Observations of LED side lights at the stage of visual piloting

Yuliia Kvach

Aerospace Department, National Aviation University, 1 Liubomyra Huzara ave., Kyiv 03058, Ukraine

E-mail: juli_k74@ukr.net

Abstract The side lights of the light signal system indicate the side boundaries of the runway and its color marking by distance. To encode sections of the runway, depending on where they are installed, the lights emit white or yellow light. The fire must be in the pilot's field of vision from the moment of recognition until the moment of flight near it, only in this case the aerodrome lights give a clear idea of the location of the aircraft. The development of LED technologies has allowed the Ukrainian Association of Lighting Enterprises of Vatra Corporation to develop a design of LED equipment for aerodrome light signal systems, namely a universal fire that performs the functions of bidirectional fire and roundabout fire. Features of fire design, angles of convergence of side lights, difficulties in observing LED airfield lights affect on the visual contact. If the light signal system fails, the crew will not be able to establish its location or visual contact may be erroneous. To solve the complex problem of visibility of light signals from LED light signal aerodrome side lights, a tool using the MatLab interface is proposed. The tool allows to model a fragment of a light signal picture in the conditions of deficit of time at a stage of visual piloting. The tool simulates the illumination created on the retina of the pilot's eye from aerodrome side lights in the MatLab interface. Lighting simulation will manage risk in order to prevent aviation events.

1. Introduction

The side aerodrome lights of the light signal system limit the runway on two sides with the appropriate lighting characteristics and color of radiation.

The lighting characteristics and location of the side lights of aerodrome lights must be such that in difficult meteorological conditions the pilot can clearly see the required number of lights of the light signal system. The aerodrome lights of the light signaling system must be visible within a horizontal angle so that the pilot can observe them while piloting the aircraft both during the day and at night.

1.1 Side lights of the runway

Each side light emits light of different intensity, depending on which part of the light beam is their line of sight. Taking into account the characteristics of the side fire, setting the angle of elevation and the angle of convergence, you can determine the intensity of the light beam directed at the pilot. The angles of convergence of the side lights are 4.5^0 with a runway width of 60 m and 3.5^0 with a runway width of 45 m. The angle of increase of the side lights is 3.5^0.

A tool using the MatLab interface is offered to solve the problem of monitoring light signals from LED light signal aerodrome side lights. The tool allows to model a fragment of a light signal picture in the conditions of deficit of time at a stage of visual piloting. The tool simulates the illumination created on the pilot's retina by side LED aerodrome lights in the MatLab interface. Such lighting modeling will allow to manage risk in order to prevent aviation events.

1.2 Review of research and publications

The current regulations [1, 2, 3, 4, 5] contain requirements for the design and lighting characteristics of the side aerodrome runway fire.

In [6], the author presents the patterns of visual observation of objects depending on the conditions of observation and the characteristics of the object.

The study of the influence of blue light on physiological and subjective human reactions was considered by the authors in [7].

The definition of visual search of objects as airfield lights, constantly emitting light on the runway depending on the transparency of the atmosphere is considered in the simulation in the created tools of the MatLab environment in [10,11].

2. Problem statement

The side lights emit a constant white light of constant light. In the presence of a shifted runway threshold, the side lights emit red light in the direction of approach to the landing and emit yellow light on the section that is one third of the length of the runway.

Side lights should be visible from all directions to help orient the pilot who is approaching or taking off in any direction. In the case where the side lights are designed to control the flight in a circle, it is necessary to observe them from all directions.

According to the requirements, the side lights emit light in all directions at angles of elevation up to 15є above the horizon with a light intensity of at least 50 cd. Except in the absence of external lighting, the light intensity of the side lights at the aerodrome shall be not less than 25 cd to prevent the pilot from being blinded.

The side lights of the runway, equipped for accurate landing, meet the technical requirements specified in Figure 1 - 2.

