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ACTIVE PULSE TELEVISION MEASURING SYSTEMS FOR ENSURING NAVIGATION OF TRANSPORT MEANS IN HEAVY WEATHER CONDITIONS

This paper presents research results of the Active Vision Area, formed by the Active Pulse Television Measuring System in conditions of decreased transparency of propagation medium.

Aim: To increase backscatter interference suppression efficiency by the Active Pulse Television Measuring System for ensuring navigation of transport means in heavy weather conditions.

Methods: Simulation of Active Vision Area considering light energy attenuation is proportionate to the square of distance and attenuation caused by propagation atmosphere. Performance of experimental researches with the Prototype of Active Pulse Television Measuring System using Big Aerosol Chamber, simulating dense fog and smoke conditions.

Results: The designed model of Active Vision Area allowed estimating the changes of light energy distribution in the observed space layer depending on range of observation and transparency of radiation propagation medium. With equal duration values of the illumination and strobing pulses of the photodetector in conditions of dense fog, significantly big residual backscatter interference was revealed, maximum intensity area of the radiation reflected from objects was displaced from a distance of strobing delay. Illumination pulse duration reduction led to increase of backscatter interference suppression efficiency, improvement of image contrast and increase of accuracy of determination of distance to the observed objects.

Conclusion: The increase of backscatter interference suppression efficiency by the Active Pulse Television Measuring System for ensuring navigation of transport means in heavy weather conditions is a relevant task

Keywords: вackscatter interference, contrast, active vision area, heavy weather conditions, active pulse television measuring system.

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АКТИВНО-ИМПУЛЬСНЫЕ ТЕЛЕВИЗИОННЫЕ ИЗМЕРИТЕЛЬНЫЕ СИСТЕМЫ ДЛЯ ОБЕСПЕЧЕНИЯ НАВИГАЦИИ ТРАНСПОРТНЫХ СРЕДСТВ В СЛОЖНЫХ МЕТЕОУСЛОВИЯХ

Аннотация. Представлены результаты исследования активной зоны ви́дения формируемой активно-импульсной телевизионной измерительной системой в условиях пониженной прозрачности среды распространения.

Цель: Повысить эффективность подавления помехи обратного рассеяния активно-импульсными телевизионными измерительными системами для обеспечения навигации транспортных средств в сложных метеоусловиях.

Методы: Моделирование активной зоны ви́дения с учетом ослабления световой энергии пропорционально квадрату расстояния и затухания, вызванного средой распространения. Экспериментальные исследования макета активно-импульсной телевизионной измерительной системы в большой аэрозольной камере в условиях плотного тумана и дыма.

Результаты: Построенная модель активной зоны ви́дения позволила оценить изменения распределения световой энергии наблюдаемого слоя пространства в зависимости от дальности наблюдения и прозрачности среды распространения излучения. При равной длительности импульсов подсвета и стробирования фотоприемного устройства в условиях плотного тумана выявлена большая остаточная помеха обратного рассеяния, область максимальной интенсивности отраженного от объектов излучения сместилась от дистанции, соответствующей задержке стробирования. Сокращение длительности импульса подсвета привело к увеличению эффективности подавления помехи обратного рассеяния, к улучшению контраста изображения и к повышению точности определения расстояния до наблюдаемых объектов.

Выводы: Применение результатов исследования позволяет повысить эффективность подавления помехи обратного рассеяния активно-импульсными телевизионными измерительными системами в сложных метеоусловиях для обеспечения навигации транспортных средств.

Ключевые слова: помеха обратного рассеяния, контраст, активная зона ви́дения, сложные метеоусловия, активно-импульсная телевизионная измерительная система.

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Introduction

Currently, in modern science and technology, there is a growing dissemination of technical vision systems which are able to efficiently perform tasks of searching and detecting the objects observed in rough weather conditions (fog, haze, dust, snowfall).

The operational range and possibility of detection of the objects by means of conventional television systems are seriously limited in the conditions of low transparency of the propagation atmosphere. The basic reason for limitation of detection and identification ranges in rough vision conditions is the impact of backscatter interference [1].

Backscatter interference occurs due to light photons' scattering on the atmosphere aerosols in the direction of the observer, which leads to significant decrease of the image contrast and, consequently, to impossibility of detecting and identifying the objects of observation [2].

There is quite a broad spectrum of monitoring systems for work in the complicated visibility conditions:

- passive and active-passive low light television systems;
- active pulse television measuring systems (AP TMS);
- thermal vision systems.

AP TMS efficiently eliminates the backscatter interference and is not sensitive to low temperatures unlike thermal vision systems. The working principle of AP TMS is based upon space pulse illumination and time strobing of the photodetector which is equipped with fast shutter.

The essence of the method is brought to the following. The object of observation is illuminated by light pulses, duration of which is significantly shorter than the light probation time to the object and back. In the case when time delay between pulse emission moment and shutter opening moment is equal to double time necessary for the light to cover the distance to the object and back, the observer will be able to see only the object itself and the area of space surrounding it. The depth of this space is determined by both the time of opening state of the shutter and the duration of the light pulse [3].

