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Volodymyr Golovenskyy

EXTENDING THE RANGE OF DETECTION OF AERODROME BEAM SIGNALS IN ADVERSE METEOROLOGICAL CONDITIONS

Kremenchuk Flight College of the National Aviation University
17/6, Peremohy Str., Kremenchuk, 39605, Ukraine
E-mail: vladimir@sat.poltava.ua

Abstract

Goal*: Successful and safe landing of the aircraft at night in adverse meteorological conditions is possible subject to the complex use of radar, satellite radio navigation systems and lighting devices, with lighting equipment being of particular importance at the end of the flight, since they provide the necessary visualization of the runway. One of the most effective methods of increasing the safety of flights is the creation of an additional independent optical transmission channel between the aircraft and the runway. As such a channel may be a system for observing aerodrome radiation signals from the aircraft in adverse meteorological conditions using the infrared (IR) radiation spectrum. The aim of the work is carrying-out of theoretical analysis of the possibilities of increasing the range of detection of beam aerodrome signals in order to increase the accuracy and reliability of the aircraft landing approach due to the use of medium and longwave infrared radiation ranges for reception of navigation information.* **Method***: we made the mathematical estimation of the dependence of the range of detection of the spot beam signals on the wavelength and source power.* **Results***: Such dependences are designed for infrared wavelengths of 0.554 µm, 1.0 µm, 4.0 µm, 10 µm, which coincide with the atmospheric transparency windows in different conditions of distribution: transparent atmosphere, haze, fog. It has been shown analytically that using infrared monochromatic emitters and frequency coherent photodetectors with a high specific detection capability, it is possible to significantly increase the detection range of beam signaling targets compared with the shorter wavelengths of the visible range, both in the conditions of a transparent atmosphere and in the presence of a water-aerosol medium. Mathematical relations for comparative estimation of the range of the source-receiver system with different working wavelengths are obtained. Numerical graphical analysis shows that at the same power sources of radiation, the range of detection of infrared beam signals occurs at significantly longer distances compared with light signals of the visible range.* **Discussion***: The use of the light signal monitoring system for following up the aircraft when landing in adverse meteorological conditions, which developed using the above mentioned principles, will allow the aircraft crew to observe landing infrared lights on the monitor screen at a considerable distance in adverse weather conditions and to make the necessary adjustments when deviating of the aircraft from the glide, which will significantly increase flight safety and reduce the negative psychological stress on the aircraft crew at the most difficult and responsible phases of the flight.*

Keywords*:* atmospheric transparency; beam signals; infrared radiation; range of visibility.

1. Introduction

Intensification of air transportation requires modernization of radio and lighting equipment of the airdromes to ensure safety and regularity of flights. Lighting equipment, which provides landing and take-off of the aircraft at night time in adverse meteorological conditions of the most difficult and critical stages of flight, becomes more and more important among this complex.

The use of instrumental landing approach and landing with autosteering and manual control is not enough for safe landing of the aircraft, due to the fact that the pilot begins to see landing lights and runway at very low altitude and distance. For example, for landing category A, the instrumental landing approach method with the use of an autopilot system provides the aircraft glide slope guidance to the height of 30 m and visibility of the runway lights from the distance of 200 m. Besides that, the important disadvantage of automatic landing is that the pilot is out of control of the aircraft for a certain period of time. At the final stage of the flight, the pilot should switch to manual control, quickly and correctly determine the location of the aircraft in the space relative to the runway, and this is achieved by visual observation of light-signal signs of the runway and approaches to it, which is especially difficult in low visibility conditions. If these parameters are not followed, the pilot should decide whether to stop landing and go-around or fly to another aerodrome with better meteorological conditions. Very often, when landing under the conditions of dense clouds, fog and haze, the crew of the aircraft can not observe landing lights for a long time, which leads to significant psychological stress, which may result in mistakes in piloting and decision making in the most critical period of time.

One of the most effective methods that will eliminate the disadvantages of the landing process listed above is the creation of an additional independent optical data channel between the aircraft and the runway. As such channel, there may be a system for monitoring beam signals to follow up the aircraft in adverse meteorological conditions using the infrared radiation spectrum.

