AEROSPACE SYSTEMS FOR MONITORING AND CONTROL

UDC 621.396:621.396.933:629.783:621.396.946

Wang Bo[1]
Volodymyr Kharchenko[2]
Andrii Grekhov[3]
Ismail Ali[4]

ESTIMATION OF DATA TRAFFIC OVERLOAD FOR SATELLITE COMMUNICATIONS

[1,2]Ningbo University of Technology
201, Fenghua Road, 315211, Ningbo, China
[2,3,4]National Aviation University
Kosmonavta Komarova Avenue 1, 03680, Kyiv, Ukraine
E-mails: [1]vanbo@ nau.edu.ua; [2]kharch@nau.edu.ua; [3]grekhovam@ukr.net; [4]shabandar33@gmail.com

Abstract. *For modelling of aviation data transmition with the help of low-orbit satellites different models of communication channel "Aircraft-Satellites-Ground Station" were built using NetCracker Professional 4.1 software. Influence of aircraft and satellites amount on average downlink utilization and message travelling time was studied for telecommunication channels with intersatellite link. The effect of communication channel overload during simultaneous data transmission through several satellites from many aircraft was investigated.*

Keywords: average utilization; data bit rate satellite; message travelling time; models for communication channel "Aircraft-Satellites-Ground Station"; telecommunications channel; traffic.

1. Problem statement

The way aircraft are tracked is radically changing today. The current radar-based approach is replaced by satellite tracking systems. Aviation telecommunications is dynamically developing due to evolution of communication characteristics and signal processing principles in a link between a satellite and aircraft.

The new system would let air traffic controllers track aircraft using a satellite network known as Automatic Dependent Surveillance Broadcast (ADS-B), which is more accurate than today's radar technology. ADS-B promises a ten-fold increase in the accuracy of satellite signals that will let air traffic controllers reduce separation standards between aircraft, significantly increasing the number of aircraft that can be safely managed [1].

To meet an increasing aviation demand for multimedia services and electronic connectivity across the world, satellite networks will play an indispensable role in the deployment of global aviation networks [2].

Satellite networks play an important role for data delivery. They are very effective for data transmitting over large geographic locations, and for reaching remote locations lacking in communication infrastructure.

For that reason the deep analysis of traffic parameters for “Aircraft-Satellites-Ground Station” channel is urgently needed.

It is important to develop models of aviation satellite communication channels for data transmitting and to research ways of channel parameters correction in critical situations.

Nevertheless issues related to the satellite channel parameters estimation leading to data traffic overload still is not investigated in detail.

2. Analysis of researches and publications

VHF Data Exchange System (VDES) is a technological concept developed by the International Association of Lighthouse Authorities Committee and now widely discussed at International Telecommunications Union, International Maritime Organization and other institutions. VDES was originally developed to address emerging indications of overload for VHF Data Link (VDL) in Automated Information System and simultaneously enabling a wider seamless data exchange for the maritime community [3].

The advent of unmanned aerial vehicles and other network-centric capabilities on land and sea led to an ever-expanding use of satellite communications. Effective communication on the battlefield is always an integral part of conflict and is decisive in a battle.

That means assured communications in remote areas of the world. As technology advances, so does the amount data that is created. Unmanned aerial vehicles alone produce huge quantities of data when they go up in the air and begin sending back crucial operational data that can create data overload for military satellite communications [4].

However, present day satellites are limited in their ability to provide high data rate communication services due to the limited availability, and high cost of satellite resources such as power, energy, and frequency bands. Moreover, present communication satellites were designed almost exclusively for supporting stream traffic such as voice, video or bulk data transfers, and are not efficient for the transmission of "bursty" data traffic such as Internet traffic. So, it is necessary to shift from traditional circuit switched technology, used for voice communication, to packet switched technology, used in data networks [5].

During last years technologies have stepped forward and today there is a set of satellite communication systems that are able to provide information exchange in aviation: INMARSAT, COSPAS/SARSAT, Iridium, Globalstar and Thuraya. Each of them has its benefits, but in terms of global data transferring Iridium has the absolute advantage, that is 66 satellites and coverage of the whole Earth surface [6].