As a photodetector in the active pulse television measuring systems, as a rule, the image intensifier tube is used, which operates in the pulse mode. The image intensifier tube in the active pulse television measuring systems functions as a fast-acting electronic shutter and image brightness enhancer. To receive video signal, the image intensifier tube is synchronised with video camera.

The synchronisation is feasible by means of joining through fiber-optic element (focon), direct joining of image intensifier tube to light-sensitive element of the television camera or with the use of the relay coupling lens.

The use of the relay coupling lens is justified by the emergence of heavy interferences in the energetics of the carried optical image. The synchronisation by means of joining through focon or direct joining of image intensifier tube to

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light-sensitive element of the television camera causes impossibility of quick change of the device components (non-module construction) and increase of its costs [4, 5].

As the illuminator for AP TMS, the laser-based or LED-based lighter is used, which works in the pulse mode. The duration of the illumination pulses may reach tens or units of nanoseconds, enabling reaching a high pulse power, with the photodetector’s short exposure time significantly decreasing background light sensitivity of the system [6].

Depending on the purpose, AP TMS may be used in air, ground, underground, surface and underwater conditions.

The increase of the range of AP TMS is possible both by means of increase of power of the illumination and decrease of the number of radiation angles and acceptance angles.

The most grounded decision, when dealing with significant illumination power, is the scheme of group module of the lighter. The lighter made according to this scheme consists of a range of standard modules with optical axes parallel to each other.

Each module has an objective and an emitter having a laser diode matrix with or without integrator. The radiation of all the modules is focused in one radiation angle, equal to the radiation angle of one module. This scheme of the lighter ensures its minimal longitudinal dimensions and simple radiation forming scheme. The scheme is also convenient with its high repairability, as in case of failure of one module, it can easily be replaced with another one [7].

Depending upon changes of weather conditions, different working modes of the active pulse television measuring systems are used: uninterrupted, active uninterrupted or active pulse mode with the time selection of radiation pulse reflected by the objects.

In the active pulse mode, the control of the AP TMS observation range is carried out by virtue of changing the delay of opening the shutter of the photodetector relative to the illumination pulse (strobing delay). The strobing delay control in the image intensifier tube enables receiving information about the distance to the observed object with a certain tolerance which depends upon the depth and the form of the active vision area.

The strobing delay control of the image intensifier tube in the AP TMS may be realised both manually and semi-automatically, with the use of programmable logic.

When operating manually, the strobing pulse delay, preliminary set for a certain value, is manually gradually and continuously, or discretely and incrementally, increased or decreased to the value corresponding to the maximum or the minimal performance range of the AP TMS. When changing the delay, the zone of the observation is continuously or discretely shifted in range and is combined with the object of interest by the operator. This mode of operation re-

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quires constant involvement of the operator and is not efficient when dealing with fast-moving objects.

When operating semi-automatically, the strobing pulse delay is periodically changed, the scanning of the zone of observation from the minimal to the maximum performance zone is carried out, and detection of the object down the depth of visibility takes place. This mode does not require constant involvement of the operator and can be used when dealing with fast-moving objects.

The AP TMS active vision area

The form of the active vision area will represent the result of convolution of the illumination pulse S_L and the strobing pulse of the image intensifier tube S_g. If the pulses are of the rectangular form and have equal duration, their active vision area will have the form of triangle (fig. 1).

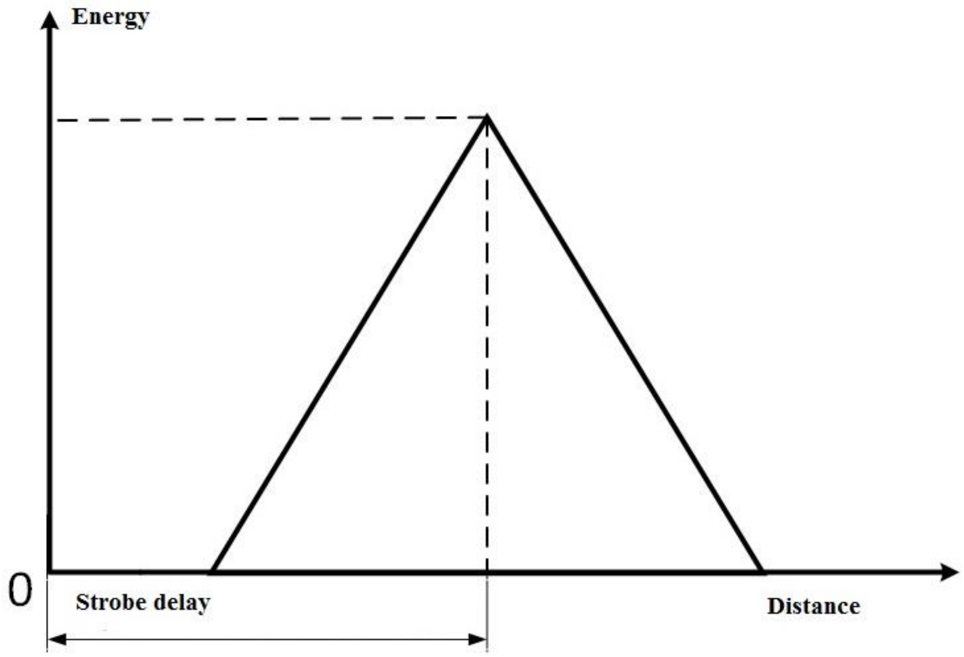

Fig. 1. Active vision area for rectangular illumination pulses and strobing at $\tau_L = \tau_g$, without taking into account reduction of light energy

