the time of connection. Such billing allows to establish continuous connection to the network, saving time required for making separate calls for packet transmission. The average transmission speed is kept high, 20–40 kbps [10].

The average time of transmission of 340 bytes from board to the control center by means of GSM/GPRS module can be assessed as follows:

U = 340 bytes = 2.72 kb (maximum amount of data);

V = 20 kbps (average speed of information transmission over GSM);

$Y \approx$ 1–2 second (average time of establishing board-earth connection);

$T = Y + U/V$ (full time of data packet transmission);

$T = 0 + 2.72/20$;

T = 0.14 second.

Transmission time of a 340 bytes packet is 0.14 seconds (which is average); it can change depending on the distance between the aircraft and the antennas of base stations, weather conditions and the quality of GSM network coverage.

In remote regions where there is no GSM coverage, the terminal will be able to transmit data via SM-1 module working at 1616 MHz – 1626.5 MHz frequencies [11]. The module can be integrated through the RS-232 interface with ASC terminal equipment. That allows determination of the aircraft attitude in regions where there is no GSM service [12]. SM-1 module is devised on the basis of the Iridium 9602 SBD modem made especially for the systems of moving vehicles tracking [13]. The maximum amount of information in one message via SBD channel is 340 bytes, which is enough for keeping track of the aircraft and assessing its status [11].

SBD connection provides the transference of data immediately after the signal has been located, (that takes about 1.5 seconds), so the average time of connection will be about 1.5 seconds for the outgoing SBDs and 3.6 seconds for the incoming SBDs. As the SBD service uses the payload of signaling link, and not the payload of ordinary communication channel, the average exchange speed is about 1.2 kbps [14].

The average time of transference of 340 bytes from board to the control center via SBD Iridium can be assessed as follows:

U = 340 bytes = 2.72 kb (maximum amount of data);

V = 1.2 kbps (average speed of information transmission via SBD connection);

Y = 1.5 second (average time of establishing board-earth connection);

$T = Y + U/V$ (full time of data packet transmission);

$T = 1.5 + 2.72/1.2$;

T = 3.8 second.

We can conclude that the transference time for 340-byte outgoing data packet via the Iridium network will be 3.8 seconds, which is considerably longer than when using GSM/GPRS modules, but is also within the required limits.

"Navigator-S". For registering and analyzing the data, the air traffic control center (ATCC) must have the software capable of displaying the information on location of the aircraft and its sensors. This software should have installation requirements acceptable for a personal computer.

The most suitable software is the automated system "Navigator-S", capable of monitoring mobile and stationary objects. "Navigator-S" is an integrated programmed unit for monitoring mobile objects, especially airborne aircraft [15; 16]. With the terminal installed in the cockpit it will be possible to control not only the attitude of aircraft, but also the parameters of their contact pickups and modulating transducers by transmitting the readings over GSM/SBD Iridium channels.

The experimental on-board system will include the exchange ASC-6 telemetric service station, the satellite communication module SM-1(Iridium antenna-equipped), GLONASS/GPS and GSM antennas (fig. 2). The operation of this system requires a supply of 10–30V DC from the vehicle's electric system.

The terminal operation principles. When switched on the terminal initially locates GLONASS and GPS satellites, detects its own attitude, ground speed, GMT, voltage on the inputs. It also registers the sensors' readings and establishes the connection with the server. As soon as the connection is established, the terminal transmits all the monitoring data to the server at preset intervals. In zones where there is no GSM network coverage (fig. 3), data will be transmitted over the Iridium network SBD channel (fig. 4); they can also be duplicated when there appears the GSM signal. If the connection with the server is not established for some reasons, all information is saved in a non-volatile memory of the terminal and transmitted as soon as the communication is reestablished.

The terminal provides transmission of the following monitoring information:

– GMT and date;
– Coordinates (latitude, longitude, height);
– Ground speed, acceleration and direction;
– Number of satellites (GLONASS+GPS);
– Horizontal Dilution of Precision (HDOP);
– Voltage at the analog inputs;
– Voltage at the impulse inputs;
– Outputs status;
– Information on recorded events;
– Fuel level sensors indication;
– CAN bus readings.

