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METHODS FOR IMPROVING THE ACCURACY OF DATA PROCESSING IN AIR TRAFFIC CONTROL SYSTEMS UNDER COMPLEX INTERFERENCE CONDITIONS IN MOUNTAINOUS AND FOOTHILL REGIONS

Abstract. *In this work, considering that traditional data processing methods in air traffic control systems in areas with complex terrain—mountainous and foothill regions—often lack sufficient accuracy, which can lead to a decrease in the level of air transport safety and efficiency, it is proposed to develop methods for increasing data processing accuracy under complex noise conditions in mountainous and foothill areas.*

Taking into account the specific features of the terrain and technical limitations, the main factors affecting the reduction in data processing accuracy operating in mountainous and foothill conditions were identified, including meteorological, radio-technical, topographical, and anthropogenic interference.

At the same time, criteria for assessing data processing accuracy under interference loads, as well as system reliability parameters depending on the degree of distortion of information flows, have been introduced and new results have been obtained, which will ensure increased safety and efficiency of air traffic in complex conditions.

Keywords: *mountainous regions, interference, navigation, system, terrain, noise.*

Introduction. The analysis of flight conditions in mountainous and foothill regions is a critical task in ensuring air traffic safety, particularly during the takeoff and landing phases. The geomorphological characteristics of the terrain, meteorological phenomena, and limitations of radar surveillance significantly affect navigation reliability and the quality of aircraft control. Under mountainous and foothill conditions, standard principles of radar support face a number of challenges related to signal shielding, multipath propagation, and unstable atmospheric characteristics.

Radio interference may arise both from technical malfunctions and from intentional actions, such as the operation of electronic warfare systems, unauthorized transmitters, or excessive spectrum congestion in densely populated areas.

In the context of radio communication and radar, interference refers to unwanted signals that disrupt or complicate the reception of useful information. Classification of such interference is carried out based on the source of origin, physical nature, and the manner in which it affects the system. In technical and scientific practice, the most significant types of interference are considered to be electronic, atmospheric, and multi-path (multipath) interferences.

Electronic interference occurs due to the intentional or unintentional emission of radio frequency signals generated by technical devices. Such interference includes industrial noise sources (e.g., electric motors, welding equipment, and pulsed power supplies) as well as deliberate electronic warfare (EW) systems designed to disrupt enemy radio communications or radar operations. Electronic interference may be narrowband or broadband, pulsed or continuous, and can exhibit either coherent or non-coherent characteristics relative to the useful signal.

Materials and methods of research.

In aviation, the impact of interference on radar, navigation, and communication systems is a particularly important issue, especially in terms of ensuring flight safety, navigation accuracy, and communication stability at airports such as Termez, Navoiy, Samarkand, and Namangan. These air traffic hubs serve both domestic and international flights, and their operation depends heavily on the reliable performance of radio-technical systems.

In radar systems used to manage air traffic and facilitate safe landings, electronic interference can reduce the accuracy of determining the aircraft's coordinates. A key parameter characterizing the effectiveness of a radar system is the probability of target detection P_d , which depends on the signal-to-noise ratio (SNR):

$$P_d = Q\left(\frac{S}{\sqrt{N}}\right) \quad (1)$$

here, S - the amplitude of the useful signal, N - is the noise power, and Q - the Gaussian error function. As the interference power NNN increases, the probability of detection sharply decreases, particularly in areas with complex terrain or dense construction, such as the vicinity of Samarkand Airport.

In navigation systems, especially satellite-based systems (GNSS), the impact of interference can lead to a loss of positioning accuracy or even a complete signal outage. This is particularly hazardous during landing at visually constrained airports, such as Termez. Electronic interference can be either unintentional (e.g., industrial noise) or deliberate, such as that generated by electronic warfare (EW) systems.

The impact on navigation accuracy can be expressed through the positioning error σ_p which depends on the satellite geometry and the level of noise:

$$\sigma_p = DOP \cdot \sigma_r \quad (2)$$

Here, DOP denotes the geometric dilution of precision, and σ_r is the standard deviation of the pseudorange error, which depends on the level of interference.

In radio communication systems that ensure the link between the crew and air traffic controllers, interference can lead to information loss, transmission delays, or distortion of commands. In particular, at high-traffic airports such as Navoiy, the high density of radio transmitters may cause mutual interference. The stability of radio communication can be assessed by the bit error probability P_b which depends on the signal-to-noise ratio (SNR):

$$P_b = \frac{1}{2} \operatorname{erfc}\left(\sqrt{\frac{E_b}{N_0}}\right) \quad (3)$$

Here, E_b represents the energy per bit, N_0 is the spectral density of noise power, and erfc denotes the complementary error function. When $\frac{E_b}{N_0}$ falls below a threshold value, the probability of error increases exponentially.

