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ZHULIANY AIRPORT AS A POSSIBLE CANDIDATE FOR RANGING INTEGRITY MONITORING STATION PLACEMENT IN KYIV REGION

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***Abstract*—*The perspective of extending the European Geostationary Navigation Overlay Service outside the European Civil Aviation Conference area is of great interest for Europe. Ukraine is among the first candidates for installation of the Ranging and Integrity Monitoring Station on its territory to provide better coverage to the Eastern part of Europe, and it was a preliminary decision of European Commission that one RIMS will be placed in Kyiv region. However, the special requirements have to be fulfilled by the RIMS hosting candidates in technical, safety, and security aspects. The authors have made investigation of the best locations for the RIMS at the territory of Ukraine in scope of UKRAINE project, funded by the European GNSS agency (Horizon 2020, Grant Agreement #641514). It appeared that Zhuliany airport was one of the most attractive locations among analyzed sites. Therefore, the purpose of this article was to present some practical results from the measurement campaign in Zhuliany airport, which is considered as a candidate for RIMS installation in Kyiv region. Raw GNSS measurements have been collected from six points near the runways with use of double frequency geodetic type GNSS receiver and limitation on the satellites' elevation angles of 5°. Among the verified parameters were: observed GNSS constellations; the "signal / noise" ratio of the received GNSS signals on L1 and L2; the number of phase "slips"; the level of multipath in navigational observations on L1 and L2 frequencies. The results of measurements and analysis are presented in corresponding graphs and plots in a paper.*

Index Terms—Global navigation satellite systems; satellite based augmentation systems; European geostationary navigation overlay service; ranging and integrity monitoring station; multipath level; "signal / noise" ratio.

I. INTRODUCTION

The Global Navigation Satellite Systems (GNSS) includes core constellation systems (like GPS, GLONASS and the future GALILEO and Beidou), and augmentation systems such as Aircraft Based Augmentation Systems (ABAS), Satellite Based Augmentation Systems (SBAS) – like WAAS in USA and Canada, EGNOS in Europe – and Ground Based Augmentation System (GBAS) [1].

The European Geostationary Navigation Overlay Service (EGNOS) is a satellite-based augmentation system (SBAS). It augments the GPS L1 positioning signals and makes them suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels. This system has been developed by the European Space Agency (ESA) under a tripartite agreement between the European Commission (EC), the European Organization for the Safety of Air Navigation (EUROCONTROL) and ESA, signed in June 1998. It is Europe's first activity in the field of GNSS and is a precursor to Galileo, the full global satellite navigation system under development in Europe.

The Civil Aviation community benefits greatly from the Safety-of-Life (SoL) service of EGNOS, whose main objective is to support civil aviation operations down to Localizer Performance with Vertical Guidance (LPV) minima by improving the accuracy and availability of user positioning services. The SoL service was available starting from March 2011, and LPV200 has been approved for use in aviation in 2015 [2].

The newer version, EGNOS V3 is expected to be released in 2024, and augment Galileo additionally to GPS starting in 2025 [3]. It will offer improved SoL services performances over Europe to Civil Aviation community and new applications for Maritime or Land users, and will improve robustness against increasing security risks, in particular cyber-security risks. Airbus has been selected by the ESA as the prime contractor to develop EGNOS V3 [4].

Current EGNOS V2 system architecture together with its service area is presented at the Fig. 1 [2].

The system combines now interconnected ground network of 39 Ranging and Integrity Monitoring Stations (RIMS), 6 Navigation Land Earth Stations

(NLES), 2 Mission Control Centres (MCC) and 3 Geostationary satellites (two Inmarsat III and IV satellites and one SES ASTRA GEO satellite SES-5) with signal transponders [2], [5].

At the moment, EGNOS offers good performance in all EU countries with the exception of certain places located in the northern, southern, and eastern extremes of EU territory (Figs 1, 2) due to current infrastructure limitations. Currently, Ukraine is not fully covered by this service, only some small western part, where the availability is ≥ 99.9% (Fig. 2) [6]. However, technically EGNOS has the capability to be extended here by implementation of one or few additional RIMS.