3. Aim of the work

The aim of this work is: 1) to create models of communication channel "Aircraft-Satellites-Ground Station" using NetCracker Professional 4.1 software; 2) to consider and analyze the dependencies of an Average Workload (AW), an Average Utilization (AU) in a downlink and a message Traveling Time (TT) on the number of aircraft and satellites, a Transaction Size (TS), a Time Between Transactions (TBT), a traffic profile, a Bit Error Rate (BER), and a Packet Fail Chance (PFC); 3) to study effect of communication channel overloading during simultaneous data transmission from many aircraft via different number of satellites; 4) to estimate the parameters of aeronautical satellite communication channel.

1. Models for "Aircraft-Satellites-Ground Station" channel

For modeling of aviation data transmission through satellite communication channel computer software NetCracker Professional 4.1 was used.

The following notations for the channel models were used: AkSmGn, where k – is the number of aircraft A, m – is the number of Satellites S, and n – is the number of ground stations G.

On Fig. 1 a model A11S10G1 with intersatellite link is shown: eleven airborne stations, ten Iridium satellites and terrestrial air traffic control centre.

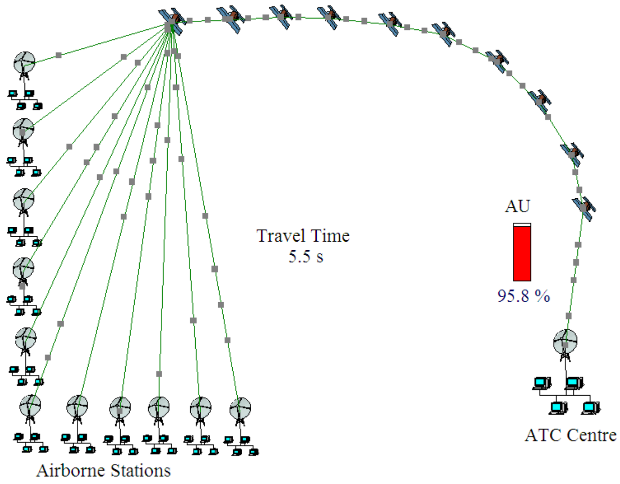

Fig. 1. "Aircraft-Satellites-Ground Station" channels

Models contain packet switching circuits with bandwidth T1=1,544 Mbit/s. Packet latency, a packet fail chance, and a BER assumed to be zero except in special cases. Different types of traffic profiles were investigated, but results in this paper are given only for InterLAN traffic.

There are local network nodes which are located geographically at a distance of more than 12 500 km (orbital space stations and centers). Despite these distances, similar networks are still referred to as local.

The following Probability Density Functions (PDF) for a TS and a TBT were considered: Constant, Uniform, Exponential, Normal, Lognormal, Gamma, and Erlang, but results are given not for all distribution laws.

2. Aeronautical Satellite Communication Channel Simulation

It is important to understand how much and what kind of messages will be able to pass with a large number of aircraft, simultaneously using satellite link. Fig. 2 shows at what value of the transaction size channel congestion occurs when the number of aircraft is increasing. In this case Const PDF for TS parameter and LogNormal and Exponential PDF for TBT parameter were taken. It can be seen that the results are radically different: the size of the transaction, which can be transmitted without congestion, is more on the order for LogNormal PDF. Common for considered distribution laws is that by increasing the number of aircraft the size of the maximal transaction is reduced to a finite value. The increase in the number of satellites has little effect, and "saturation" of the channel occurs at slightly larger values of a transaction size.

Fig. 3 shows the variation of a parameter AW in dependence on a parameter TS (for a fixed value of a parameter TBT) when changing the type of a PDF for a parameter TBT.