Since the illumination radiation pulse reflected from the object, which is located at a distance corresponding to the strobing delay of the image intensifier tube, will be being received during the entire opening state of the image intensifier tube, with the duration pulses being equal, the centre of the active vision area will have the maximum energy in one point and will correspond to the strobing delay of the image intensifier tube [8].

The depth of the active vision area d_Z will depend upon the total duration of the illumination and strobing pulses of the image intensifier tube

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$$d_z = \frac{(\tau_L + \tau_g) \cdot c}{2}, \tag{1}$$

where τ_L – the illumination pulse duration,

τ_g – the strobing pulse duration of the image intensifier tube;

c – the speed of light.

In case the duration of the illumination pulse is less than that of the strobing pulse of the image intensifier tube, the active vision area will acquire the form of trapezoid. The maximum energy area will be somewhat extended, and the point, corresponding to the strobing delay of the image intensifier tube, will be located in the beginning of the maximum energy area (fig. 2) [9].

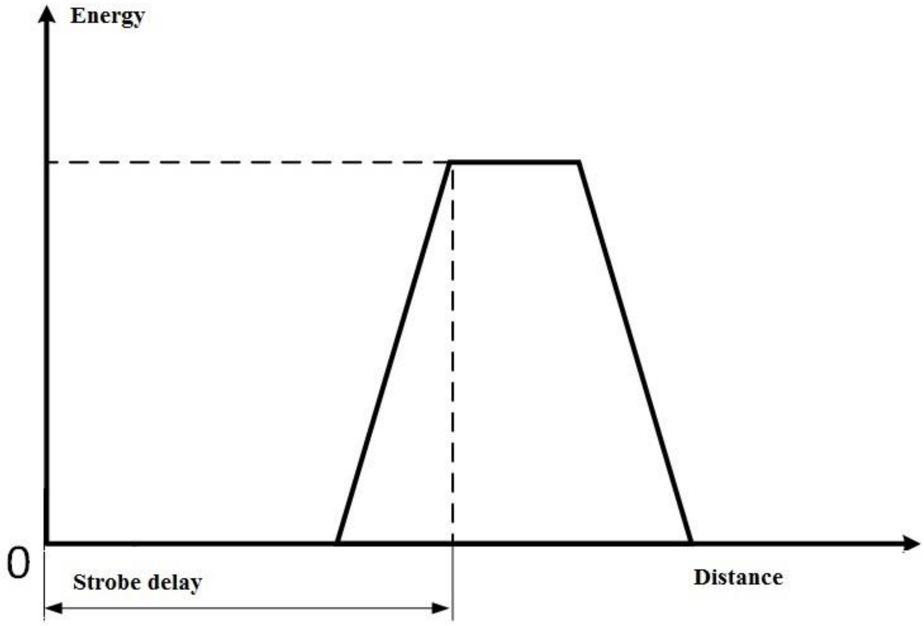

Fig. 2. Acitve vision area for rectangular pulses at $\tau_L < \tau_g$

The starting point of the active vision area d_{Zstart} at any duration relations depends upon the illumination pulse duration and is determined by the expression

$$d_{zstart} = \frac{(t_D - \tau_L) \cdot c}{2}, \tag{2}$$

where t_D – the strobing delay of the image intensifier tube;

τ_L – the illumination pulse duration;

c – the speed of light.

In the fig. 3, there are given expressions by means of which the major points of the active vision area, at $\tau_L < \tau_g$ for square waveforms, can be calculated.