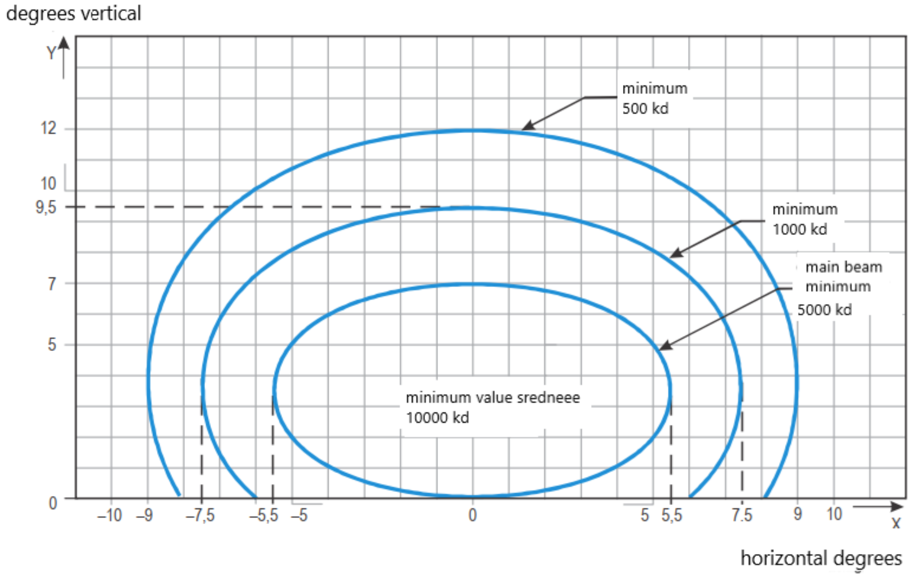


Figure 1. Diagram of isocandles of side lights at a runway width of 45 m (White lights)

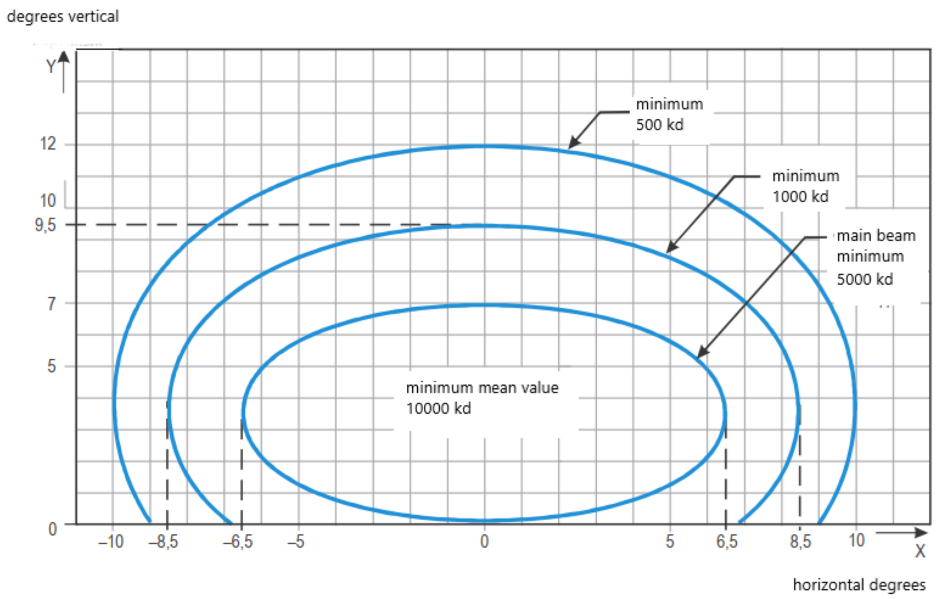


Figure 2. Diagram of isocandles of side lights at a runway width of 60 m (White lights)

Given the fact that the observation of the side light must be provided from a certain area of space, it is clear that the photometric body should be normalized in accordance with the recommendations of ICAO [1]. Spatial parameters of radiation (Figure 1, 2) provide the necessary guidance during the approach.

According to the perception of light color by the pilot, it is necessary that the technical conditions in determining the chromaticity of the colors of airfield lights meet the current conditions of the International Commission on Lighting (ICL) (Figure 3) [3,4].