The route is registered in the form of separate time points at which all the information that comes to the terminal from sensors and auxiliary equipment is recorded. The time point is stored in the memory in case of events such as: some deflection in the direction of flight; the point of recording is missed; events at analog / discrete inputs; the device status change. Data on the aircraft attitude and its systems' functioning are stored and sent as one packet via GSM or Iridium systems to the air traffic control center.

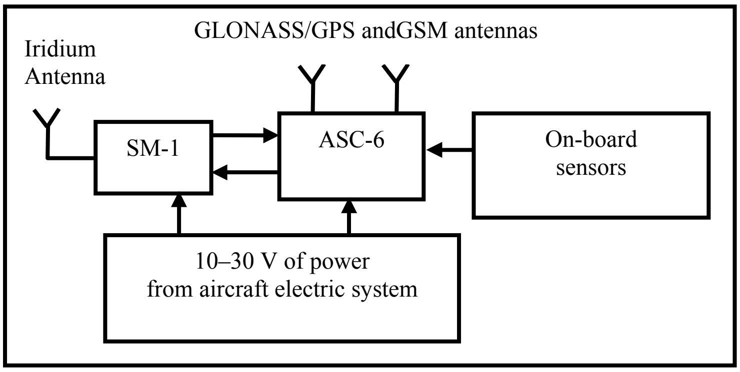

Fig. 2. On-board terminal (experimental make)