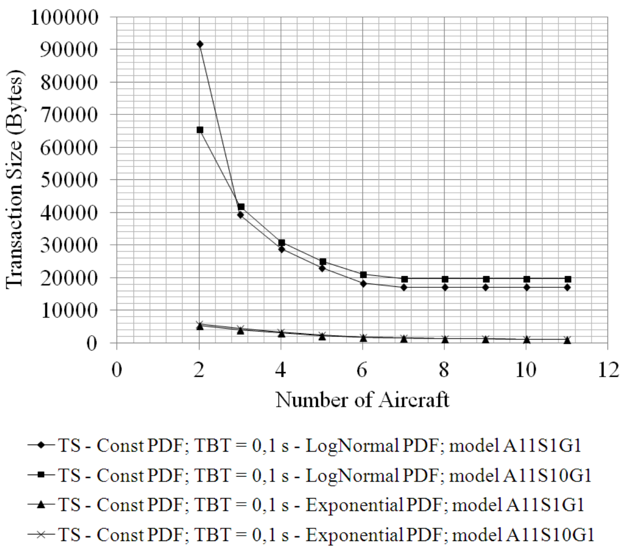

Fig. 2. Number of aircraft for which Average Utilization of Downlink is 100%

The lowest value of a parameter AW is observed for LogNormal distribution, and the highest value - for Uniform PDF. All types of distributions are characterized by "saturation" (for LogNormal law AW ≈ 36846 bytes/s, for Exponential law - AW ≈ 67004 bytes/s, for Normal and Uniform laws AW ≈ 99650 bytes/s).

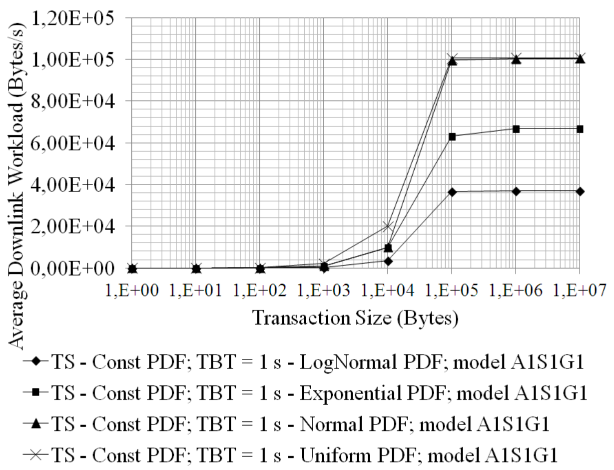

Fig. 3

On Fig. 4 as an example a dependence of a parameter AU on a BER is shown (at TBT = 0,2 s and Exponential PDF) for TS = 10^3 bytes and TS = 10^5 bytes with Const PDF. For BER = 0% an average downlink utilization is 3% and 25% respectively. With increasing a BER a parameter AU for TS = 10^3 bytes is increasing too but slowly (data are transmitted with a small number of errors), and for TS = 10^5 bytes increases rapidly up to 100%. For other types of distributions the nature of change of these curves is similar.

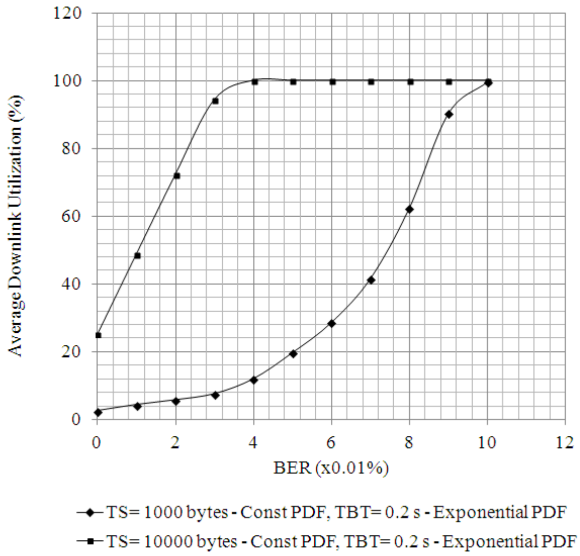

Fig. 4

On Fig. 5 as an example a dependence of a parameter AU on a PFC is given (at TBT = 0,2 s and Exponential PDF) for TS = 10^3 bytes and TS = 10^5 bytes with Const PDF.