2. Goal and objectives of research

The goal of work is the theoretical evaluation of the extending the range of detection of spot beam signals in the water-aerosol environment through the use of the IR range waves.

3. Analysis of recent research and publications, problem statement

The mechanisms for extending the visibility range as a category of subjective visual perception of objects are known and determined by the characteristics of the atmosphere, the background and the object. Information about the visibility range (like on the runways) can be obtained visually or by measurement results, using continuously improved calculation methods [1, 2].

Air traffic control, using radar and satellite radio navigation systems, controls the aircraft in the air; the ground services control the aircraft that have already landed. When approaching and landing, it is traditionally used the observation over lighting equipment of the airdrome. The least secured technical measures and, accordingly, visual information on the control of the glide slope is landing approach and landing in particularly adverse meteorological conditions, clouds and fog.

In the 70-80’s the work was done to create an optical laser instrument landing system “Glade slope”. The basis of its work was the principle of linear reference point navigation – beam of lasers, which were installed near the runway and created a landing corridor. Due to the laser light scattering in the atmosphere, the pilot visually perceives a combination of beams in the form of a symbol that determines the position of the aircraft relative to the landing trajectory and the point of landing. In the presence of a haze or thin fog, the beams are more strongly scattered and are observed even brighter, but with a heavy fog, the laser beams of the visible range can be completely scattered and absorbed without reaching the necessary illumination of the apple of the pilot’s eye. Further extending the power of the laser beam can damage the eye retina. Work on modernization of this system continued until the 90’s, but with the collapse of the USSR, the studies on this topic were suspended [3].

With the advent of effective electron-optical devices, instead of visual observations of light signals, the Electro Optical Systems are begun to use [4, 5].

In the visible range of wavelengths, television optoelectronic systems are being actively developed. The scientific and technological process has led to the advent of fundamentally new Electro Optical Systems, which now occupy a leading position among systems operating in the infrared range of wavelengths of 3-5 and 8-14 microns. Their main element is a photodetector, the sensitivity of which is determined by the level of internal noise of the individual channel and the number of photosensitive channels. The use of multichannel optoelectronic detection devices makes it possible to offset the advantages of one channel against disadvantages of another one [6].

High-performance remote monitoring devices and distance measuring equipment are laser location systems developed by ALTACAS Company. They consist of lasers with microprocessor control, which allow controlling the runways, the area surrounding them, the courses of the aircraft, which takeoff and approach to land. The lasers are mounted on the wings and fuselage of the aircraft on rotating platforms, which are closed by hemispherical aerodynamic caps. Such laser scanner LIDAR uses infrared pulsed beams to scan the surrounding area within a radius of several kilometers. The second part of the system is the device for the perception of reflected laser radiation, its processing by the computer and the transfer of results to the display, installed in the cockpit. [7]

During the flight, the scanners "inspect" all 360 angular degrees of the surrounding space, transmitting information to the collision prevention system. When approaching and preparing for this maneuver the system switches back to the landing corridor monitoring mode.

Active-impulse night vision devices are recommended for landing helicopters at night time on unprepared pads [8].

Laser systems have a number of disadvantages:

- when locating them on the runway, radiation of a visible range with a power exceeding 1 megawatt can damage the eyes;
- strict requirements for the pointing and holding the beam of illumination on the observation object;
- significant extinction of light by the atmosphere in adverse weather conditions;
- when using the LIDAR system, absorption occurs when the beam passes through the drowning atmosphere from the aircraft to the runway and back and a significant absorption when the beam is reflected from the observation object – the runway;
- a relatively small coefficient of transformation of electrical energy into the light one by the laser leads to an increase in the mass-size parameters of the system as a whole.

The examples of use of infra-red LED emitters and Electro Optical Systems for the purpose of performing reconnaissance and observation tasks on land objects raise the possibility of the efficient use of similar devices of this type also for the detection of aerodrome signal lights [9].