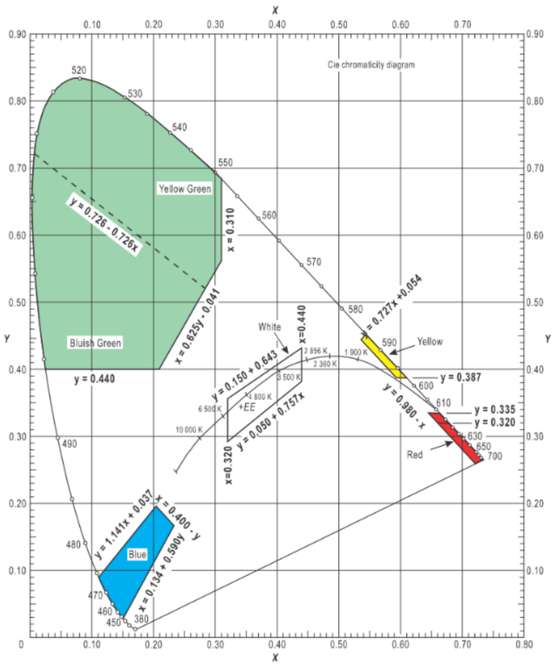


Figure 3. Colors of LED aerodrome light signals

But it is impossible to set the technical conditions for colors so as to completely eliminate the possibility of their misperception. For sufficiently reliable recognition, it is important that the illumination of the eye significantly exceeds the threshold of perception, that the color does not undergo significant changes due to selective (selective) atmospheric attenuation (absorption) and the color vision of the observer was normal. There is also a risk of distorted color perception in very bright light, which can be caused by a high-intensity light source at close range. Experience has shown that satisfactory recognition is possible when these parameters are given due attention.

Characteristics of chromaticity are made on the basis of research of visual perception and correspond to the coordinate system accepted by ICL. The parameters of the fire color are compared with the parameters determined on the outer curve of the isocandel, in order to ensure the absence of such a color change that could lead to incorrect perception of the light signal by the pilot.

3. Computational methodology

The development of LED technologies has allowed the Ukrainian corporation "Fire" to develop a design of LED aerodrome universal side light NL 02V-RWY 45-R (L) -W / Y, NL 02V-RWY 60-R (L) -W / Y (Figure 4) . The use of LED modules in the construction of airfield lights has a number of advantages. The most significant advantages of LED airfield light include: low power consumption, instant on and off, vibration resistance, long service life, high light quality with a color rendering index in the range of 80-95 and an optimal radiation pattern with the ability to create directional light.

Figure 4. Ground side fire of the runway NL 02V-RWY 45-R (L) -W / Y, NL 02V-RWY 60-R (L) -W / Y

The design of the ground side runway light consists of two oppositely directed LED assemblies of eight LEDs mounted on a board complete with special optics to assemble and maximize light flux. Each module is represented by eight Cree LEDs (Figure 5).

Figure 5. Ground bidirectional side fire of the runway.

The design of the bidirectional LED side light of the runway is additionally supplemented by a reflector that forms the output light in the upper hemisphere. Thus, the improved design of the bidirectional side light of the runway can be considered a universal fire, which is a replacement for the installation of two ground lights and a roundabout type "bush". This design of universal fire must emit light intensity in the upper hemisphere of not less than 50 cd, performing the function of circular fire (Figure 6).

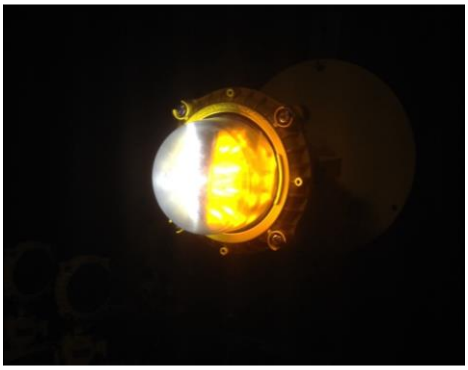
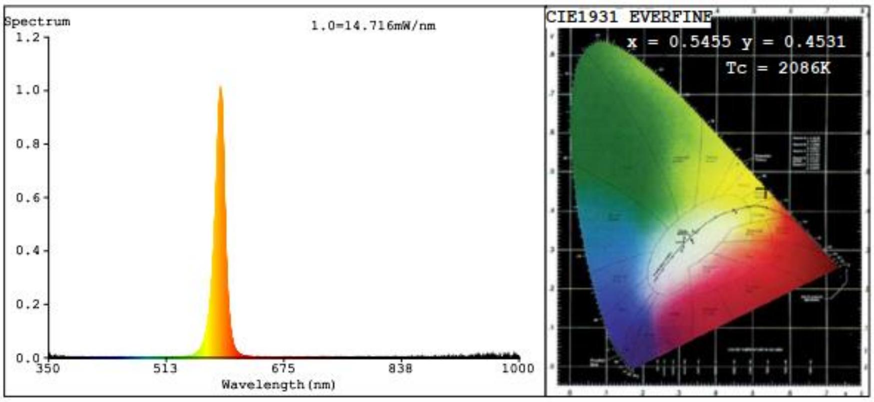


Figure 6. Improved design of bidirectional runway side lights.