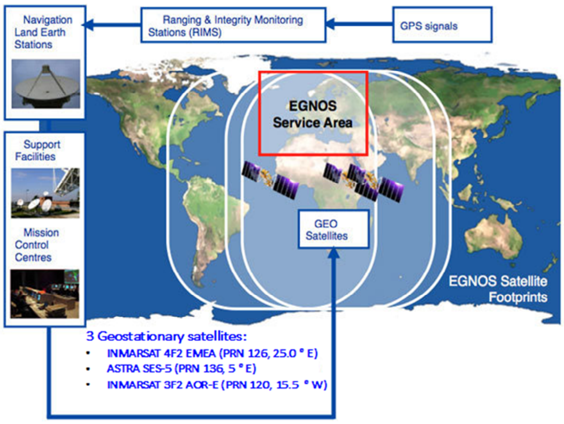

Fig. 1. High-level scheme of EGNOS infrastructure

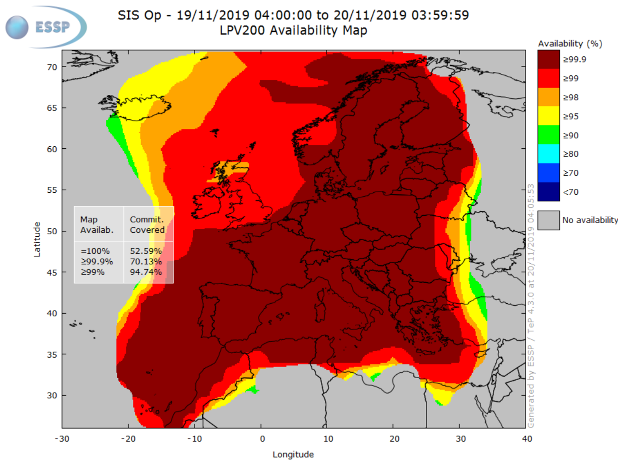

Fig. 2. LPV-200 availability map [6]

II. Problem Statement

As a matter of fact, the perspective of extending the EGNOS outside the European Civil Aviation Conference (ECAC) area is of great interest for Europe not only at technical level but also at commercial and political ones. According to the agreements with the EC, at least one RIMS station will be placed in Ukraine, in Kyiv region in the nearest few years. This initiation is confirmed by corresponding agreements between EC and Ukraine.

It has to be mentioned that special requirements are made to the RIMS hosting candidates, which should be capable to fulfil the technical, safety, and security requirements and who are prepared to provide support during the deployment and on-site integration and validation phase. The most significant technical constraints concerning RIMS hosting are given in [7]. Here we will refer to some of them, which were checked during our measurement sessions.

To provide two independent measurement flows to the Central Processing Facilities (CPF) to each MCC, distance between two RIMS antennas on a given site shall be separated by several tens of meters: not less than 60 meters, with an objective of 120 m (when feasible taking into account site constraints). At the same time, cable run from receiver to antenna must not exceed 80 meters in order to limit the radio frequency (RF) losses.

The site shall allow a RIMS antenna location with clear horizon above 5° elevation.

To ensure that multipath level is acceptable, taking into account the large spectrum of RIMS site surrounding: various type of reflective source, multiple multipath signals, multipath dependency with elevation.

In order to be sure that mentioned above requirements are satisfied, comprehensive survey campaigns have to be done at each possible candidate host site.

Actually, in scope of Ukraine project, funded by the European GNSS agency (Horizon 2020, Grant Agreement # 641514), the investigation of the best locations for the RIMS at the territory of Ukraine has been done by the National Aviation University (NAU). The research included simulation for the whole territory of Ukraine and comprehensive measurement surveys for the selected and agreed with the State Space Agency of Ukraine (SSAU) locations near Kyiv region, namely, premises of Zhuliany and Boryspil airports, Main center of special control (Horodok of Zhytomyr region), State Enterprise "KyivPrylad" and NAU [8].

The aim of this paper was to present the results of the measurement campaign from Zhuliany airport, which has been selected as the most suitable location for the RIMS installation in Kyiv region.

III. Related Studies

The authors have been investigating different aspects of EGNOS performance on latitude 50.5 ° and longitude 30.5 ° starting from 2009, when its operability was declared [9] – [11].

In full, these materials are presented on the website of the Aerospace Center [12] and in the repository of the NAU [13] in the form of reports automatically generated by the PEGASUS software, containing positions processed information: HPL versus HPE, VPL versus VPE, for vertical guidance approaches, LPV200, as well as information on integrity, availability, multipath, signal-to-noise ratio, Stanford diagrams, position statistics.