At regional airports such as Namangan, where infrastructure may be less protected against external influences, it is particularly important to account for atmospheric and multipath obstacles. The latter occur when the signal is reflected from buildings, mountain ranges, or other objects, leading to signal interference and attenuation. This effect can be modeled using the Rayleigh model:

$$P_r = \sum_{i=1}^n A_i \cos(\omega t + \phi_i) \quad (4)$$

Here, A_i is the amplitude of the wave, ϕ_i is the phase shift, and ω_i is the angular frequency. In cases of destructive interference, the resultant signal may approach zero, potentially leading to a complete loss of communication.

Thus, addressing the impact of interference on aviation radio-technical systems requires a comprehensive approach: from technical solutions (filtering, equalization, adaptive antennas) to organizational measures (frequency coordination, spectrum monitoring). Ensuring electromagnetic compatibility and resilience to obstacles at Uzbek airports, including regional air traffic hubs, is a key element for maintaining air traffic safety and operational efficiency.

Mathematical models of signal propagation in mountainous and foothill regions play a crucial role in the design and optimization of radio communication, navigation, and radar systems, particularly under complex terrain conditions such as those found in the city of Namangan. Namangan is located at the northern edge of the Fergana Valley, near mountain ranges, and represents a typical foothill zone where multipath propagation, shadowing, and diffraction effects are prominently observed.

In mountainous regions, the propagation of radio waves differs significantly from that in open terrain. The primary physical mechanisms include reflections from slopes, diffraction over peaks, shadowing in valleys, and scattering on irregularities. Empirical and analytical models are used to describe these processes.

One of the fundamental models adapted for foothill conditions is the Hata model. It expresses the path loss of a UL signal in decibels as a function of distance, antenna height, and frequency:

$$L = 69,55 + 26,16 \log_{10}(f) - 13,82 \log_{10}(h_t) - a(h_r) + (44,9 - 6,55 \log_{10}(h_t)) \log_{10}(d)$$

Here, f is the frequency (MHz), h_t is the height of the transmitting antenna, h_r is the height of the receiving antenna, d is the distance (km), and $a(h_r)$ is the correction factor for mountainous areas.

For more accurate modeling under Namangan conditions, the ITU-R P.1546 model is applied, which takes into account the region's digital elevation model (DEM) and the terrain profile along the path. In this model, diffraction effects, which are particularly significant in the presence of mountain ranges, are considered using the Deygout method (Dune method). This method estimates the additional path loss L_d according to the following formula:

$$L_d = \sum_{i=1}^n L_{di} \quad (5)$$

Here, L_{di} represents the loss at each obstacle along the path, determined by the geometric parameters of the path and the wavelength of the signal.

In foothill regions, the Rayleigh multipath propagation model is also highly relevant, especially in the presence of reflecting surfaces such as rocks and buildings. The received signal is modeled as the sum of multiple waves with different phases:

$$r(t) = \sum_{k=1}^N A_k \cos(\omega t + \phi_k) \quad (6)$$

Here, A_k is the amplitude of the k -th wave, ϕ_k is the phase shift, and ω is the angular frequency. In cases of destructive interference, the signal may experience deep fading, which necessitates the use of spatial or frequency diversity techniques.

Air traffic services within the airspace of the Republic of Uzbekistan are organized in accordance with international standards and the Regulations on the Use of the Airspace of the Republic of Uzbekistan. The provision of services depends on the classification of the airspace where they are implemented.

In the absence of continuous radar surveillance and when onboard navigation instruments operate unreliably, descent below the lower safe flight level is prohibited. In such cases, the aircraft must proceed to an alternate airport.

In recent years, civil aviation in Uzbekistan has experienced significant growth, including the expansion of the aircraft fleet with new airplanes, the introduction of advanced technologies in airport systems, and a concomitant increase in scientific research activities [1–5].

Among foreign scientific studies that have made a significant contribution to the development of theoretical and practical aspects of air traffic control, [6] proposes the use of Kalman adaptive filters based on a transition model between non-interacting states to address the problem of limited accuracy in partial navigation state estimation. In integrated navigation using inertial data, the estimation of the process noise covariance matrix is generalized as the maximum likelihood estimation of variance based on heterogeneous Gaussian samples. A sampling method is then proposed that prevents the influence of uncertain portions of various samples on the estimated variance, thereby improving the accuracy of the process noise covariance matrix estimation in inertial-based integrated navigation systems.