4. Materials and methods of research

In order to choose the way of constructing the Electro Optical Systems, there is a need to perform comparative analysis of the work of the Electro Optical Systems at different wavelengths of the electromagnetic waves. In this regard, one of the most important parameter is the signal / noise ratio for capacities at the output of the system. Taking into account the fact that the receiver is adjusted on the working wavelength λ of an absolutely monochromatic source, the output power of the signal Φ_λ in general form can be represented [10]:

$$\Phi_\lambda = E_\lambda G_0(\lambda, \tau, A, \ldots), \tag{1}$$

where: $E_\lambda\left[\frac{Bm}{м^2}\right]$ – irradiance in the plane of the input lens of the Electro Optical Systems;

$G_0(\lambda, \tau, A, \ldots)[м^2]$ – the function of the optical system, which depends on the physical and structural properties of the system (τ is the transmission coefficient, *A* is the lens area, etc.).

The choice of the working wavelength is largely determined by the level of loss of signal strength by the atmosphere on which the value E_λ depends. The probability *P* of the signal function (or object detection) is determined specifically by the signal / noise ratio, as well as by the value E_λ. The maximum range x_m, at which a signal with a given probability *P* can be detected occurs if inequation $E_\lambda \geq E_{\lambda\,\min}(P)$ is performed. For a point monochromatic source it can be written in the atmospheric transparency windows:

$$E_\lambda = I_\lambda \frac{e^{-\alpha_\lambda x_m}}{x_m^2}, \tag{2}$$

where: I_λ – radiation source intensity;

α_λ – indicator of loss.

The maximum signal x_m detection range can be approximately determined with (2):

$$x_m \approx \left(\frac{I_\lambda}{E_{\lambda,\min}}\right)^{\frac{1}{2}} \text{при } x_m \cdot \alpha_\lambda << 1,$$
$$x_m \approx \frac{1}{\alpha_\lambda} \ln\left(\frac{\alpha_\lambda^2 I_\lambda}{E_{\lambda,\min}}\right) \text{при } x_m \cdot \alpha_\lambda >> 1. \tag{3}$$

The formula (3) shows that in a sufficiently transparent atmosphere at distances, less than $1/\alpha_\lambda$, signal detection range is determined only by two parameters: irradiance $E_{\lambda,\min}$ and the radiation source power I_λ. In case of a significant loss of the radiation, which is the result of scattering in microparticles, the most significant change rate x_m is determined by the parameter α_λ. Decrease of α_λ “enlightens” atmosphere by extending the range x_m. For an atmosphere, this possibility can be realized on different areas of the infrared range that correspond to the transparency windows. By extending the working wavelength relative to the size of the scattering and absorbing aerosol particles, the general loss index α_λ is decreased in accordance with the laws of wave optics. The stronger the inequation $\frac{2\pi r}{\lambda} << 1$ (r is the radius of the spherical scattering particle), the greater the transparency of the turbid medium at the fixed sizes of r and the concentration of particles [11, 12].

The advantages over the signal detection range of one wave or another can be estimated by comparing the relations (3) for different λ. Under conditions of limited visibility, the advantage of instrumental detection of a signal on the wavelength λ over the visual one will take place when performing the inequation:

$$\left[\frac{\alpha_\lambda^2 I_\lambda}{E_{\lambda\min}}\right]^{\frac{3,9}{S_M \alpha\lambda}} > \frac{(3,9)^2 I_0}{S_M^2 E_{nop}}, \tag{4}$$

where: I_0, E_{nop} – integral on the visible spectrum, light source intensity and threshold sensitivity of the eye, respectively;

S_M – meteorological range of visibility.

Inequation (4) makes it possible to compare the efficiency of the source-receiver system in energy units outside the light range with the photometric characteristics of the visible. The transition of the operation of the source of the signal lights to the long-wavelength range of the infrared spectrum can be quite effective due to the current advances in the technology of obtaining photodetectors with ultra-high threshold sensitivity [13]. The receivers of infrared radiation of the near and medium long-wavelength ranges have a high specific detecting power. So the threshold of sensitivity of modern avalanche photodiodes reaches 10^{-17} W/hz$^{1/2}$, which is at the level of threshold sensitivity adapted to the absolute darkness of the human eye.

On the other hand, the use of solid-state infrared sources in comparison with incandescent lamps of the visible range has its advantages, such as efficiency, and a rather narrow half-width of the radiation spectrum (~ 50 nm), which is consistent with the atmospheric transparency windows.