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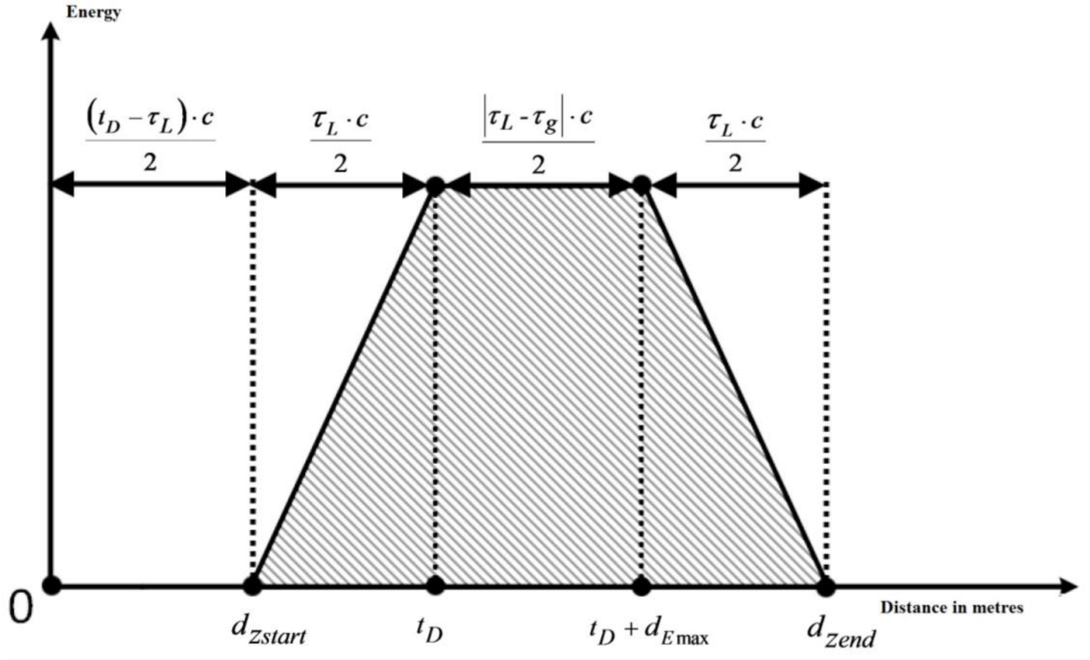

Fig. 3. Calculation of major points of the area for $\tau_L < \tau_g$

Practically, during the propagation in the atmosphere, the attenuation of the illumination is determined by two factors. One of them is reversely proportional to the square of the distance to the object, the other has a negative exponent. Therefore, the decrease of transparency of the atmosphere will be followed by the increasing distortion of the active vision area form [10].

Besides, rectangular short duration pulses with high amplitude are technically difficult to realise, therefore the calculation of the active vision area should be conducted taking into account the signal edges' duration, which will influence the form of the active vision area.

To calculate the form of the active vision area, taking into account the attenuation of light energy of the illumination proportionately to the square of the distance and attenuation in the hazy propagation atmosphere, the following expression is used

$$S_Z(L)=\frac{1}{L^2\cdot\sigma^2(L)}\cdot\int_0^{\tau}S_g\left(t+\frac{2L}{10^{-9}c}\right)\cdot S_L(t)dt, \quad (3)$$

where τ – the integration time;

L – the distance;

$S_L(t)$ – the illumination signal;

$S_g(t)$ – strobing signal of the image intensifier tube;

$\sigma(L)$ – the coefficient of the optical quenching of the propagation atmosphere.

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In the fig. 4, there is a result of calculation of the active vision area for 15 metres (area 1) and 30 metres (area 2) at the same illumination pulse duration and strobing pulse duration of the image intensifier tube (60 ns), taking into account the illumination attenuation proportionately to the square of the distance and considering the optical quenching in the propagation atmosphere (light fog), which equals 20 dB/km.

Thus, it has been shown that at short observation distances, the active vision area is significantly distorted in the conditions of decreased transparency of propagation atmosphere. The area of the maximum energy of the active vision area is shifted from the centre of the area to its starting part, which leads to enhancement of the residual backscatter interference, light clutter from near objects, reduction of image contrast and tolerances in determination of the distance to the object under observation.

To minimise the consequences of the active vision area distortion, the duration of pulses of the illumination source should be reduced. The reduction of the duration of the pulses of the illumination source relative to the duration of strobing pulses of the image intensifier tube will result in the enhancement of steepness of the active vision area leading edge and the shift of the point, which corresponds to the strobing delay of the image intensifier tube, to the initial area of the active vision area.

The fig. 5 shows the result of calculation of the active vision areas for the distances of 15 metres (area 1) and 30 metres (area 2) in the parameters of the propagation atmosphere. The duration of the illumination pulse has been reduced twice, to 30 ns, the duration of the strobing pulse of the image intensifier tube has been increased to 90 ns.

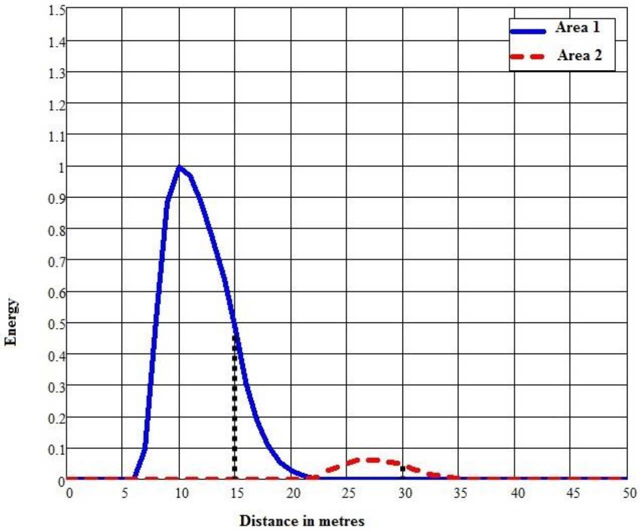

Fig. 4. The model of the active vision area for distances of 15 and 30 metres (the points mark the distance, which corresponds to the strobing delay of the image intensifier tube)