In [7], for the first time, data collected from February to December 2022 in the Baltic States, Eastern Europe bordering the Black Sea, and the Eastern Mediterranean regions were used to assess the scale and duration of these events and their impact on civil aviation. The analyses demonstrate a range of characteristics, from isolated incidents to regularly occurring, large-scale, and repetitive disruptions. Subsequently, the types of aircraft for the corresponding flights were identified, and information on the flight plan relative to navigation equipment was evaluated to determine flights that rely solely on satellite navigation and would require assistance in the event of satellite navigation loss. Finally, the study highlights the impact of satellite navigation on flight safety.

Modern satellite navigation systems increasingly provide the capability to operate on dual frequencies, which enhances navigation accuracy and reduces residual errors. Recently, the aviation community has begun developing new standardized minimum performance standards for GNSS equipment, enabling the future use of dual-frequency multi-constellation (DFMC) systems. In such conditions, residual errors introduced by the user GNSS antenna become more critical, requiring precise characterization and mitigation both in antenna technical specifications and in models for aircraft multipath operation. In [8], this issue was examined, and results were presented on the development of new models for airborne multipath radio signal propagation for the L1/E1 and L5/E5a frequency bands, as well as for their ionosphere-free combinations.

The experimental equipment includes a high-precision radio frequency recording device [9] that allows for in-depth preliminary correlation analysis of the radio frequency spectrum around the primary GPS and Galileo carrier frequencies. The results confirm that the observed disruptions were likely caused by artificial radio interference. Additionally, this setup enables the in-situ study of commercial avionics behavior under GNSS interference conditions.

Millimeter-wave (mmWave) communication systems can utilize a wide spectrum and therefore provide high data transmission rates, for example, several gigabits per second. In these systems, directional antennas are used to ensure optimal distances between communication links. Consequently, directional receiving antennas rotate in azimuth to capture the strongest signal in line-of-sight (LOS) zones rather than in non-line-of-sight (NLOS) areas. In [10], measurement

results are presented for the 90 GHz band under three different scenarios: indoors, in open space, and in unconventional conditions, such as within an airport maintenance hangar.

These issues are particularly critical in areas with complex terrain, such as mountainous and foothill regions. In such locations, natural and anthropogenic factors create additional obstacles for navigation and communication. Under these conditions, conventional methods of data processing in air traffic control systems often do not provide sufficient accuracy, which can lead to a reduction in the safety and efficiency of air transportation.

Solving radar support issues for flights in mountainous and foothill regions requires a comprehensive approach that combines engineering, algorithmic, and organizational measures. The main challenges—signal masking, multipath reflections, unstable refraction, and limited coverage—are being addressed using modern technologies and adaptive strategies.

In [11], a method for detecting and suppressing navigation noise through signal field analysis is presented. The difference between this method and phased antenna arrays is described, where the noise suppression procedure is based on removing the combined contribution of peripheral antenna signals, designated as noise, from the main antenna signal, which may introduce minor distortions in the radiation pattern. Results of experiments on interference suppression are provided.

In [12, 13], the use of ground-based augmentation systems, inertial navigation systems, and distance-based applications for airport operations is considered, while airport auxiliary aids support landing both visually and instrumentally. In [14], photometric characteristics of the lighting system are described; in [15], studies for conditional wide-fuselage commercial aircraft are presented to illustrate and verify the proposed method; in [16], an analysis of passenger traffic dynamics over a decade at Vilnius, Riga, Tallinn, and Krakow airports is provided; and in [17], it is shown that the proposed approach can assist airport operators in forecasting airport load and selecting the optimal strategy to enhance throughput during unexpected situations.

Results and their discussion.

For practical applications in Namangan, such as the design of cellular base stations or navigation beacons, a combination of models is used: empirical (e.g., COST-231 Hata), geometric (ray-tracing methods), and statistical (Rayleigh or Rician models). This approach allows for accounting both the macro-effects of terrain and the micro-obstacles arising from urban structures.

Mathematical modeling of signal propagation in mountainous and foothill regions requires a comprehensive approach that integrates wave physics, terrain geometry, and multipath channel statistics. In the Namangan context, such models are particularly important for ensuring stable communication, accurate navigation, and reliable radar performance, especially in aviation and emergency applications.

For the foothill area of Namangan, which features complex terrain and urban structures, additional models complement classical approaches for radio signal propagation:

A hybrid model developed based on experimental data in complex terrain, forested areas, and urban environments combines empirical and analytical components. It allows for the evaluation of electromagnetic radiation levels along various sections of nearby radio paths. The model accounts for non-uniform terrain, including shadowing, reflection, and scattering effects, and can be adapted to the Namangan region, where open valleys alternate with dense urban structures.