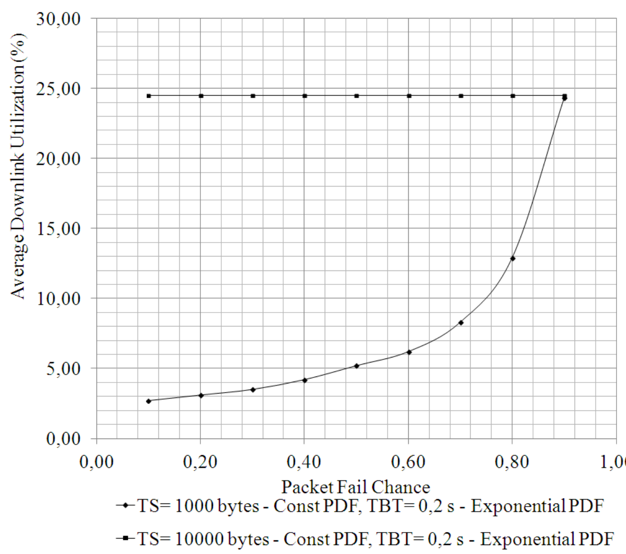

Fig. 5

It is seen that for TS = 10^3 bytes a parameter AU grows slowly, giving a total AU = 5% at PFC = 0.5. For large transactions (TS = 10^5 bytes) at selected traffic settings a parameter AU is constant and equal to 25%. Notice, that with increasing a probability of packet fail chance a parameter AU is not increased.

Fig. 6 demonstrates the dependence of a parameter AU on the types of a distribution law for a parameter TS. These are the same values up to the parameter values TS = 10^3 bytes, and a significant difference only for large transactions.

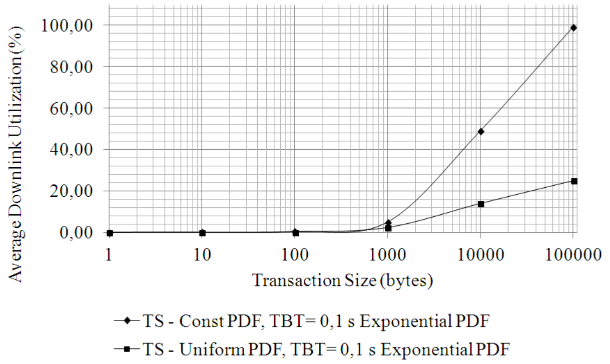

Fig. 6

This is because for Const distribution law all transactions have the same dimensions, and at Uniform law different-sized transactions within the prescribed limits are sent with equal probability.

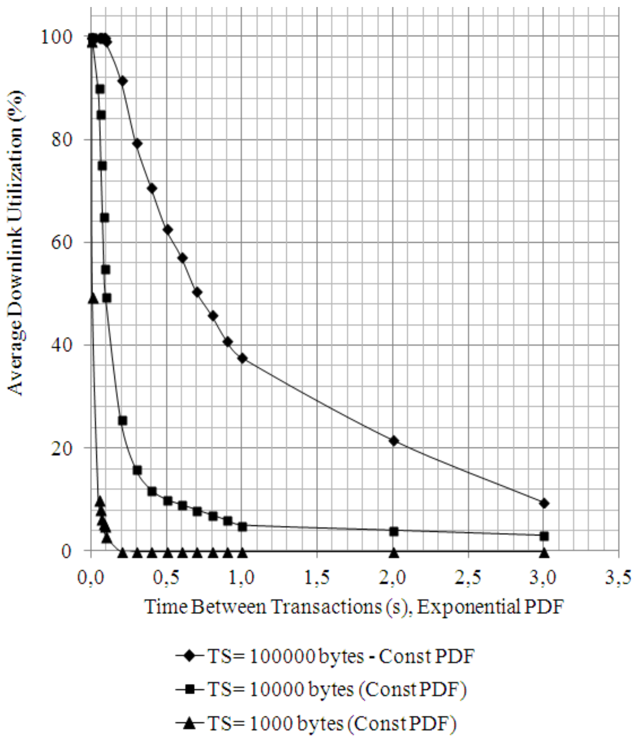

Fig. 7

Fig. 7 shows the dependence of a parameter AU on a parameter TBT with Exponential PDF for three different parameters TS with Const PDF. The result was trivial - the more a parameter TS, the greater is a parameter AU. But attention is drawn to the character of a parameter AU recession with an increasing of a parameter TBT, - the larger the transaction size, the slower is decreasing of a parameter AU during an increasing of a parameter TBT.