IV. EXPERIMENTAL MEASUREMENTS AND RESULTS

The measurement points in Zhuliany airport are presented in the Fig. 3, from which it can be seen that GNSS antennas have been placed in a manner to form triangle shapes with sides of ≈ 80 m length. As it can be seen from the figure, redundant number of points have been taken, in order to choose the best location inside the airport premises.

Fig. 3. Measurement point in Zhuliany airport

To register the measurement information double frequency geodetic type GNSS receiver (DL-4, on the basis of Novatel OEM4-G2 board) with 703GGG NovAtel antenna have been used. The limitation on the satellites elevation angle has been set to 5 ° to fulfil the requirement mentioned above. The photos from the measurement session in Zhuliany are presented in the Fig. 4, where the adjustment ofequipment and data recording process may be seen.

The following features of measurement session have been analyzed:

- observed GNSS constellation;
- the "signal / noise" ratio of the received GNSS signals on L1 and L2;
- the number of phase "slips";
- the level of multipath in navigational observations on L1 and L2 frequencies.

The observed working GNSS constellation was compared with planned constellation, calculated by means of almanac data for the current time and location of measurement session. In case when really observed constellation didn't coincide with the planned one the possible sources of such discrepancy were defined (not sufficient number of GNSS receiver channels, low elevation angles of observed satellites, low signals level, limitations on the way of signals propagation, tracking losses, etc.) [1], [14].

Then the multipath levels of navigation observations were calculated, correspondent graphics and maps were plotted, the possible sources of increased multipath occurrence were identified and, in case of such possibilities, the ways of its decreasing are defined (for example, removal the sources of signals reflection, GNSS antenna allocation in another place, etc.).

To process the data, the TEQC utility and OCTAVA_PPA complex have been used [13] – [18]. The results of the analysis of the information registered at point 1 are presented at the Figs 5 – 11. Here Fig. 5 demonstrates the intervals of satellites visibility. The signals multipath levels at the frequencies L1 and L2 are represented at the Figs 6 and 8 correspondently. The signal/noise ratio on L1 and L2 frequencies, plotted according to the data from the TEQC utility (corrected from phase "slips"), are demonstrated at the Figs 7 and 9 correspondently.

It has to be clarified that Figs 6 – 9 are plotted in the form of sky plots, where the satellites' path together with elevation angles may be seen. The information regarding signals multipath level and signal / noise ratio is shown by corresponding colors of satellite tracks.