The Longley-Rice model is designed to calculate propagation losses of radio waves over distances up to 200 km and frequencies ranging from 20 MHz to 20 GHz. It takes into account the digital terrain model, surface type, moisture, as well as diffraction and tropospheric effects. In Namangan, particularly in areas where mountain obstacles and valleys are present, the Longley-Rice model provides accurate assessment of coverage and shadow zones, which is especially important for navigation and radar systems.

The Longley-Rice model takes into account the following factors:

1. The digital elevation model (DEM) of the terrain;
2. Surface type (soil, vegetation, water);
3. Heights of the transmitting and receiving antennas;
4. Climatic conditions (humidity, temperature);
5. Signal diffraction, reflection, and tropospheric propagation.

For Namangan, located in a foothill zone, the following parameters can be considered:

Namangan Airport is located in a foothill zone at an elevation ranging from 400 to 1000 meters. The terrain is undulating, with individual hills capable of partially obstructing radio signals. The area is moderately populated, with vegetation fields and sparse buildings.

Frequencies used at the airport include:

- VOR/DME: 116.0 MHz
 - ILS (localizer): 110.1 MHz
 - ILS (glide path): 334.4 MHz
 - GNSS (GPS, GLONASS): 960–1215 MHz
- For modeling purposes, the VOR/DME frequency of 116.0 MHz is selected.

Antenna parameters:

- VOR/DME antenna heights: 5 m (ground), 1000 m (airborne)
- Distance: up to 150 km

Free-space path loss is calculated using the adapted form of equation (2.11) as follows:

$$L_{\text{Open Area}} = 32.45 + 20 \log_{10}(f) + 20 \log_{10}(d)$$

Here, f denotes the frequency (MHz) and d is the distance (km).

For a frequency of 116.0 MHz and a distance of 150 km:

$$L_{\text{Open Area}} = 32.45 + 20 \log_{10}(116) + 20 \log_{10}(150) = 32.45 + 41.0 + 20 = 117.25 \text{ dB}$$

Similarly, for a frequency of 330 MHz (ILS):

$$L_{\text{open area}} = 32.45 + 20 \log_{10}(330) + 20 \log_{10}(10) = 32.45 + 50.4 + 20 = 102.85 \text{ dB}$$

For a frequency of 1090 MHz (voice communication station):

$$L_{\text{free}} = 32.45 + 20 \log_{10}(1090) + 20 \log_{10}(10) = 32.45 + 60.75 + 20 = 113.2 \text{ dB}$$

The Longley-Rice model accounts for diffraction, reflection, and shadowing. In mountainous areas, additional losses ranging from 10 to 40 dB are introduced depending on the terrain profile. For the foothill region of Namangan, an average correction factor can be applied as follows:

- for 110 MHz: +15 dB (lower frequency, better absorption);
- for 330 MHz: +25 dB;
- for 1090 MHz: +35 dB (higher frequency, more susceptible to shadowing).

Total path loss:

- 110 MHz: $L \approx 93.45 + 15 = 108.45 \text{ dB}$
- 330 MHz: $L \approx 102.85 + 25 = 127.85 \text{ dB}$
- 1090 MHz: $L \approx 113.2 + 35 = 148.2 \text{ dB}$.

At frequencies below 200 MHz (VOR, ILS), signals propagate relatively stably in mountainous areas with moderate losses. At frequencies above 1000 MHz (radar, GNSS), losses increase, particularly in the presence of obstacles.

Based on these parameters, modeling using the Longley-Rice method with the Radio Mobile software produces the following representation (Figure 1).