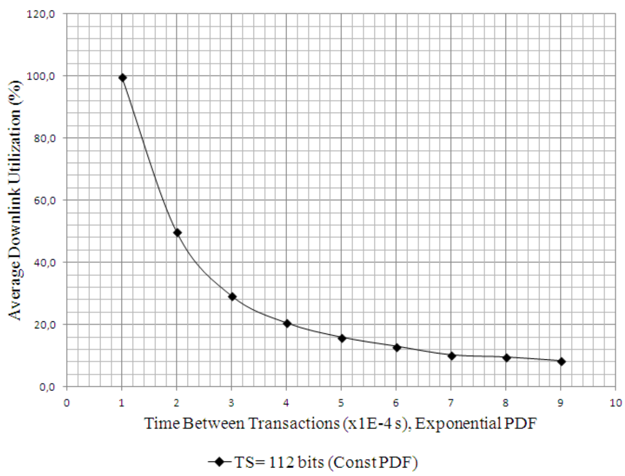

Fig. 8. Transmission of ADS-B messages

A "special **c**ase" is given on Fig. 8 for dependence of a parameter AU on a parameter TBT for ADS-B messages with transaction size 112 bits (in Mode S Extended Squitter). A parameter AU reaches 100% at TBT = 0,1 s with Exponential PDF. Then there is a rapid decline of a parameter AU with increasing of a parameter TBT.

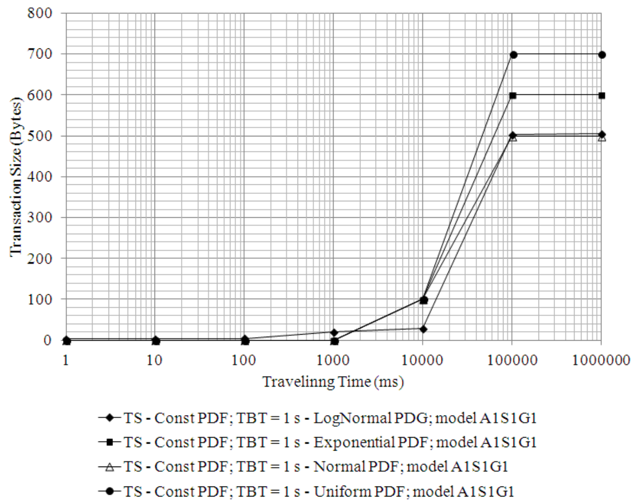

Fig. 9

Fig. 9 shows the dependence of a parameter TS on a parameter TT with different distribution laws for a time between transactions. The "Best" is LogNormal distribution, and the "Worst" - the Uniform one.

4. Conclusions

1. A number of satellites doesn't influence on an average workload and an average utilization neither "Aircraft–Satellite" link nor "Satellite–Ground station" link. The only parameter that is affected by a number of satellites in the link is a message Travel Time.

2. An Average Utilization and an Average Workload of "Satellite-Ground station" link are growing proportionally to the number of aircraft connected with the satellite channel.

3. An Average Workload and an Average Utilization of each link are not affected by the cable length. The only indicator that is sensitive to cable length changes is a Travel Time.

4. A Transaction Size affects an Average Workload, an Average Utilization and a Travel Time. The behavior of influence depends on probability distribution law. The system that transmits messages with small transaction size should implement Constant and Uniform distribution laws. For the systems where transaction size is in the range of 100 – 1000 bytes the best operational characteristics are achieved with Constant, Uniform, Normal and Exponential laws. In case of big size of transactions (more than 1000 bytes) the LogNormal law should be used. Gamma distribution law is not suitable at all.