The influence curves between the maximum possible range of detection of the beam signal and the source radiation power for different wavelengths and parameters of water aerosol environment calculated according to the formula (2) can be found on Fig. 1 (a, b). For the possibility of comparison with the light wavelength range, the curves were calculated for $E_{\lambda\min}$ = 0,878 · 10^{-9} W/m^2, which is approximately the energy equivalent of the threshold sensitivity of the eye at the maximum of the visibility curve at background brightness of 5 · 10^{-2} cd/m^2 [14].

Indices and factors of loss were calculated for water aerosols of different monodispersity. For molecular scattering in the air, the Raileigh dependence was used [15]:

$$\alpha_\lambda(P,T) = \frac{8\pi^3\left[n^2(\alpha,P,T)-1\right]}{3N(P,T)\alpha^4}\cdot\frac{6+3\delta}{6-7\delta}, \tag{5}$$

where: P, T – atmospheric pressure in Pa and absolute temperature in °K; $\delta = 0,035$ – factor of depolarization of the air molecule; $N = \frac{1}{k}\cdot\frac{P}{T}$, $k = 1,38\cdot 10^{-23}$ J/°K – Boltzmann’s constant.

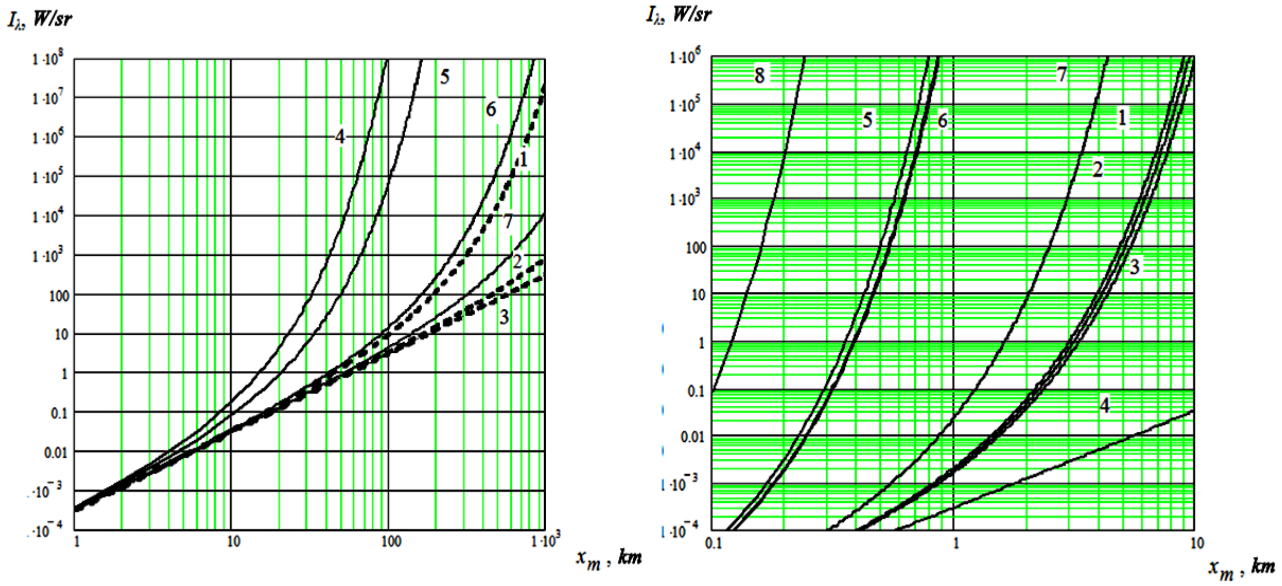
Dependence of the index of refraction of air on temperature, pressure and wavelength was taken into account by an empirical formula valid in a wide range of wavelengths (0.2-20) micrometers [16]:

$$n_{\Pi} - 1 = 10^{-8}\left(77,6 + \frac{0,584}{\lambda^2}\right)\frac{P}{T}, \tag{6}$$

where λ – in micrometers, T – in °K, P – in Pa.