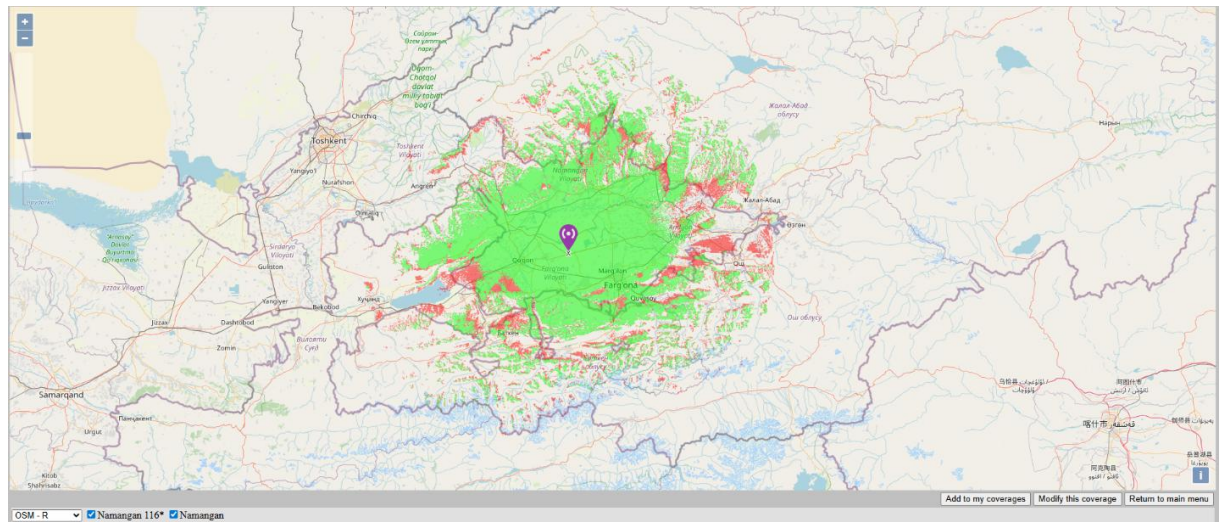


Figure 1 – Radio wave coverage of the Namangan region (Longley-Rice model for VOR/DME)

Modeling the radio wave coverage for the 116 MHz VOR/DME in Namangan region illustrates the extent of radio coverage under the complex mountainous terrain of the eastern part of the Fergana Valley. The maximum signal strength is observed in the central area of the region—Namangan city—and the adjacent flat areas, including parts of the valley between Chust, Pop, and Kosonsoy. In this area, the signal propagates along a direct line, ensuring stable operation of navigation equipment at low and medium flight levels.

However, along the perimeter of the high-quality signal coverage area (green zone), particularly in the east and southeast, significant shadow zones are formed due to foothills and mountain ridges that create natural obstacles for VHF signal propagation. The modeling results clearly show shadowed areas (red zones) along the borders with Kyrgyzstan and in the direction of the southern mountain slopes. In these zones, “blind” areas occur as a result of natural topographic barriers. Signal loss is especially pronounced in the southwest and southeast regions, where the terrain rises sharply.

In the western direction, along the route toward Kokand and Margilan, signal coverage gradually weakens with increasing distance from the station. In these areas, particularly during low-altitude flights, the terrain has a maximal negative effect on radio coverage, leading to fragmented zones with signal loss.

Thus, the 116 MHz VOR/DME coverage at Namangan Airport ensures reliable navigation over the flat parts of the Fergana Valley but requires special attention when planning routes in mountainous areas. To compensate for “blind” zones, it is advisable to implement additional ground stations, repeaters, or integration with satellite GNSS systems. Ensuring high-quality radio coverage at these frequencies may also require increasing antenna heights, using repeaters, or deploying high-gain directional antennas.

For the Samarkand region, modeling using the Longley-Rice method with the Radio Mobile software yields the following results (Figure 2).

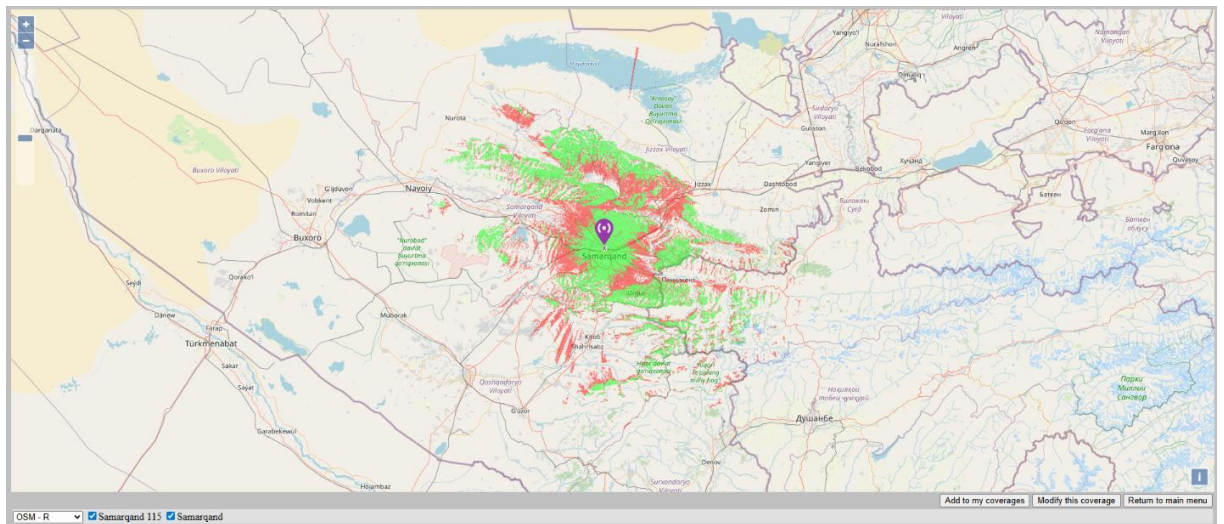


Figure 2 – Radio wave coverage of the Samarkand region (Longley-Rice model for VOR/DME)

Modeling the 115 MHz VOR/DME coverage at Samarkand Airport illustrates the extent of radio coverage for the Bukhara, Navoi, and Jizzakh regions. The highest signal strength is observed in the central area, particularly over Samarkand and the adjacent flat terrain. This corresponds to zones where aircraft navigation systems can reliably receive signals at low and medium flight levels (depicted as the green area in the figure).