5. Increasing of a Time Between Transactions leads to increasing of potential number of aircraft that can be connected to the channel. In the case of Constant, Uniform, Exponential or Normal distribution laws for a Time Between Transactions its value should be within 100 ms – 10s range. Gamma distribution law doesn't give the proper values required by aviation systems. The most reliable and acceptable result from an Average Utilization point of view is obtained by applying LogNormal law to distribution of a Time Between Transactions.

6. The increasing of link bandwidth doesn't influence on an Average Workload value. But an Average Utilization of the link where changes are applied is decreasing. A Travel Time of message transmission over the communication channel is declining as well.

7. Link latency directly affects a Travel Time. This influence depends on the distribution law of traffic transmitted by the link. The most acceptable results are obtained for Constant, Exponential, Normal and Uniform distribution laws. The Gamma law causes bigger value of data travel time that doesn't meet the requirements for the systems developed for aviation purposes.

8. Different suitable traffic profiles slightly influence on the performance of communication channel.

9. A Bit Error Rate and a Packet Fail Chance are affected by link Average Workload, Average Utilization and messages Travelling Time. In order to get the best operational capabilities of the communication channel the values of a Bit Error Rate and a Packet Fail Chance should tend to zero.

10. It was discovered that a Bit Error Rate and a Packet Fail Chance values extremely grow when an Average Utilization of the link is increasing. That means that all parameters that cause an Average Utilization changes, namely a Transaction Size, a Time Between Transaction and a Link Bandwidth, should be chosen in such a way to prevent the exceeding of an Average Utilization the acceptable level.

The practical significance of this paper is determined by the following:

– The conditions were determined of satellite link overload.

– Simulation models were developed for determination the optimal aviation satellite link parameters.

– Recommendations on the choice of aviation satellite channel parameters were formulated.

References

[1] Global Air Navigation Plan for CNS/ATM Systems. ICAO, 1998. Doc. 9750. Available from Internet: <http://www.icao.int/publications/Documents/9750_2ed_en.pdf>.

[2] *Kota S., Goyal M., Goyal R., Jain R.* Multimedia Satellite Networks and TCP/IP Traffic Transport. International Journal of Computers and Applications. – 2001. – v. 23. - N 2. – P. 115-128.

[3] Electronic Communications Committee. Information Paper on VHF Data Exchange System

[4] (VDES). 3rd Meeting CPG PTC Bucharest, 08-11 October 2013. Available from Internet: <cept.org/documents/cpg-pt-c/13547/cpg-tc>.

[5] *Turnbull G.* Data overload: satellite communications on the battlefield. – 2013. Available from Internet: http://www.airforce-technology.com/features/feature-data-overload-satellite-communications-battlefield.

[6] *Modiano E.* Satellite Data Networks. Journal of Aeropace Computing, Information, and Communication. – 2004. – v.1. – P. 395 – 398.

[7] Iridium Satellites. 2008. Available from Internet: <http://www.highspeedsat.com/iridium-satellite.php>.

Received 10 December 2015.

Ванг Бо[1], В.П. Харченко[2], А.М. Грехов[3], І.М. Алі[4]. Оцінювання умов перевантаження при передаванні даних через супутниковий канал зв’язку

[1,2]Технологічний університет Нінгбо, дорога Фенхуа, 201, Нінбо, Китай, 315211

[2,3,4]Національний авіаційний університет, просп. Космонавта Комарова, 1, Київ, Україна, 03680

E-mails: [1]vanbo@ nau.edu.ua; [2]kharch@nau.edu.ua; [3]grekhovam@ukr.net; [4]shabandar33@gmail.com

Для моделювання передачі авіаційних даних через низьоорбітальні супутники з використанням програмного комплексу NetCracker Professional 4.1 побудовано різні моделі каналу зв'язку «Літаки-Супутники-Наземна станція». Вивчено вплив кількості літаків і супутників на середнє завантаження каналу «Униз» і час проходження повідомлень для телекомунікаційних каналів з міжсупутниковим зв'язком. Досліджено умови виникнення перевантаження каналу зв'язку при одночасній передачі даних через декілька супутників від багатьох літаків.