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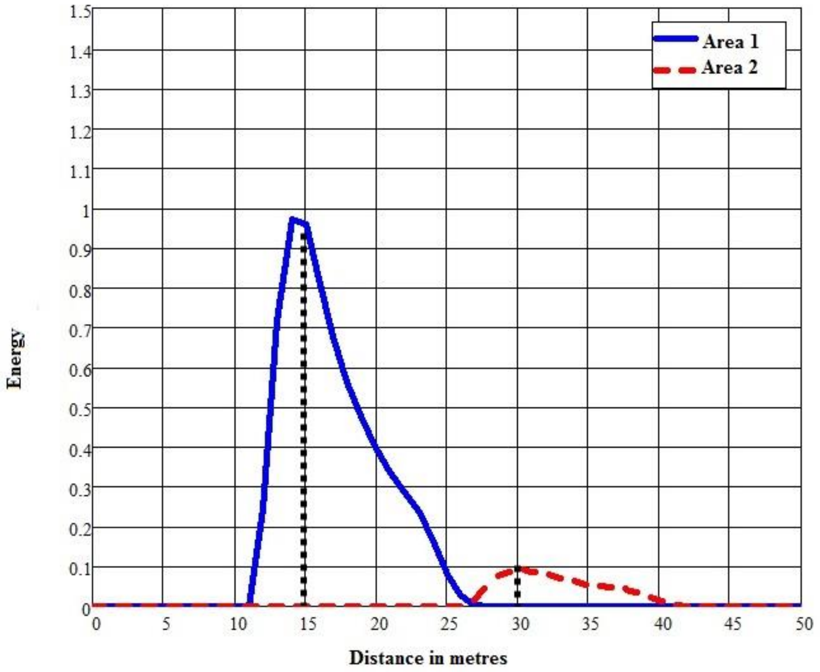

Fig. 5. The model of the active vision area (the distortions are compensated with the steepness of the leading edge of the active vision area)

Experimental research of the model of Active Pulse Television Measuring Systems (AP TMS)

To test the results of the modelling, a range of experiments under conditions of decreased transparency of the propagation atmosphere by means of AP TMS has been carried out. The system was developed by the authors of the article, at the Department of Television and Management, Tomsk State University of Control Systems and Radioelectronics (TUSUR).

The system comprises (fig. 6): the input objective, the image intensifier tube (IIT), which matches the objective, the image source (a monochrome CMOS 800 TVL) with increased sensitivity, the illuminator, the power source, the control blocks and computers with special software. The illuminator is the pulsed semiconductor laser which operates in the NIR.

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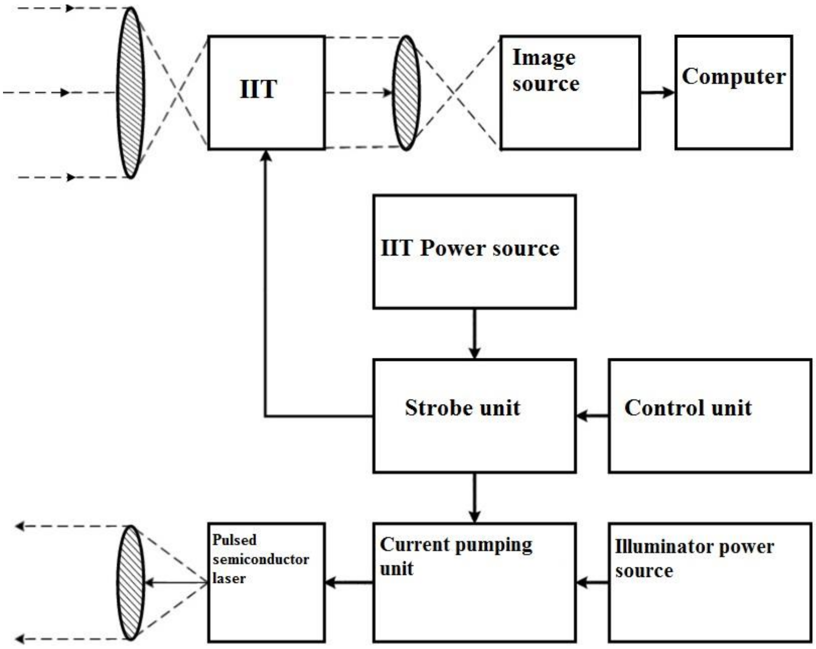

Fig. 6. Structural scheme of AP TMS

The appearance of the AP TMS model is seen in the fig. 7.
Technical characteristics of the AP TMS model:

- the system’s range vision up to 200 metres;
- the system’s vision angle 6–12 degrees;
- optical power of the illumination in the pulse 320 W;
- wave length of the illumination radiation 842 nanometres;
- pulse repetition frequency of the illumination 50–4950 hertz;
- duration of the illumination pulse 30–120 nanoseconds;
- duration of the IIT strobing pulses 30–120 nanoseconds;
- depth of the active vision area 9–36 metres.