However, along the perimeter of this zone, especially toward the east and southeast, significant shadow zones are formed due to the foothills and complex terrain of the Zarafshan mountain range. These areas are critical, as they can restrict radio coverage during landing or takeoff at low altitudes, creating “blind” zones.

To the west and northwest, along the Navoi and Bukhara directions, signal coverage gradually weakens. This is associated both with the increasing distance from the station and with local elevations that obstruct signal propagation. In these areas, particularly near water bodies and forested regions, fragmented signal loss zones appear. These zones result in further attenuation of radio waves due to terrain and vegetation effects.

Modeling the localizer of the ILS system at Samarkand Airport using the Longley-Rice method with Radio Mobile yields the following results (Figure 3).

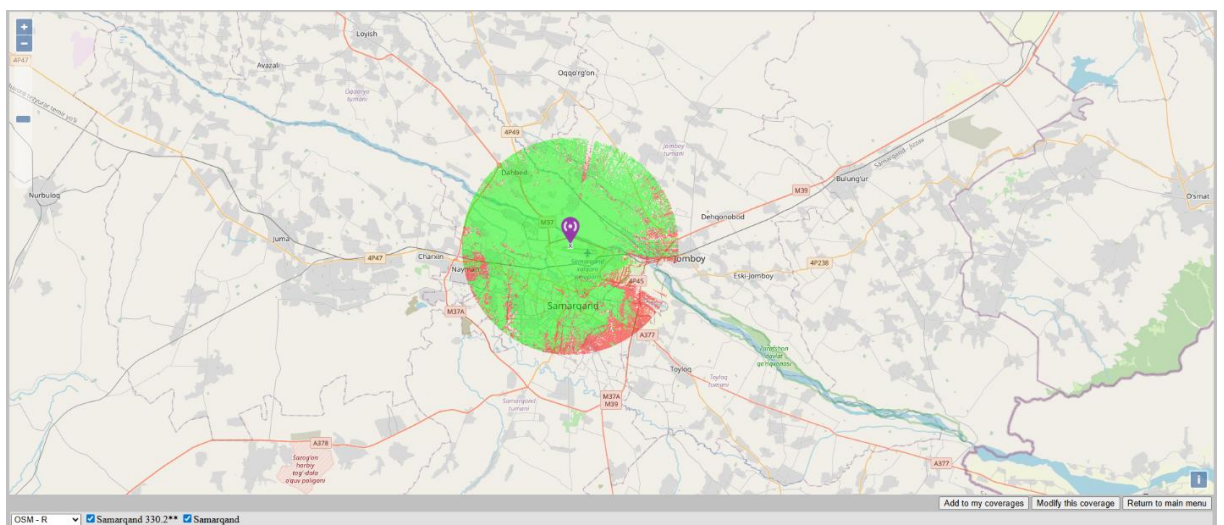


Figure 3 – Radio wave coverage of the Samarkand region (Longley-Rice model for the ILS localizer)

Modeling the generalized ILS localizer signal coverage at Samarkand Airport, for both approach and departure courses at a frequency of 330.2 MHz, demonstrates the characteristic propagation of the directed signal along both runway alignments. Areas where the signal can be received with high quality and minimal loss cover the airport itself and the adjacent regions (depicted as green zones in the figure). In these areas, the signal forms a symmetrical directional pattern, ensuring precise guidance of aircraft along the runway centerline during approaches from both directions.

These zones include the flat areas of Juma, Nurbuloq, Loyish, and partially Bulungur. In these regions, the terrain has minimal impact on signal propagation, ensuring reliable operation of the localizer even at low altitudes.

However, along the perimeter of these areas, particularly to the south and southeast where the foothills of the Zarafshan mountain range begin, significant shadow zones are formed (depicted as red areas in the figure). In these regions, especially during approaches on the 271° course, the localizer signals may be blocked by terrain elevations, leading to a loss of navigation accuracy. Specifically, considering aircraft approaching Samarkand Airport from the eastern part of the country, including from Tashkent Airport, the disruption of the signal pattern symmetry in these zones can significantly reduce landing precision.