In the study of bidirectional side LED runway light, the light radiation has parameters that meet (Figure 7):
- chromaticity coordinates: x = 0,5455 y = 0,4531 / u '= 0,2970 v' = 0,5551
- dominant wavelength 585.2 nm with 99.8% color purity
- luminous flux 138.2 lm
- RGB color ratio: R = 5.4% G = 94.6% B = 0.0%



Color Parameters:

Chromaticity Coordinate:x=0.5455 y=0.4531/u'=0.2970 v'=0.5551

Tc=2086K(Duv=0.0118) Dominant WL:Ld =585.2nm Purity=99.8%

Ratio:R=5.4% G=94.6% B=0.0%¡¡Peak WL:Lp=587.5nm HWL:Lhd=14.1nm

Render Index:Ra=9.4

R1 =0	R2 =37	R3 =25	R4 =0	R5 =0	R6 =12	R7 =2	
R8 =0	R9 =0	R10=0	R11=0	R12=0	R13=0	R14=49	R15=0

Photo Parameters:

Flux = 138.2 lm Fe = 256.0 mW

Figure 7. The result of the study of the chlorine characteristics of the side fire of the runway.

To solve the problem of observing light signals from LED side lights of the runway, a toolkit using the MATLAB interface is proposed [8, 9]. The toolkit allows to model fragments of a light signal picture of a runway in the conditions of deficit of time at a stage of visual piloting. Using the tools in the environment MatLab [8, 9] simulates the illuminance created on the retina of the pilot from the system of side LED lights of the runway, depending on the input to the input field (Figure 8):

Figure 8. Tools for determining the visual recognition of LED side lights of the runway depending on the angle of flight, individual characteristics of the observer, the transparency of the atmosphere.

- coordinates (X, Y, Z) and angles (V, G) of glide firets on the runway;
- photometric data of glide fires by means of the respective ies-files of corresponding fires [11];
- the coordinates of the pilot's finding in relation to the glide fire system to determine the length of the trajectory between the light emitter and the receiver;
- parameters characterizing the complexity of meteorological conditions with indicating the background brightness (L_{back}), atmospheric transparency and meteorological of visibility range (MVR).

Toolkit allows to get:

- illumination taking into account the cosine dependence created by glide fires on the retina of the pilot's eye (E_0);
- illumination by Allard, generated by glide fires on the retina of the pilot's eye ;
- total illumination generated by glide fires on the retina of the pilot's eye (E) with the determination of minimum, average and maximum values;
- the threshold of illumination, which allows to estimate the visibility of glide fires depending on difficult meteorological conditions;

a graphic representation of illumination from each individual glide fire (Figure 9);

- graphical representation of illumination from the system of glide fires;
- graphical representation of the radiation direction of glide fires (Figure 10).

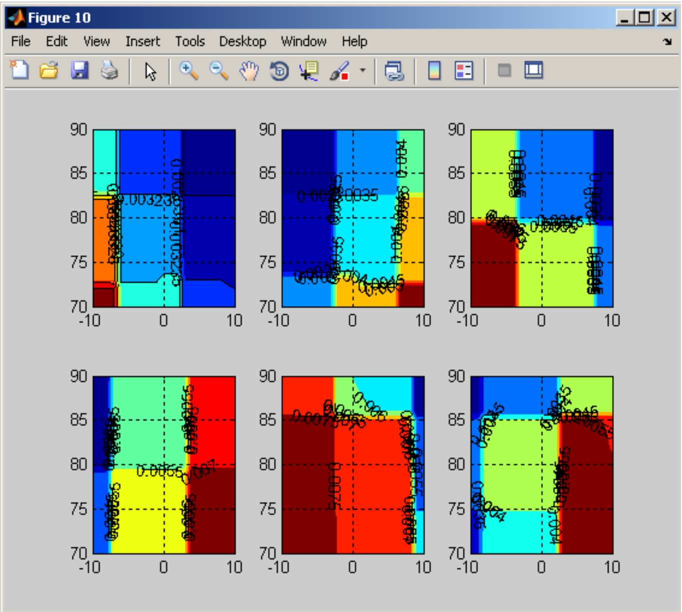


Figure 9. Graphic representation of illumination of LED glide lights.