Fig. 7. Appearance of the AP TMS model

The experimental researches of the Active Pulse Television Measuring System have been carried out in the Big Aerosol Chamber (BAC) of V.E. Zuev Institute of Atmospheric Optics of Siberian Branch of the Russian Academy of Science.

The imitation of fog in the BAC was performed with the help of the fog generator which evaporated hydroglyceric mixture. Filling of the BAC with smoke was carried out by means of incineration of pine logs in a special furnace. As a rule, turbidity of the propagation atmosphere with fog or smoke kept till in the active uninterrupted mode of performance of the AP TMS (without strobing of the IIT, with active illumination), it was impossible to detect measuring test charts and objects of observation, located in the field of vision of the system. After that, the mixture of aerosols was evenly distributed in the entire BAC by ventilators during the course of 30 minutes.

In the fig. 8, 9 there are video frames of the AP TMS depending on the modes of performance and level of transparency of the propagation atmosphere.

During the experimental researches of the model of the AP TMS in the BAC, for testing the results of the simulation of the active vision area, the durations of illumination pulse and the IIT strobing pulse at constant delay of strobing were controlled.

The fig. 10 shows the frames of the AP TMS in the conditions of dense fog. The object of the observation was test chart (marked as a rectangular) placed at a distance of 21 metres (strobing delay of the IIT – 140 nanoseconds) with the strobing pulse delay of the IIT of 120 nanoseconds.

As it is seen from the fig. 10, the contrast of the image of the observed object, obtained at equal durations of the illumination and strobing pulses of the image intensifier tube, is significantly decreased due to impact of the backscatter interference, and the objects having the maximum brightness in the frame are located at a distance of 15 metres. On the contrary, the image of the observed object, obtained at a duration of the illumination pulse of 30 nanoseconds, has the maximum brightness in the frame and is distinctively more contrasting, which, on the whole, confirms the results of the simulation of the active vision area of the AP TMS.

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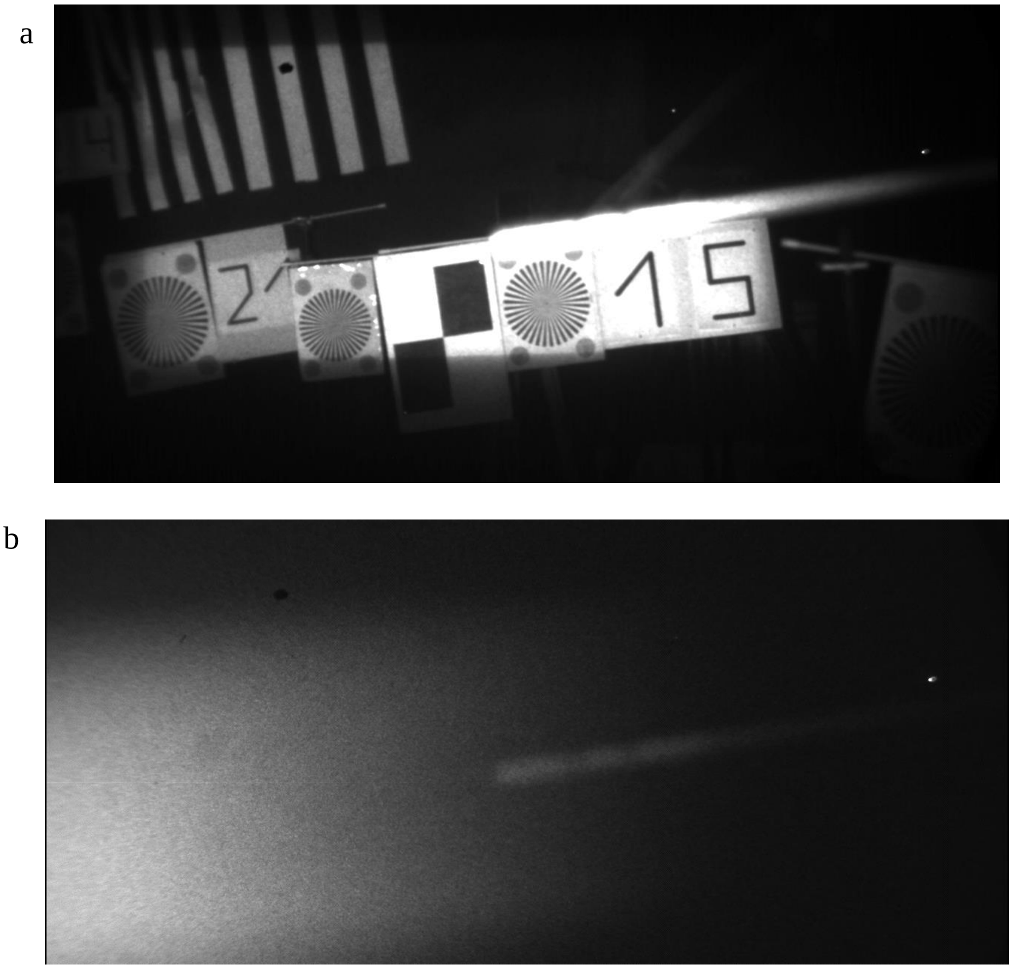