Рис. 2. Схема экспериментальной установки

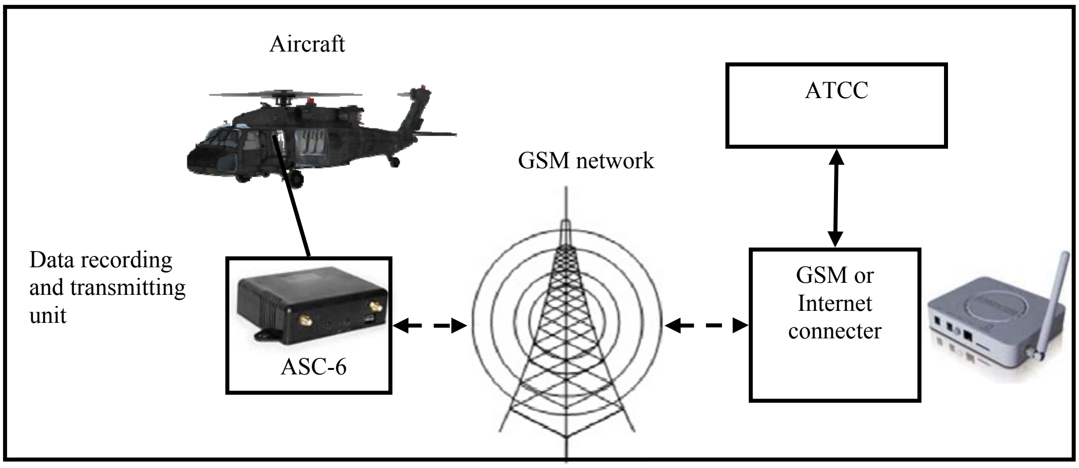

Fig. 3. GSM board-ATCC exchange scheme

Рис 3. Передача данных с борта ВС в диспетчерский центр с помощью GSM-связи

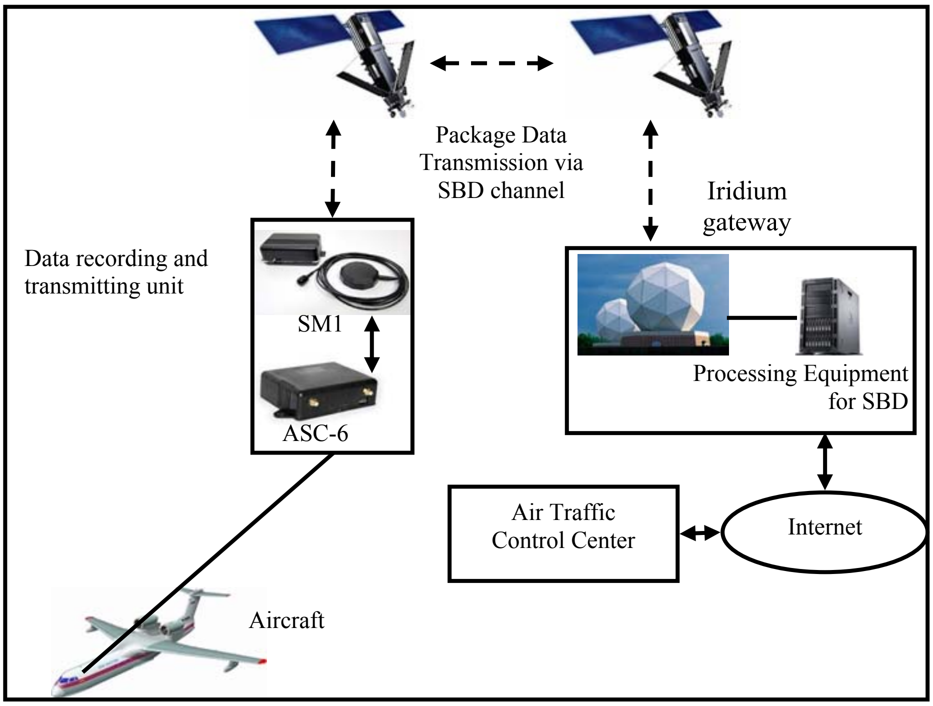

Fig. 4. Iridium board-ATCC exchange scheme

Рис. 4. Передача данных с борта ВС в диспетчерский центр с помощью спутниковой связи

Conclusion. It is obvious that for the purpose of global aircraft monitoring it is impossible to deploy a network of communication stations on the ground; it seems much more effective to employ the widely used GSM network, along with the satellite communication Iridium network which covers the whole surface of the globe.

For receiving and transmitting the flight data, it is advisable to use the subscriber telemetry terminal ASC-6 together with the satellite communication module SM-1. This system will monitor the aircraft route and flight status to provide control of the air traffic, and to organize rescue operations in case of accidents. For the air traffic control system, the "Navigator-S" software is a suitable option, as it has low system requirements acceptable for any modern computer connected to the Internet or equipped with GSM/Iridium modules. The system of satellite monitoring based on the use of the ASC-6 module and "Navigator-S" software will make it possible not only to receive the on-board data in flight, but also to deploy the ATCs in the required locations.

References

1. *Primenenie sistem sputnikovogo monitoringa transportnykh sredstv, dlya obespecheniya effektivnosti logisticheskikh protsessov* [The use of satellite monitoring of vehicles, to ensure the efficiency of logistics processes]. Available at: http://www.rae.ru/forum2012/21/2998 (accessed: 12.03.2017).

2. *Primenenie GLONASS/GPS monitoring transporta* [The use of GLONASS/GPS monitoring of transport]. Available at: W8http://gigabaza.ru/doc/49862.html (accessed: 12.03.2017).

3. *Monitoring Transporta* [Monitoring of transport]. Available at: http://monitoringtransporta.ru (accessed: 12.03.2017).

4. Gromakov Yu. A. *Standarty i sistemy podvizhnoy radiosvyazi* [Standards and mobile radio systems]. Moscow, Eco-Trendz Publ., 1997, 239 p.

5. *Sistema sputnikovoy svyazi Iridium* [The system of satellite communication Iridium]. Available at: http://www.marsat.ru/Technologies-Iridiumnetwork (accessed: 12.03.2017).

6. *Rukovodstvo po aviatsionnoy podvizhnoy sputnikovoy (marshrutnoy) sluzhbe* [Guidelines for the aeronautical mobile-satellite (route) service]. ICAO. 2010. P. II.2.18–II.2.21

7. *Rukovodstvo po aviatsionnoy sputnikovoy sluzhbe* [Guidelines for the aeronautical mobile-satellite service]. Available at: http://libed.ru/knigi-nauka/967188-4-opublikovano-otdelnimi-izdaniyami-russkom-angliyskom-arabskom-ispanskom-kitayskom-francuzskom-yazikah-mezhdunaro.php (accessed: 12.03.2017).

8. ASC-6 GLONASS/GPS Available at: http://glonassclub. com/index.php?newsid=86 (accessed: 12.03.2017).

9. *Abonentskiy telematicheskiy terminal ASC-6 rukovodstvo po ekspluatatsii* [Subscriber telematics terminal ASC-6 manual. "Company AIC COM"]. Perm, 2014. P. 4–7.