In calculations of the loss index $\alpha_{\lambda,r}$ the model of “soft” transparent aerosol particles of a spherical shape, which can be considered drops of water, was adopted. In this case, $\alpha_{\lambda,r}$ is maximally determined by the radiation scattering index and absorption can be neglected. The van de Hullst approximation formula with correction factor $Q(\rho_\lambda)$ was used [17]:

$$\alpha_{\lambda,r} = 2\pi r^2 N_r \times$$
$$\times\left[1 - \frac{2}{\rho_\lambda}\sin\rho_\lambda + \frac{2}{\rho_\lambda^2}\left(1-\cos\rho_\lambda\right)\right]Q(\rho_\lambda) \tag{7}$$



a *b*

Fig. 1. The dependence between the radiation intensity of the point source I_λ and the maximum detection distance x_m of its signal:
a – Transparent atmosphere: Curves: *1* – λ = 0,554 micrometers; *2* – λ = 1 micrometers; *3* – λ = 4 micrometers, λ = 10 micrometers. Haze (r = 0,05 micrometers; $N_r = 10^2 \text{cm}^{-3}$), Curves: *4* – λ = 0,554 micrometers; *5* – λ = 1 micrometers; *6* – λ = 4 micrometers; *7* – λ = 10 micrometers.
B – Fog I (r = 1,8 micrometers, $N_r = 10^2$ cm^{-3}), Curves: *1* – λ = 0,554 micrometers; *2* – λ = 1 micrometers; *3* – λ = 4 micrometers; *4* – λ = 10 micrometers. Fog II (r = 6,5 micrometers, $N_r = 10^2$ cm^{-3}), Curves: *5* – λ = 0,554 micrometers; *6* – λ = 1 micrometers, λ = 4 micrometers; *7* – λ = 10 micrometers. Fog III (r = 18 micrometers, N_r = 10 cm^{-3}), Curve *8* – λ = 0,554 micrometers, λ = 1 micrometers, λ = 4 micrometers, λ = 10 micrometers.

where N_r – concentration of aerosol particles

$$\rho_\lambda = \frac{2\pi r(m-1)}{\lambda},$$

m – complex index of water refraction,

The value of the true index of water refraction at various λ was taken from the calculation tables [18]. All parameters of air and water are brought to climatic conditions: P = 101325 Па, T = 293,15 °К.

For practical purposes, it is important to have the effect of extending the range with the growth of λ in a very turbid medium. It is easy to see from the comparison of characteristic curves that with the same source radiation intension the signal detection range is always more in the infrared range than in visible one (at λ = 0.554 microns). However, with the decrease of the atmospheric transparency due to the increase of the size of aerosol particles, the effect is leveled and with considerable turbidity, the "enlightenment" disappears. This means that many types of haze and fog in the considered infrared ranges will be transparent. It is also easy to see that, with the same meteorological visibility range, the use of an infrared source-receiver is economically beneficial.

5. Conclusions

When developing systems for detecting beam signals to follow up the aircraft when landing in adverse meteorological conditions, it is necessary to use three basic principles:

- to indicate the runway, the approach and horizon lights, the infrared spotlights must be used in addition to the visible range floodlights;
- in order to achieve the maximum infrared radiation penetration range in adverse meteorological conditions, it is necessary to coordinate the wavelengths of infrared floodlights with appropriate atmospheric transparency windows. For the development of light-signal devices that make the most use of atmospheric transparency windows, the light sources with a narrow spectrum of radiation are required, which must fully coincide with the corresponding atmospheric transparency window. Such light sources can be high-

performance floodlights, in which radiating nodes use infrared light-emitting diodes that have almost quasi-monochromatic radiation;

- the aircraft is equipped with devices for registration of infrared radiation. Sensitive matrices for the perception of infrared radiation must also be adjusted to the appropriate atmospheric transparency window. It should be noted that the sensitivity of the existing matrices for the registration of infrared radiation above the threshold illumination of the observer's pupil of the eye, at which the light signal begins to perceive.