Fig. 8. Active uninterrupted mode of the AP TMS:
a) normal transparency of the propagation atmosphere; b) dense fog

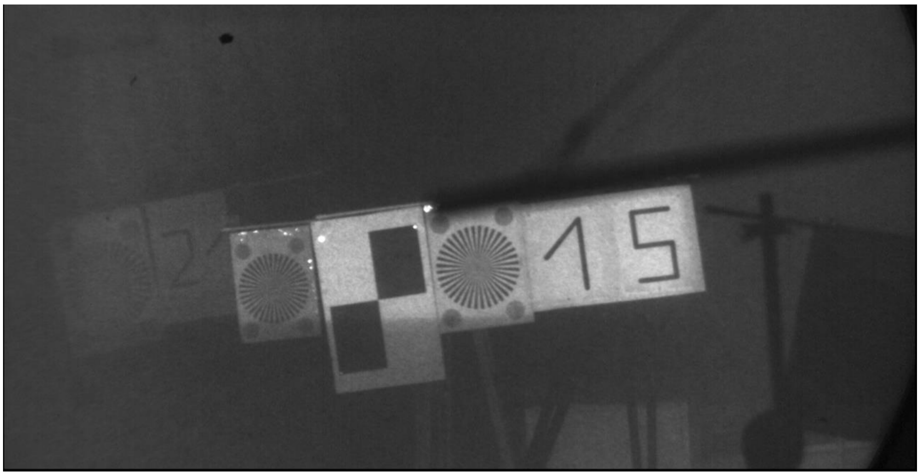

Fig. 9. Active pulse mode of the AP TMS, dense fog

a b

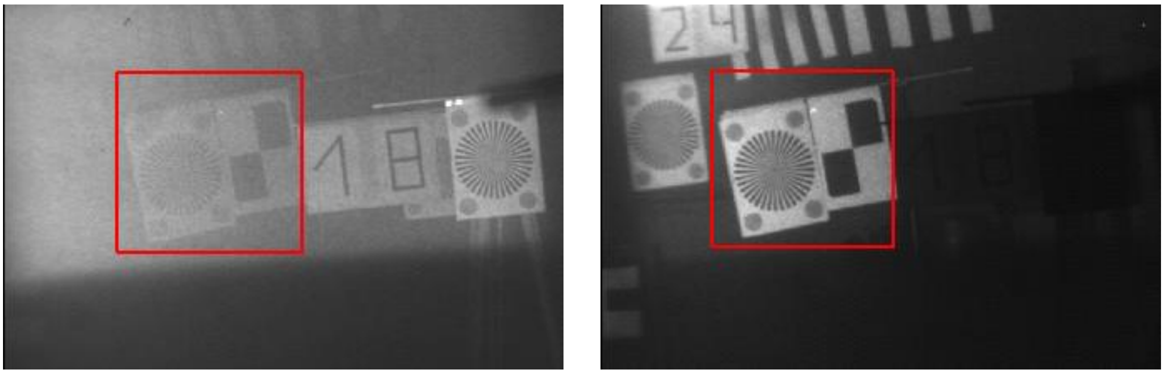

Fig. 10. The image of the object of observation:
a) duration of the illumination pulse – 120 nanoseconds,
b) duration of the illumination pulse – 30 nanoseconds

Shows the results of measuring the digital contrast of the object of observation depending upon duration of the illumination at constant duration of the strobing pulse of the IIT (120 nanoseconds) and strobing delay (140 nanoseconds). Duration of the illumination pulse is 120, level of contrast of the object observed is 97, 60 nanoseconds – 193, 30 nanoseconds – 230.

Conclusions

As a result of the researches, the models of the active vision areas were obtained, taking into account the attenuation of the optical radiation proportionately to the square of the distance and its quenching in the propagation atmosphere. It has been found out that if the durations of the illumination and strobing pulses of the image intensifier tube are equal, then in the conditions of low transparency of the propagation atmosphere, the form of the active vision area significantly distorts. The area of the maximum energy of the zone is shifted from the centre of the zone to its initial part, which leads to increase of the residual backscatter interference and, consequently, to decrease of the contrast of the image of the observed object. The decrease of the illumination pulse duration relatively to the duration of the strobing pulse of the IIT leads to increase of steepness of the leading edge of the active vision area and concentration of the maximum of energy in the point, corresponding to the temporary strobing delay of the IIT. High steepness of the leading edge of the active vision area enables efficient eliminating the backscatter interference, and the maximum energy in the point which corresponds to the temporary strobing delay of the IIT, increases accuracy of determination of the distance to the objects under observation. The results of simulation have been confirmed by experimental researches of the model of the AP TMS, which enables concluding that making efficient systems of navigation of transport modes in heavy weather conditions with the use of the AP TMS is feasible.