Figure 10. Graphic representation of the radiation direction of the LED side lights of the runway with the appropriate light intensity on the retina of the pilot.

Graphical representations of the direction of a single runway side light or a group of runway side lights with appropriate light intensity on the pilot's retina allow conclusions to be drawn as to their contribution to the overall visual observation picture perceived by the pilot.

4. Results and discussion

Universal runway side lights help the pilot follow the correct descent trajectory during approach and accurately control the distance from the runway even in difficult weather conditions. Therefore, it is important that the aerodrome side lights of the runway emit light both in the direction of approach to the landing and in the upper hemisphere. Thus, there is a designation of the geometric parameters of the artificial surface of the runway, ie a picture of observation is formed, which allows the pilot to navigate in three-dimensional space.

In the calculations of the visibility of light signals it is necessary to take into account the light threshold, ie the lowest value of illumination on the pupil of the observer, when the light signal is confidently perceived.

Taking into account the design of the ground side fire, the modeling of the illumination created on the retina of the pilot's eye in different meteorological conditions was carried out.

When simulating the pilot's perception of the light signal from the group of side lights of the runway in fog (Figure 11), the lights are not recognized, which is confirmed by the calculation of the probability of observation

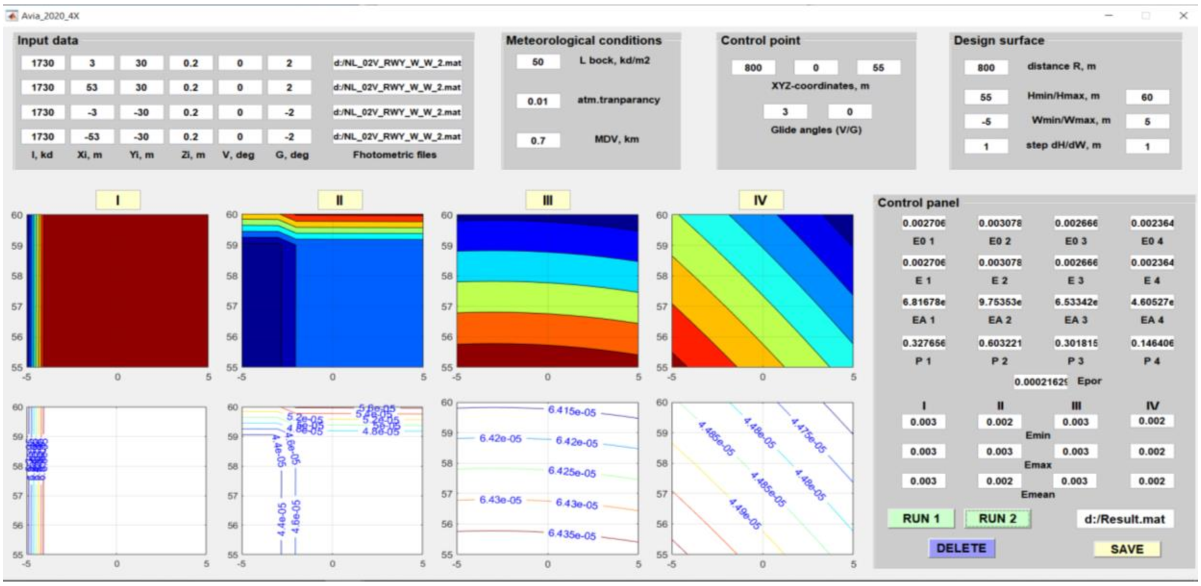


Figure 11. Modeling of determination of visual recognition of LED side lights in conditions of visible fog.

When modeling the pilot's perception of the light signal from the subsystem of the side lights of the runway in a haze (Figure 12), but at dusk and against the background of snow - universal lights are not recognized.