Fig. 4. Measurement equipment adjustment and GNSS data recording

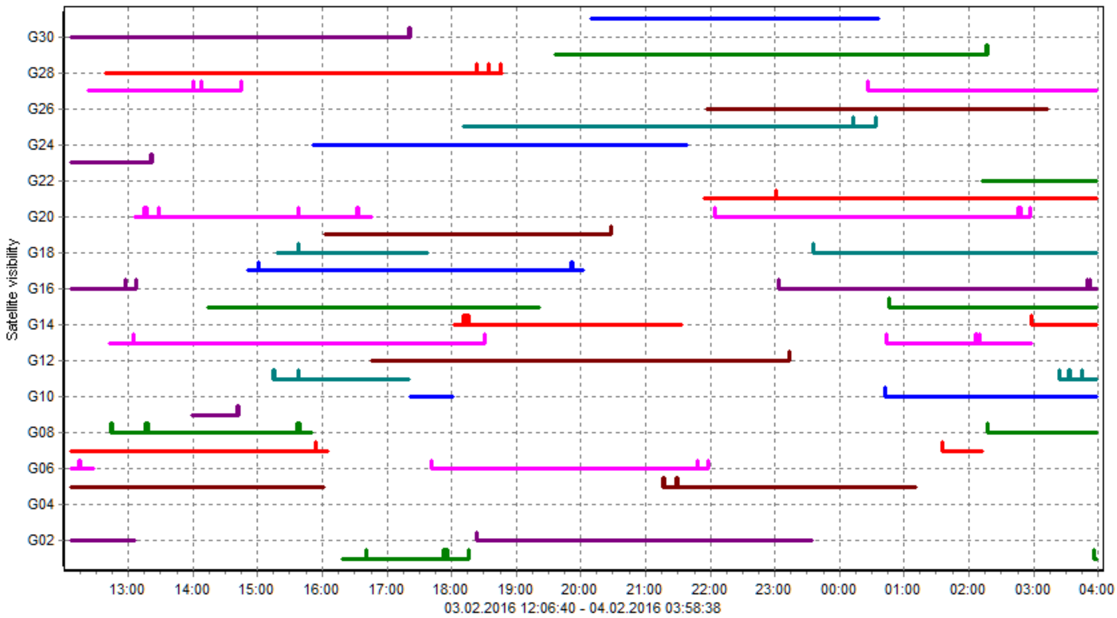

Fig. 5. Intervals of GPS satellites visibility

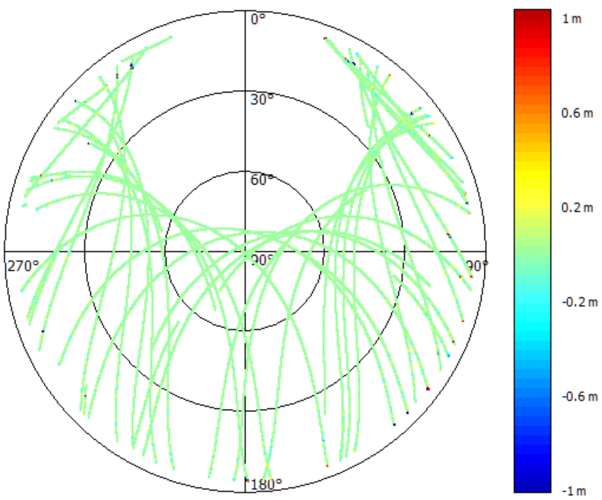

Fig. 6. Signals multipath level at the frequency L1

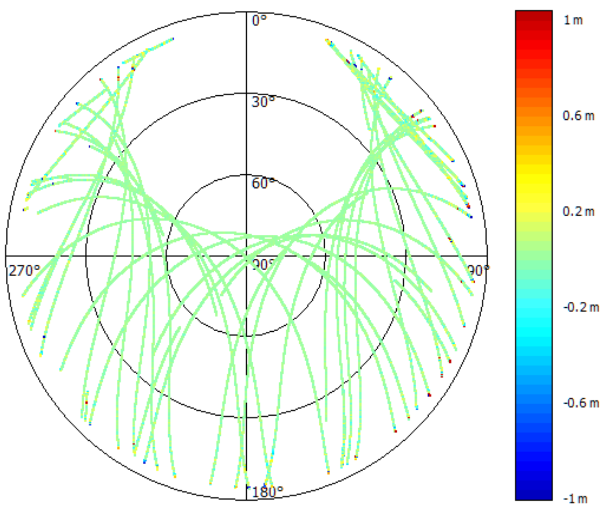

Fig. 8. Signals multipath level at the frequency L2

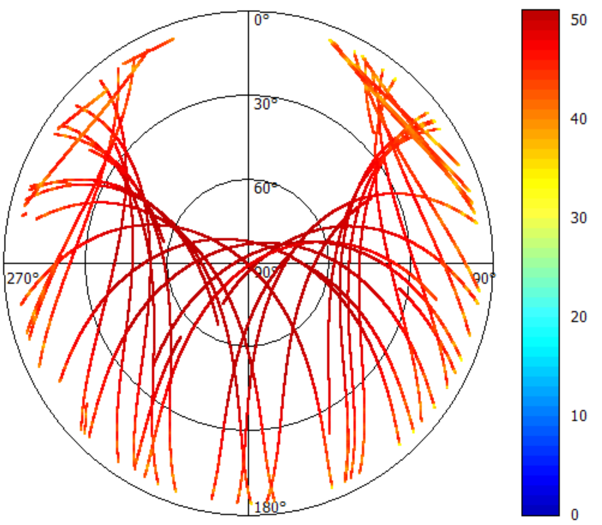

Fig. 7. Signal / noise ratio on L1 frequency (dB)

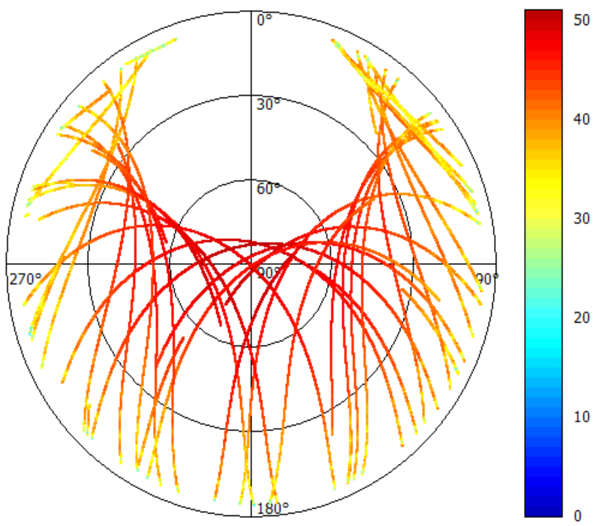

Fig. 9. Signal / noise ratio on L2 frequency (dB)