10. GPRS. Available at: http://www.smartphone.ua/w_gprs.html (accessed: 12.03.2017).

11. *Modul' sputnikovoy svyazi SM1 rukovodstvo po ekspluatatsii* [Satellite communication module SM1 manual. "Company APK COM"]. Perm, 2013. 3 p.

12. *Modul' sputnikovoy svyazi SM-1* [Satellite communication module SM-1]. Available at: http://glonassclub.com/index.php?newsid=90. (accessed: 12.03.2017).

13. *Modem Iridium 9602 SBD* [Iridium Modem 9602 SBD]. Available at: URL: http://iridium-russian.ru/Oborydovanie/Spytnikovyi_modem_SBD_IRIDIUM_9602.html (accessed: 12.03.2017).

14. *Usluga paketnoy peredachi dannykh Iridium SBD* [short data packet service Iridium SBD]. Available at: http://bezprovodov.net/page/page20.html (accessed: 12.03.2017).

15. *Avtomatizirovannaya sistema monitoringa mobil'nykh i statsionarnykh ob''ektov "Navigator-S" Rukovodstvo pol'zovatelya* [The monitoring automated system of mobile and stationary objects "Navigator-S" Manual Eagle]. 2006, P. 3–7.

16. *Sistema monitoringa transporta Navigator-S* [The system of monitoring of transport Navigator C]. Available at: http://www.glonass-portal.ru/catalog/soft/monitoring/navigator_s (accessed: 12.03.2017).

Библиографические ссылки

1. Применение систем спутникового мониторинга транспортных средств для обеспечения эффективности логистических процессов [Электронный ресурс]. URL: http://www.rae.ru/forum2012/21/2998 (дата обращения: 12.03.2017).

2. Применение ГЛОНАСС/GPS-мониторинга транспорта [Электронный ресурс]. URL: W8http://gigabaza.ru/doc/49862.html (дата обращения: 12.03.2017).

3. Мониторинг транспорта [Электронный ресурс]. URL: http://monitoringtransporta.ru (дата обращения: 12.03.2017).

4. Громаков Ю. А. Стандарты и системы подвижной радиосвязи. М. : Эко-Трендз. 1997. 239 с.

5. Система спутниковой связи Iridium [Электронный ресурс]. URL: http://www.marsat.ru/Technologies-Iridiumnetwork (дата обращения: 12.03.2017).

6. Руководство по авиационной подвижной спутниковой (маршрутной) службе / ICAO. 2010, С. II.2.18–II.2.21.

7. Руководство по авиационной подвижной спутниковой службе [Электронный ресурс]. URL: http://libed.ru/knigi-nauka/967188-4-opublikovano-otdelnimi-izdaniyami-russkom-angliyskom-arabskom-ispanskom-kitayskom-francuzskom-yazikah-mezhdunaro.php (дата обращения: 12.03.2017).

8. ASC-6 ГЛОНАСС/GPS [Электронный ресурс]. URL: http://glonassclub.com/index.php?newsid=86 (дата обращения: 12.03.2017).

9. Абонентский телематический терминал ASC-6: руководство по эксплуатации / ООО «Компания АПК КОМ». Пермь, 2014. С. 4–7.

10. GPRS [Электронный ресурс]. URL: http://www.smartphone.ua/w_gprs.html (дата обращения: 12.03.2017).

11. Модуль спутниковой связи SM1: руководство по эксплуатации / ООО «Компания АПК КОМ». Пермь, 2013. 3 с.

12. Модуль спутниковой связи SM-1 [Электронный ресурс]. URL: http://glonassclub.com/index.php?newsid=90. (дата обращения: 12.03.2017).

13. Модем Iridium 9602 SBD [Электронный ресурс]. URL: http://iridium-russian.ru/Oborydovanie/Spytnikovyi_modem_SBD_IRIDIUM_9602.html (дата обращения: 12.03.2017).

14. Услуга пакетной передачи данных Iridium SBD [Электронный ресурс]. URL: http://bezprovodov.net/page/page20.html (дата обращения: 12.03.2017).

15. Автоматизированная система мониторинга мобильных и стационарных объектов «Навигатор-С»: руководство пользователя. Орел, 2006. С. 3–7.

16. Система мониторинга транспорта «Навигатор-С» [Электронный ресурс]. URL: http://www.glonass-portal.ru/catalog/soft/monitoring/navigator_s (дата обращения: 12.03.2017).

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