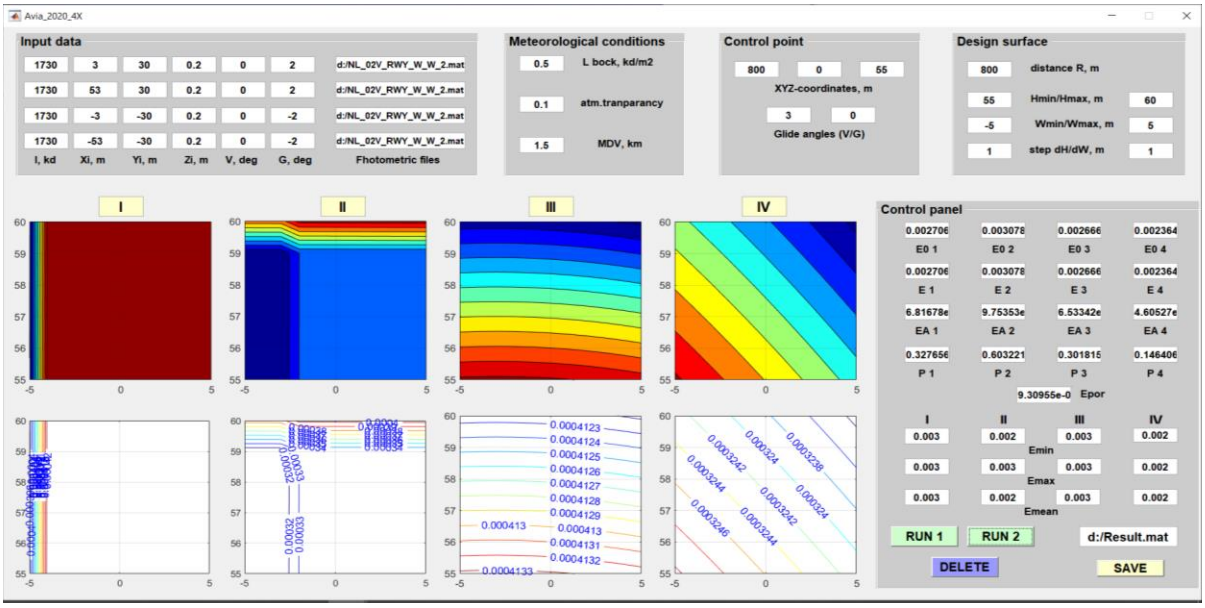


Figure 12. Simulation of the definition of visual recognition of LED side lights in a haze on a background of snow.

When modeling the pilot's perception of the light signal from the subsystem of the side lights of the runway in conditions of good visibility (Figure 13) during the day against the background of grass - the whole group of side lights of the runway is confidently different.