The analysis of the measurement information registered at point 1 near the runway of the Zhuliany airport (Fig. 3) showed that the receiver tracked all planned satellites, with no limitations. The mean level of signals multipath was 20–25 cm at the frequency L1 and 30–40 cm at L2. The maximal value of multipath levels at low elevation angles didn't exceed 1.5 m. However, there was one abnormal portion of measurements with duration of ≈ 30 s (04.02.2016, 15:37:27–15:38:01). Here the rapid decrease of the signal / noise ratio (Figs 10, 11) and increase of the signals multipath for all satellites happened (especially on L2 frequency).

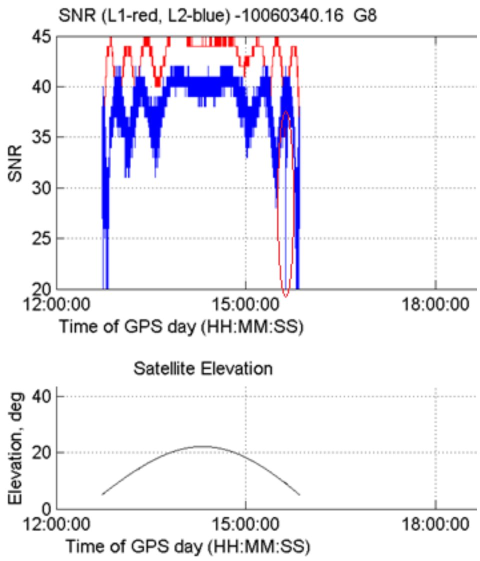

Fig. 10. The signal / noise ratio and elevation angle for satellite number 8

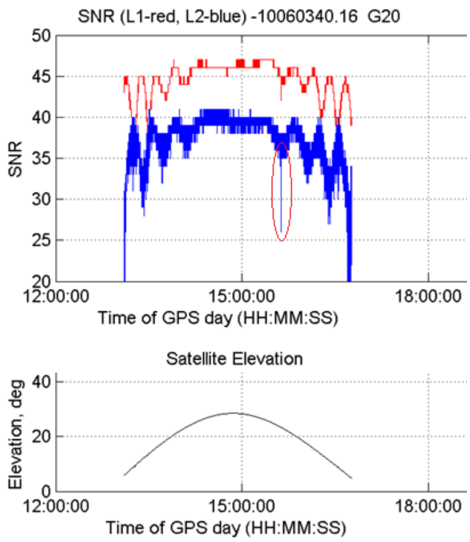

Fig. 11. The signal / noise ratio and elevation angle for satellite number 20

As a result, the GNSS receiver lost tracking of four satellites (numbers 8, 11, 18 and 20). Satellites 8, 11, 18 had been observed at low elevation angles (about 10 °), and the satellite 20 was at a sufficiently high elevation angle (about 24 °). The signal / noise ratios together with elevation angles for the satellite 8 and 20 are presented correspondently in the Figs. 10 and 11. Since the azimuths of mentioned satellites were different, then this abnormal portion of measurements can't be caused by a limited visibility. At 15:38:01 the receiver started tracking again all visible satellites, sharp fluctuations in the signal / noise ratio disappeared.

It has to be underlined that the results, similar to the ones presented in Figs 5 – 9 (excluding abnormal portions), have been obtained for the rest five points (Fig. 3) and other days during 2 months of measurement campaign as well [8]. Therefore, they may be used to characterize Zhualiany measurement site in general.

VI. CONCLUSIONS

Comparison of the analysis results of the raw measurement data collected in all points in Zhuliany airport showed that information in all points were practically of the same quality. Restrictions to the signals' reception were absent and the receiver tracked all planned satellites. Typically, the average signals multipath level didn't exceed 45 cm at the L1 and L2 frequencies. The maximum value of multipath levels at low elevation angles did not exceed 1.5 m.

At the same time, several abnormal portions of measurement had been revealed. At these portions the decrease in signal level and increase of multipath level, sometimes even loss of signals tracking for satellites with low elevation angles have been observed. The most likely reason of the anomaly was the interferences to the signal reception caused by radiation from exterior radio equipment, maybe, transmitting means of Zhuliany Airport. To determine the source of those interferences it was recommended to use special technical means (like radiogoniometers, spectrum analyzers), and perhaps to compare timetable of the airport's radio equipment work with time of abnormal portion of measurements.