Ключові слова: авіаційний канал супутникового зв'язку; моделі каналу зв'язку «Літаки-Супутники-Наземна станція»; середнє завантаження каналу; трафік трафік; час проходження повідомлення.

Ванг Бо[1], В.П. Харченко[2], А.М. Грехов[3], И.М. Али[4]. Оценивание условий перезгузки при передаче данных через спутниковый канал связи

[1,2]Технологический университет Нингбо, дорога Фенхуа, 201, Нинбо, Китай, 315211

[2,3,4]Национальный авиационный университет, просп. Космонавта Комарова, 1, Киев, Украина, 03680

E-mails: [1]vanbo@ nau.edu.ua; [2]kharch@nau.edu.ua; [3]grekhovam@ukr.net; [4]shabandar33@gmail.com

Для моделирования передачи авиационных данных через низкоорбитальные спутники с использованием программного комплекса NetCracker Professional 4.1 построены различные модели канала связи «Самолеты-Спутники-Наземная станция». Изучено влияние количества самолетов и спутников на среднюю загрузку канала «Вниз» и время прохождения сообщений для телекоммуникационных каналов с межспутниковой связью. Исследованы условия возникновения перегрузки канала связи при одновременной передаче данных через несколько спутников от многих самолётов.

Ключевые слова: авиационный канал спутниковой связи; время прохождения сообщения; модели канала связи «Самолеты-Спутники-Наземная станция»; средняя загрузка канала; трафик.

Wang Bo (1980). Doctor`s degree in aviation fuel cost control (National Aviation University Ukraine). Aassociate Professor.

College of Economics and Management of Ningbo University of Technology China.

Research area: Presided over a “high-end project” launched by Chinese Bureau of Foreign Experts; Presided over and accomplished a longitudinal project launched by the provincial education department; Presided over a 800-thousand Yuan horizontal project launched by Ningbo Traffic Detachment; Took a major part in a project on international cooperation launched by Ministry of Science and Technology of China (2/6); Took part in a municipal project on social sciences and quite a number of horizontal projects in Ningbo.

Publications: 35.

E-mail: vanbo@ nau.edu.ua

Kharchenko Volodymyr. Doctor of Engineering. Professor.

Winner of the State Prize of Ukraine in Science and Technology, Honored Worker of Science and Technology of Ukraine. Acting Rector of the National Aviation University, Kyiv, Ukraine. Professor of Traffic College of Ningbo University of Technology, Ningbo, China. Editor-in-Chief of the scientific journal Proceedings of the National Aviation University.

Education: Kyiv Institute of Civil Aviation Engineers, Kyiv, Ukraine. Research area: management of complex socio-technical systems, air navigation systems and automatic decision-making systems aimed at avoidance conflict situations, space information technology design, air navigation services in Ukraine provided by CNS/ATM systems.
Publications: 500.
E-mail: knarch@nau.edu.ua

Grekhov Andrii (1951). Doctor of Physics and Mathematics (1990). Professor (1991). Expert of EUROCONTROL for ADS-B systems.
Department of Air Navigation Systems, National Aviation University, Kyiv, Ukraine.
Education: Physical Department of the Kyiv State Taras Shevchenko University, Ukraine (1973), M.Sc. Degree with Honors confirming qualification of Physicist Theorist.
Research area: satellite communications and information channels, computer modeling of information flows in airborne collision avoidance systems, ADS-B systems, surveillance processes and modern signal processing, expansion of terrestrial surveillance systems for ADS-B using satellite system IRIDIUM, noise resistant coding and forward error correction, aviation security assessment based on simulation.
Publications: 175.
E-mail: grekhovam@ukr.net

Ali Ismail (1990). Post-graduate Student.
National Aviation University, Kyiv, Ukraine.
Publications: 5.
E-mail: shabandar33@gmail.com