The use of the light signal monitoring system for following up the aircraft when landing in adverse meteorological conditions, which developed using the above mentioned principles, will allow the aircraft crew to observe landing infrared lights on the monitor screen at a considerable distance in adverse weather conditions and to make the necessary adjustments when deviating of the aircraft from the glide, which will significantly increase flight safety and reduce the negative psychological stress on the aircraft crew at the most difficult and responsible phases of the flight.

References

[1] Nacharov D.V. (2017) Razvitie metodiki otsenki dnevnoi opticheskoi dal'nosti vidimosti po tsifrovym televizionnym izobrazheniyam [Development of the method for evaluation the daily optical range of visibility by digital television images]. *Zhurnal radioelektroniki* [Magazine of Radioelectronics], ISSN 1684-1719, no 8, (In Russ.) Available at: http://jre.cplire.ru/jre/aug17/index.html.

[2] Rukovodstvo po opredeleniyu dal'nosti vidimosti na VPP/RD 52.21.680-2006. [Guidelines for determining the visibility on runway / taxi way 52.21.680-2006.] (In Russian). Available at: http://autou.ykt.ru/study/laudiug/ laudiug.htm.

[3] Nikitin D.A. (2006) *Kurso-glissadnye sistemy posadki v grazhdanskoi aviatsii SSSR (70-80es gg. 20th v.)* [Instrument landing system in Civil Aviation of USSR (70-80s of twentieth century)]. Moscow, Nauchnyi vestnik MGTU GA Publ., pp. 35-38.

[4] Yakushenkov Yu. G. (1999) *Teoriya i raschet optiko-elektronnykh priborov* [Theory and calculation of optoelectronic devices]. Moscow, Logos, 480 p. (In Russian)

[5] Klymenchenko V.Y., Kamalynov H.H., Misailov V.L., Svystunov D.Yu. (2011) *Obhruntuvannia vymoh do OEP vizualnoho vyiavlennia suprovodzhennia povitrianykh tsilei i interesakh radiotekhnichnykh viisk PS zbroinykh syl Ukrainy* [Substantiation of requirements for the electrooptical devices for the visual identification of following of air targets and the interests of radio-technical troops of the Air Forces of the Armed Forces of Ukraine]. Collection of scientific works of the Kharkiv University of Air Forces Publ., Issue 1 (127), pp. 80-85. (In Ukrainian)

[6] Geikhman I.L., Volkov V.G. (1999) *Osnovy uluchsheniya vidimosti v slozhnykh usloviyakh* [Basics of improving visibility in difficult conditions]. Moscow, Nedra-biznestsentr LTD Publ., 286 p. (In Russian)

[7] Stavrov A.A., Pozdnyakov M.G. (2003) *Impul'snye lazernye dal'nomery dlya optiko-lokatsionnykh sistem* [Pulsed laser rangefinders for optical locating systems]. Reports of The Belarusian State University of Informatics and Radioelectronics, Volume 1, no 1. (In Russian)

[8] Volkov V.G. (2006) *Aviatsionnye PNV* [Aviation night vision devices] Special equipment, vol.3 no.3, pp. 2-20, no. 4, pp 41-47. (In Russian)

[9] Nikiforov M.M., Pampukha I.V., Zhyrov H.B. (2017) *Obgruntuvannia typu ta vymoh do optyko-elektronnykh system v interesakh vykonannia zavdan rozvidky ta okhorony obiektiv* [Substantiation of the type and requirements for optoelectronic systems in the interests of performing the tasks of reconnaissance and protection of facilities]. Collection of scientific works of the Military Institute of the Kyiv Taras Shevchenko National University Publ, issue 55, pp. 71-81. (In Ukrainian)

[10] Lloyd, J.M. (1975) Thermal Imaging Systems (Optical Physics and Engineering). ISBN 10: 0306308487, ISBN 13: 9780306308482, Publisher: Springer, (Russ. ed: per. s angl. pod red. A. I. Goryacheva N. V. Vasil'chenko. s predisloviem L .N. Kurbatova, (1978) *Sistemy teplovideniya*. Moscow, Mir Pub.l, 416 p.

[11] G. Mie. (1908). Annalen der Physik, Vierte Folge. Band 25, no. 3, pp. 377-445.