The results of the further research, done by the European GNSS Agency (GSA) with use of the specialized radio measurement equipment are not presented here, but general conclusions regarding necessity to detect and mitigate possible interference source coincide.

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В. М. Кондратюк, В. В. Конін, С. І. Ільницька, О. В. Куценко. Аеропорт Жуляни як можливий кандидат на встановлення станції моніторингу дальності та цілісності у Київській області

Перспектива розширення Європейської служби геостаціонарного навігаційного покриття поза зоною Європейської конференції цивільної авіації складає великий інтерес для Європи. Україна входить до числа перших кандидатів на встановлення на її території станції моніторингу дальності та цілісності (RIMS) для кращого охоплення Східної частини Європи. Попередньо з Європейською Комісією було узгоджено, що одна RIMS станція буде розміщена на Київщині. Однак кандидат на встановлення такої станції повинене відповідати певним вимогам щодо техніки та безпеки. Автори провели дослідження кращих локацій для RIMS на території України в рамках проекту UKRAINE, що фінансувався Європейським агентством ГНСС (Горизонт 2020, Грантова Угода №641514). Виявилося, що серед проаналізованих локацій аеропорт Жуляни є однією із найпривабливіших. Тому метою цієї статті було представити деякі практичні результати проведеної вимірювальної кампанії в аеропорту Жуляни, який вважається кандидатом на встановлення RIMS станції на Київщині. З шести точок біля злітно-посадкових смуг зібрано первинні вимірювання сигналів ГНСС, з використанням двохчастотного приймача та накладеним на нього обмеженням щодо кутів підйому супутників у 5°. Серед проаналізованих параметрів були: спостережувані сузір'я ГНСС; співвідношення «сигнал / шум» отриманих ГНСС-сигналів на частотах L1 і L2; кількість фазових «ковзань»; рівень багатопроменевості у навігаційних спостереженнях на частотах L1 і L2. Результати вимірювань та аналізу представлені на відповідних графіках у статті.

Ключові слова: глобальні навігаційні супутникові системи; супутникова система функціонального доповнення; Європейська служба навігаційного геостаціонарного покриття; станція моніторингу дальності та цілісності; рівень багатопроменевості; співвідношення «сигнал / шум».

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В. М. Кондратюк, В. В. Конин, С. И. Ильницкая, А. В. Куценко. Аэропорт Жуляны как возможный кандидат для установки станции мониторинга дальности и целостности в Киевской области

Перспектива расширения Европейской службы геостационарного навигационного покрытия за пределы зоны Европейской конференции гражданской авиации представляет большой интерес для Европы. Украина является одним из первых кандидатов на установку станции контроля дальности и целостности на ее территории для обеспечения лучшего покрытия восточной части Европы. Согласно предварительной договоренности с Европейской комиссией одна из RIMS станций будет расположена в Киевской области. Тем не менее, принимающими RIMS кандидатами должны быть выполнены специальные требования в технических аспектах и по безопасности. Авторы провели исследование лучших мест размещения RIMS на территории Украины в рамках проекта UKRAINE, финансируемого Европейским агентством ГНСС (Horizon 2020, Грантовое соглашение №641514). Среди анализируемых объектов аэропорт Жуляны оказался одним из самых привлекательных мест. Поэтому целью данной статьи было представить некоторые практические результаты измерительной кампании в аэропорту Жуляны, который рассматривается в качестве кандидата на установку RIMS станции в Киевской области. В шести точках вблизи взлетно-посадочных полос были записаны первичные ГНСС измерения с использованием двухчастотного приемника геодезического типа и ограничениями на нем по углам места спутников в 5 °. Среди проанализированных параметров были: наблюдаемые созвездия ГНСС; отношение «сигнал / шум» принятых ГНСС сигналов на частотах L1 и L2; количество фазовых «проскальзываний»; уровень многолучевости в навигационных наблюдениях на частотах L1 и L2. Результаты измерений и анализа представлены на соответствующих графиках в статье.

Ключевые слова: глобальные навигационные спутниковые системы; спутниковая система функционального дополнения; Европейская служба навигационного геостационарного покрытия; станция мониторинга дальности и целостности; уровень многолучевости; отношение «сигнал / шум».

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