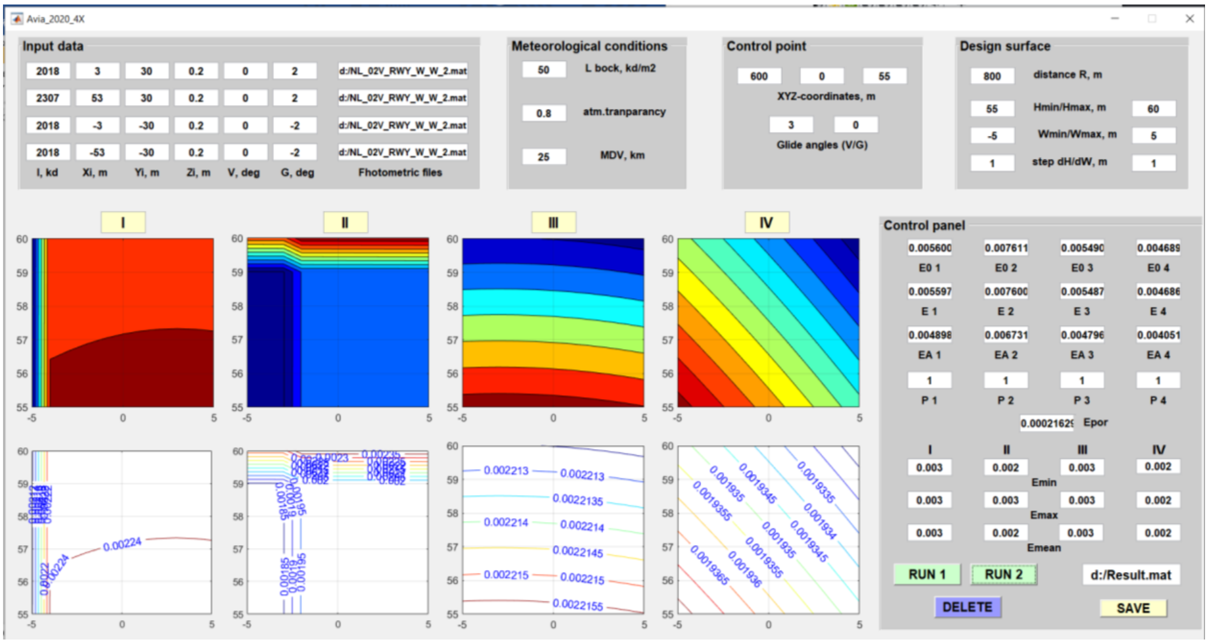


Figure 13. Simulation of visual recognition of LED side lights in conditions of good visibility against grass background.

Thus, the simulation of the illumination created on the retina of the pilot takes into account the determination of the brightness of the background, which recognizes the individual ground sideways of the runway or subsystem of side lights of the runway depending on location coordinates and their photometric characteristics taking into account complex meteorological conditions.

Simulation of the light signal picture and observation of the LED side lights of the runway will allow to manage the risk in order to prevent aviation events.

Conclusions

According to the simulation of the visibility of the LED side lights of the runway by the pilot when visually guiding the observation at a distance of 800 m, which corresponds to the complexity of the category I aerodrome in conditions of visible fog, the decision error is quite high.

In conditions of light fog, the pilot does not recognize lights according to the simulation, which is not favorable. Therefore, the universal side LED light NL 02V-RWY 45-R (L) -W / Y and NL 02V-RWY 60-R (L) -W / Y in fog conditions is not recommended for use.

In haze conditions, the side lights are not recognized by the pilot simulation, which is not acceptable. Therefore, the universal side LED lights NL 02V-RWY 45-R (L) -W / Y and NL 02V-RWY 60-R (L) -W / Y in haze conditions both on the background of grass in the light of stars and on the background of snow when stars appear lights are not recommended for use.

The study of universal side lights in difficult weather conditions allows to say that the universal side LED lights NL 02V-RWY 45-R (L) -W / Y and NL 02V-RWY 60-R (L) -W / Y can be reliably recognized if illuminance on the retina of the pilot exceeds the threshold illuminance and the probability of observation is not less than one.

References

[1] Doc 9157-AN / 901 ICAO Aerodrome Design Guide. P 4. Visual aids. 4th ed. ICAO 2004

[2] Doc 9157, Part 5 - Electrical Systems, Aerodrome Design Manual. Second Edition-2017, ICAO 226 p

[3] CIE – Publication No. 15, Colorimetry, 1971

[4] ISO / CIE 11664-4: 2019 (E) Colorimetry. Part 4. CIE Color Space 1976 L * a * b *

[5] Doc 9328-AN / 908 ICAO, A Guide to the Practice of Tracking and Reporting on Visibility Observation to Runways, 3rd ed. ICAO 2005 124 p

[6] Jung Choi "White Light Enriched with Blue Light to Wake You Up in the Morning" is available at: https://www.eurekalert.org/pub_releases/2019-03/tkai-bwl030619.php (as of 03/22/2020)

[7] Travnikova N P 1985 Visual search efficiency. (Moscow: Mechanical Engineering). 128p

[8] Kondrashov V and Korolev S 2002 MatLab as a system for programming scientific and technical calculations. (Moscow: Mir, Institute of Strategic Stability of the Minatom of the Russian Federation) 350 p

[9] Badriev I B, Banderov V V and Zadvornov O A 2010 *Developing a graphical user interface in MatLab. Tutorial.* (Kazan: Kazan State University) 113 p

[10] Kvach Yu 2018 Modeling the influence of factors on the observation of civil aviation aerodrome fires in MatLab. *Electronics and control systems.* Vol **4** (58) pp 115-119

[11] Kvach Yu 2007 Simulation of light-signal fires of aerodrome in simulators of visual environment of aviation simulators. *Bulletin of the National Aviation University.* Issue **1** pp 55-58

[12] Kvach Yu 2019 Modeling illumination on the retina of the pilot’s eye during in complicated meteorological conditions in MatLab environment. *Lighting and Energy.* Issue **2** (55) pp 59-62