[12] McCartney E. (1979) Optics of the atmosphere. Series Pure & Applied Optics, 1976, 426 p. Publisher John Wiley & Sons Inc (Russ.: per. s angl. pod red. K. S. Shifrina *Optika atmosfery*. Moscow, Mir Publ., 421 p.)

[13] Baranochnikov M.L. (1985) *Priemniki infrakrasnogo izlucheniya. Analiticheskii obzor* [Receivers of infrared radiation. Analytical review]. Moscow Publ., 94 p. (In Russian)

[14] Frid Yu.V., Velichko Yu. K. i dr. (1988) *Elektrosvetosignal'noe oborudovanie aerodromov*

[Electrical Lighting Equipment of Aerodromes] Moscow, Transport Publ., 318 p. (In Russian)

[15] Mironov A.V. (2008) *Osnovy astrofotometrii. Prakticheskie osnovy fotometrii i spektrometrii zvezd* [Fundamentals of astrophotometry. Practical fundamentals of photometry and spectrometry of stars]. Moscow, Fizmatlit Publ., 260 p. (In Russian)

[16] Matveev L.T. (1984) *Kurs obshchei meteorologii. Fizika atmosfery* [Course of general meteorology. Physics of the atmosphere]. Leningrad, Gidrometeoizdat Publ., 751 p. (In Russian)

[17] Deirmendzhan D. (1986) Scattering of electromagnetic radiation by spherical polydisperse particles. The RAND Corporanion, Santa Monica, California, American Elsevier Publishing Company, INC. New York, 1969, 303 p. (Russ. ed: perevod s angl. O. I. Smoktich, pod red. K. Ya. Kondrat'eva *Rasseyanie elektromagnitnogo izlucheniya sfericheskimi polidispersnymi chastitsami.* Moscow, Mir Pub.l, 664 p.

[18] Zuev V.E., Krekov G.V. (1986) *Opticheskie modeli atmosfery* [Optical atmospheric models]. Leningrad, Gidrometeoizdat Publ., 256 p. (In Russian)

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В.В. Головенський

Збільшення дальності виявлення аеродромних променевих сигналів у складних метеорологічних умовах

Кременчуцький льотний коледж Національного авіаційного університету, вул. Перемоги, 17/6, м. Кременчук, 39605, Україна
E-mail: vladimir@sat.poltava.ua

Мета: успішна та безпечна посадка повітряного судна (ПС) у нічний час у складних метеорологічних умовах можлива при комплексному використанні радіолокаційних, супутникових радіонавігаційних систем та світлотехнічних пристроїв, причому на завершальному етапі польоту світлотехнічні засоби мають особливе значення, тому, що забезпечують необхідну візуалізацію злітно-посадкової смуги. Одним із найефективніших методів підвищення безпеки польотів є створення додаткового незалежного оптичного каналу інформації між ПС та посадковою смугою. В якості такого каналу може бути система спостереження аеродромних променевих сигналів з ПС у складних метеорологічних умовах з використанням інфрачервоного (ІЧ) діапазону спектру випромінювання. Метою роботи є проведення теоретичного аналізу можливостей збільшення дальності виявлення променевих аеродромних сигналів для підвищення точності та надійності заходу ПС на посадку за рахунок використання середнього та довгохвильового діапазонів інфрачервоного випромінювання для прийому навігаційної інформації. **Метод:** проведено математичну оцінку залежності дальності виявлення точкових променевих сигналів від довжини хвилі та потужності джерела. **Результати:** такі залежності розраховані для ІЧ довжин хвиль 0,554 мкм., 1,0 мкм., 4,0 мкм., 10 мкм, які збігаються з «вікнами прозорості» атмосфери в різних умовах поширення: прозора атмосфера, серпанок, туман. Аналітично показано, що з використанням інфрачервоних монохроматичних випромінювачів та узгоджених по частоті фотоприймачів з високою питомою виявною здатністю можна значно збільшити дальність виявлення променевих сигнальних орієнтирів у порівнянні з більш короткохвильовими сигналами видимого діапазону як в умовах чистої атмосфери так і при наявності водно-аерозольного середовища. Одержано математичні співвідношення для порівняльної оцінки дальності дії системи джерело-приймач з різними робочими довжинами хвиль. Чисельно-графічним аналізом показано, що при однакових потужностях джерел випромінювання дальність виявлення інфрачервоних променевих сигналів відбувається на значно більших відстанях в порівнянні з світловими сигналами видимого діапазону. **Обговорення:** використання системи спостереження світлових сигналів для супроводу повітряних суден при посадці у складних метеорологічних умовах дозволить екіпажу ПС спостерігати посадкові ІЧ- вогні на екрані монітора на значній відстані при несприятливих погодних умовах і заздалегідь вносити необхідні корективи при відхиленні ПС від глісади, що значно підвищить безпеку польотів та зменшить психологічне негативне навантаження на екіпаж ПС на найбільш важких та відповідальних етапах польоту.