To the northwest, along the Jomboy and Avazali directions, signal coverage further weakens due to distance and local elevations. Dense constructions and terrain in these areas increase the likelihood of fragmented signal loss.

Thus, the coverage of the 115 MHz VOR/DME and the 330.2 MHz ILS localizer at Samarkand Airport provides reliable navigation over the central and flat parts of the region but requires consideration of terrain when planning routes in mountainous and peripheral areas. As emphasized in the Namangan example, compensating for “blind” zones necessitates additional mitigation measures.

For the Termez region, modeling using the Longley-Rice method with the Radio Mobile software yields the following results (Figure 4).

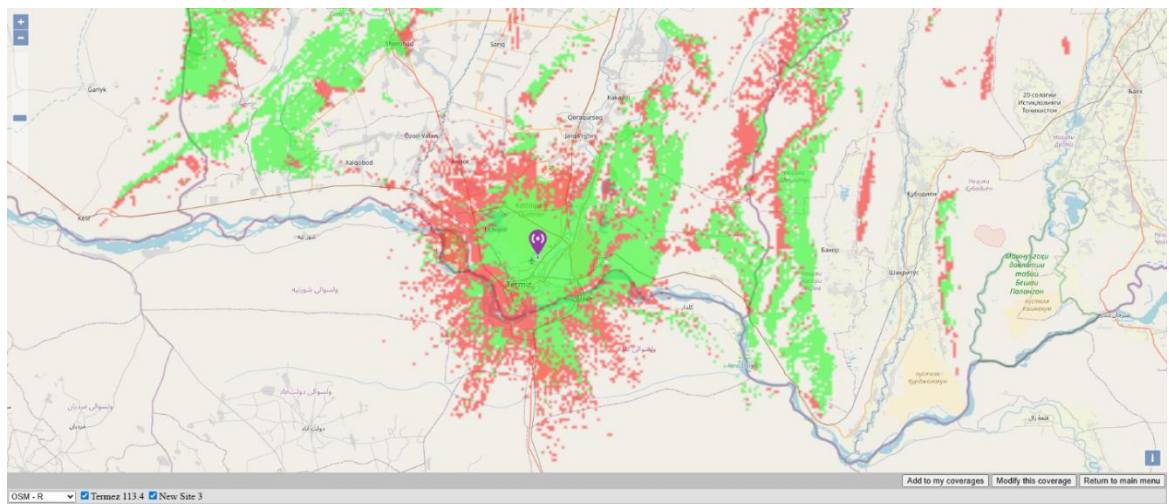


Figure 4 – Radio wave coverage of the Termez region (Longley-Rice model for VOR/DME)

Modeling the coverage of the 113.4 MHz VOR/DME signal at Termez Airport using the Longley-Rice method reflects a distinctive signal pattern due to the complex terrain in the southern regions. The high-quality signal coverage encompasses the center of Termez and the adjacent flat areas along the Amu Darya, where the signal propagates with minimal obstruction, providing reliable navigation at low and medium altitudes.

However, as distance from the station increases, particularly toward the east and northeast, significant shadow zones appear. In these areas, the terrain rises further, especially at the foothills of the Hisor mountain range, causing signal blockage. The red zones in Figure 4 indicate “blind” areas where radio waves do not reach the ground due to orographic obstacles. These zones are particularly critical near the settlements of Darband and Sherobod, as well as along the border with Tajikistan, where elevations increase sharply.

To the west and southwest, along the Surkhandarya and Qilif directions, signal coverage gradually weakens. This is associated both with the increasing distance from the source and with local elevations that create fragmented signal loss zones. In these areas, navigation interruptions may occur, which can particularly affect flights at low altitudes or during approaches.

The 113.4 MHz VOR/DME coverage at Termez Airport ensures safe flight and landing over flat terrain but requires the dispatcher’s special attention for operations in mountainous and foothill regions. To enhance navigation reliability in shadow zones near the airport—especially under complex terrain, adverse weather conditions, or dust storms typical for Termez—combined solutions such as integration with GNSS, relay stations, or additional ground-based stations are advisable in low-visibility conditions. For airports located in areas with an active radiofrequency environment (such as military sites, dense urban constructions, or mountainous terrain), the following measures are necessary:

- use of high-gain directional antennas;
- implementation of spectrum monitoring and interference detection systems;
- deployment of backup navigation aids (inertial, visual);
- training flight crews to operate in the event of signal loss.

The Longley-Rice model allows for the pre-assessment of shadow zones, identification of optimal locations for antennas and relay stations, and prediction of signal behavior under varying weather and terrain conditions. This is particularly critical for approach navigation systems, GNSS, and ADS-B applications, where signal accuracy and reliability are essential.