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References	Библиографический список
1. Mishchenko NI, Pustynsky IN, Kapustin VV. *Dokladi Tomskogo gosudarstvennogo universiteta system upravlenia i radioelektroniki*. 2016;19(3):42–46. (In Russ.)	1. Мищенко Н.И., Пустынский И.Н., Капустин В.В. Методы и средства повышения эффективности активно-им-пульсных телевизионно-вычислительных систем мониторинга и обеспечения безопасности объектов // Докл. Томск. гос. ун-та систем управления и радиоэлектроники. – 2016. – Т. 19, № 3. – С. 42–46.
2. Belov VV, Matviyenko GG, Pack RYu, Shiyanov DV, Kirpichenko YuR, Kuryachy MI, Pustynsky IN, Shurygin YuA. *Datchiki i sistemy*. 2012;3:25–30. (In Russ.)	2. Белов В.В. и др. Активные ТВ-системы видения с селекцией фонов рассеяния // Датчики и системы. – 2012. – № 3. – С. 25–30.
3. Geykhman IL, Volkov VG. Bases of Improvement of Visibility in Difficult Conditions. Moscow, 1999. 286 p. (In Russ.)	3. Гейхман И.Л., Волков В.Г. Основы улучшения видимости в сложных условиях. – М.: Недра-Бизнесцентр, 1999. – 286 с.
4. Kirpichenko YuR. *Doklady Tomskogo Gosudarstvennogo Universiteta System Upravleniia i Radioelektroniki*. 2012;2:150–154. (In Russ.)	4. Кирпиченко Ю.Р. Минимизация искажений в процессе преобразования изображения с экрана ЭОП в видеосигнал // Электронные средства и системы управления. – 2012. – № 2. – С. 150–154.
5. Buzuk VV, Vergiles SA, Gusachenko AV. *Vestnik SGGA*. 2002;7:152–156. (In Russ.)	5. Бузук В.В., Вергилес С.А., Гусаченко А.В. и др. Особенности построения оптических систем низкоуровневых телевизионных камер // Вестн. СГГА, 2002. – Вып. 7. – С. 152–156.
6. Kirpichenko YuR, Kuryachy MI, Pustynsky IN. *Doklady Tomskogo Gosudarstvennogo Universiteta System Upravleniia i Radioelektroniki*. 2012;2(26):105–110. (In Russ.)	6. Кирпиченко Ю.Р., Курячий М.И., Пустынский И.Н. Видеоинформационные системы наблюдения и контроля при сложных условиях видимости // Докл. ТУСУР. – 2012. – № 2 (26). – Ч. 1. – С. 105–110.
7. Volkov VG. *Poluprovodnikovaiia svetotekhnika*. 2012;1:45–50. (In Russ.)	7. Волков В.Г. Лазерные полупроводниковые излучатели для приборов ночного видения // Полупроводниковая светотехника. – 2012. – № 1. – С. 45–50.
8. Kapustin VV, Movchan AK, Kuryachiy MI. Vision Area Parameters Analysis for Active-Pulse Television-Computing Systems. Int. Siberian Conf. on Control and Communications (SIBCON). 2017. Pp. 1–4.	8. Kapustin V.V., Movchan A.K., Kuryachiy M.I. Vision area parameters analysis for active-pulse television-computing systems // Int. Siberian Conf. Control and Communications (SIBCON), 2017. – P. 1–4.

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9. Wang X, Zhou Y, Fan S, Liu Y, Liu H. *Echo Broadening Effect in Range-Gated Active Imaging Technique. Proc. of SPIE.* 2009, vol. 7382 738211-9, pp. 1–9. Available from: https://www.spiedigitallibrary.org/conference-proceedings-of-spie / 7382/1/Echo-broadening-effect-in-the-range-gated-active-imaging-technique / 10.1117/12.836025.pdf (cited 2017Dec 12).

9. Wang X., Zhou Ya., Fan S., Liu Yu., Liu H. Echo Broadening Effect in Range-Gated Active Imaging Technique. Proc. of SPIE, 2009. – Vol. 7382 738211–8. – P. 1–9. – URL: https://www.spiedigitallibrary.org/conference-proceedings-of-spie/7382/1/Echo-broadening-effect-in-the-range-gated-active-imaging-technique/10.1117/12.836025.pdf (12.12.2017).

10. Andreyev YuM, Voyevodin VG, Geyko PP, Gorobets VA, Kabanov MV. Lidar Systems and their Optical Electronic Elements. Tomsk, 2004. 526 p. (In Russ.)

10. Андреев Ю.М. и др. Лидарные системы и их оптико-электронные элементы. – Томск: Ин-т оптики атмосферы СО РАН, 2004. – 526 с.

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