Ключові слова: дальність видимості; інфрачервоне випромінювання; прозорість атмосфери; променеві сигнали.

В.В. Головенский

Увеличение дальности обнаружения аэродромных лучевых сигналов в сложных метеорологических условиях

Кременчугский лётный колледж Национального авиационного университета, ул. Победы, 17/6, г. Кременчуг, 39605, Украина

Цель: успешная и безопасная посадка воздушного судна (ВС) в ночное время в сложных метеорологических условиях возможна при комплексном использовании радиолокационных, спутниковых радионавигационных систем и светотехнических устройств, причем на завершающем этапе полета светотехнические средства имеют особое значение, так как обеспечивают необходимую визуализацию взлетно-посадочной полосы. Одним из наиболее эффективных методов повышения безопасности полетов является создание дополнительного независимого оптического канала информации между ПС и посадочной полосой. В качестве такого канала может быть система наблюдения аэродромных лучевых сигналов ВС в сложных метеорологических условиях с использованием инфракрасного (ИК) диапазона спектра излучения. Целью работы является проведение теоретического анализа возможностей увеличения дальности обнаружения лучевых аэродромных сигналов для повышения точности и надежности захода ВС на посадку за счет использования среднего и длинноволнового диапазонов инфракрасного излучения для приема навигационной информации. **Метод**: проведена математическая оценка зависимости дальности обнаружения точечных лучевых сигналов от длины волны и мощности источника. **Результаты**: такие зависимости рассчитаны для ИК длин волн 0,554 мкм., 1,0 мкм., 4,0 мкм., 10 мкм, которые совпадают с «окнами прозрачности» атмосферы при различных условиях распространения: прозрачная атмосфера, дымка, туман. Аналитически показано, что с использованием инфракрасных монохроматических излучателей и согласованных по частоте фотоприемников с высокой удельной обнаружительной способностью можно значительно увеличить дальность приёма лучевых сигнальных ориентиров по сравнению с более коротковолновыми сигналами видимого диапазона как в условиях чистой прозрачной атмосферы, так и при наличии водно-аэрозольной среды. Получены математические соотношения для сравнительной оценки дальности действия системы источник-приемник с различными рабочими длинами волн. Численно-графическим анализом показано, что при одинаковых мощностях источников излучения приём инфракрасных лучевых сигналов будет осуществляться на значительно больших расстояниях по сравнению со световыми сигналами видимого диапазона. **Обсуждение:** использование системы наблюдения световых сигналов для сопровождения воздушных судов при посадке в сложных метеорологических условиях позволит экипажу ВС наблюдать посадочные ИК огни на экране монитора на значительном расстоянии при неблагоприятных погодных условиях и заранее вносить необходимые коррективы при отклонении ВС от глиссады, что значительно повысит безопасность полетов и уменьшит психологическую негативную нагрузку на экипаж ВС на наиболее тяжелых и ответственных этапах полета.

Ключевые слова: дальность видимости; инфракрасное излучение; лучевые сигналы; прозрачность атмосферы.

Golovenskyy Volodymyr (1954).
Chief of Kremenchuk Flight College of the National Aviation University.
Education: National Aviation University (2005), Kyiv, Ukraine.
Research area: scientific and methodical substantiation of the technical implementation of the aircraft landing approach system in adverse meteorological conditions using infrared emitters and photodetectors.
Publications: 9.
E-mail: vladimir@sat.poltava.ua