The Longley-Rice model indicates that signal losses significantly increase in mountainous areas, particularly at higher frequencies (above 1000 MHz). In regions like Namangan, where the terrain is hilly and foothill, radio wave propagation requires careful calculation and adjustment of antenna heights, especially for GNSS and radar systems. Frequencies below 200 MHz (VOR, ILS) demonstrate the best penetration capability and resistance to shadowing.

Conclusion.

For aerodromes located in zones with an active radio frequency environment (military facilities, densely built-up areas, mountainous terrain), the following is required:

- use of high-amplifier directional antennas;
- implementation of spectrum monitoring and interference detection systems;
- application of backup navigation tools (inertial, visual);
- training crews to act when the signal is lost.

The use of the Longley-Reiss model allows for the preliminary assessment of shadow zones, the determination of optimal antenna and relay placement points, and the prediction of signal behavior under various weather and terrain conditions. This is especially important for landing access navigation systems, GNSS, and ADS-B, where signal accuracy and reliability are critical.

Generally speaking, modern aviation requires not only precise navigation systems but also resistance to radio interference. Modeling, technical auditing, and rapid response to failures are key elements in ensuring flight safety, especially in regions with complex terrain and saturated radio frequency environments such as Namangan.

ТАУЛЫ ЖӘНЕ ТАУ БӨКТЕРІНДЕГІ КҮРДЕЛІ КЕДЕРГІЛЕР ЖАҒДАЙЫНДА ӘУЕ ҚОЗҒАЛЫСЫН БАСҚАРУ ЖҮЙЕЛЕРІНДЕГІ ДЕРЕКТЕРДІ ӨҢДЕУ ДӘЛДІГІН АРТТЫРУ ӘДІСТЕРІ

Аңдатпа. Бұл жұмыста күрделі жер бедері бар аудандарда – таулы және тау бөктеріндегі аймақтарда – әуе қозғалысын басқару жүйелеріндегі дәстүрлі деректерді өңдеу әдістері көбінесе жеткілікті дәлдікке ие емес екенін, бұл әуе көлігінің қауіпсіздігі мен тиімділігі деңгейінің төмендеуіне әкелуі мүмкін екенін ескере отырып, таулы және тау бөктеріндегі аудандардағы күрделі шу жағдайында деректерді өңдеу дәлдігін арттыру әдістерін әзірлеу ұсынылады.

Жер бедерінің ерекшеліктері мен техникалық шектеулерді ескере отырып, таулы және тау бөктеріндегі жағдайларда жұмыс істейтін деректерді өңдеу дәлдігінің төмендеуіне әсер ететін негізгі факторлар, соның ішінде метеорологиялық, радиотехникалық, топографиялық және антропогендік кедергілер анықталды.

Сонымен қатар, кедергі жүктемелері кезінде деректерді өңдеу дәлдігін бағалау критерийлері, сондай-ақ ақпарат ағындарының бұрмалану дәрежесіне байланысты жүйенің сенімділік параметрлері енгізілді және күрделі жағдайларда әуе қозғалысының қауіпсіздігі мен тиімділігін арттыруды қамтамасыз ететін жаңа нәтижелер алынды.

Түйін сөздер: таулы аймақтар, кедергі, навигация, жүйе, жер бедері, шу.

МЕТОДЫ ПОВЫШЕНИЯ ТОЧНОСТИ ОБРАБОТКИ ДАННЫХ В СИСТЕМАХ УПРАВЛЕНИЯ ВОЗДУШНЫМ ДВИЖЕНИЕМ В УСЛОВИЯХ СЛОЖНЫХ ПОМЕХ В ГОРНЫХ И ПРЕДГОРНЫХ РАЙОНАХ

Аннотация. В данной работе, учитывая, что традиционные методы обработки данных в системах управления воздушным движением в районах со сложным рельефом — горных и предгорных регионах — часто не обладают достаточной точностью, что может привести к снижению уровня безопасности и эффективности воздушного транспорта, предлагается разработка методов повышения точности обработки данных в условиях сложного шума в горных и предгорных районах.

С учетом специфики рельефа и технических ограничений были выявлены основные факторы, влияющие на снижение точности обработки данных при работе в горных и предгорных условиях, включая метеорологические, радиотехнические, топографические и антропогенные помехи.

Одновременно были введены критерии оценки точности обработки данных при помеховых нагрузках, а также параметры надежности системы в зависимости от степени искажения информационных потоков, и получены новые результаты, которые обеспечат повышение безопасности и эффективности воздушного движения в сложных условиях.

Ключевые слова: горные районы, помехи, навигация, система, рельеф, шум.

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