Запропоновані структурні та методологічні рішення, мінімізація кількості оптичних каналів дають можливість відновити проміжні значення і виключити недоліки багатоканального спектрометра як ускладнення структуру і зниження достовірності результатів вимірювань

Ключові слова: спектрометр, мінімізація, рідкий кристал, екологічний моніторинг

Предложены структурные и методологические решения, минимизация количества оптических каналов дают возможность восстановить промежуточные значения и исключить недостатки многоканального спектрометра, такие как усложнение структуры и снижение достоверности результатов измерений

Ключевые слова: спектрометр, минимизация, жидкий кристалл, экологический мониторинг

The proposed structural and methodological solutions, minimization of the number of optical channels make it possible to restore intermediate values and to eliminate shortcomings of multi-channel spectrometer, such as the structure and complexity reduction in reliability of measurement results

Keywords: spectrometer, minimization, liquid crystal, ecological monitoring

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BOARD SPECTROMETR OF GROUND-BASED OBJECTS FOR ECOLOGICAL STATE OF MONITORING SYSTEM

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1.Introduction

At present time one of the global world problems is unsatisfied ecological state of natural environment (NE). Even in the developed countries the problem is not fully solved, we do not to mention the other countries, where there are a lot of regions which do not meet the modern norms of the environmental safety. A lot of hazardous substances created by the industrial domestic sources and all types of transport devices, etc. are injected into the atmosphere, onto the ground and water surfaces. One of the basic methods of NE ecological state monitoring is the method of the ground-based objects remote sounding from the pilot and pilotless aircrafts. At present time the remote sounding undersatellite systems (RSUS) using fields extension and their metrological and exploitation requirements increase are observed. These methods allow to carry out the NE monitoring and to discover anthropogenic pollutions.

An important device mounted on the board of aircraft is the multi-channel spectrometer (MCS) that allows to determine the spectral luminance of the groundbased objects in visible range of spectrum [1].

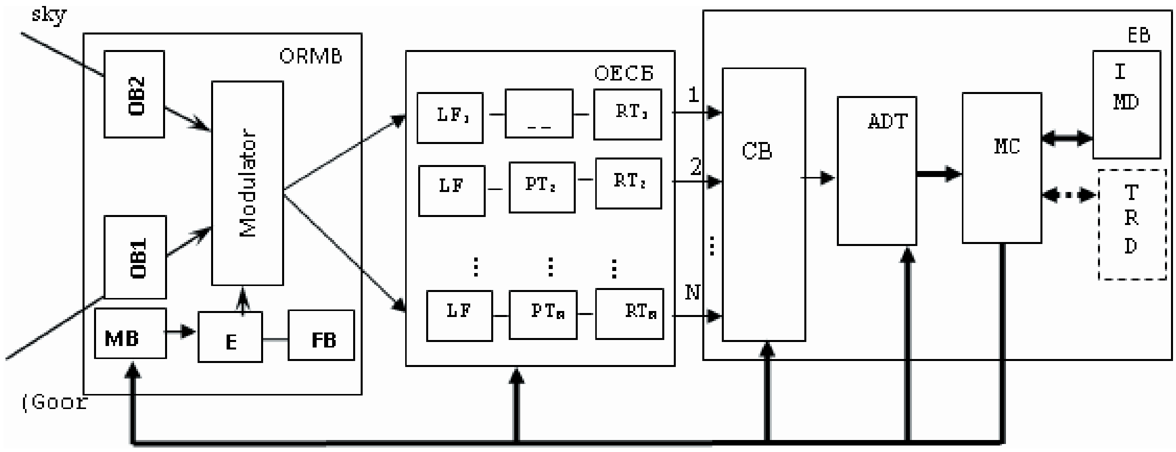
During the investigation of ground based objects (GO) the measuring complex consists of board and ground parts. The board part carries out measurement and initial processing. The complete processing of measurement results and classification of investigated objects are carried out in the ground-based part of the complex-ground center.

Multi-channel board spectrometric complex consists of optic receiver and modulator block (ORMB), optic electron converter block (OECB) and electron block (EB) (fig. 1) [1, 2].

To characterize investigation object ORMB provides transmission of light rays received from various sources by optic block 1 (OB1) and optic block 2 (OB2) to OECB by mechanical modulator in corresponding regimes o/+f the complex.

Mechanical modulator is regulated by (MB) management block, feed block (FB) and engine (E).

Each channel of OECB consists of light filter (LF), photo converter (PT) and rating converter. In this block received polychromatic RP light flux having filter is converted to monochromatic flux in the narrow ranges corresponding to N number of wave lengths, then these electric signals convert to the electric number by PC and having been strengthened, it is sent to analogue digital converter (ADC) by commutation block placed inside of electron block (EB).



Fiq. 1. N-channel spectrometrical complex

Besides these two blocks there are microcontroller (MC), transmission and receiving device (TRD), internal memory device (IMD) and indication device inside of EC. Usually in the existing systems in order to get truthful information about the investigated object, they try to divide measuring range to the narrower sub ranges.

Depending on the purpose and aim of the board MCS, the required number of channels (N) is selected (as usual, the number is from 12 to 240, sometimes even more).

Remote sounding method of natural ground objects and all investigation methods are based on the analysis of spectral characteristics of ground surface in various spectrum fields.

The characteristic feature of such analysis is the greatness of data volume and it causes definite difficulties during organization of information transmission to the surface of spectrometric complex and its processing on the ground surface. At the same time during the solving of definite problem the greater part of useful information, as a rule, is obtained from a little measurement results in optimal spectral intervals. That's why one of the ways to increase efficiency of remote sounding is special sequence of spectral zones. Such an approach requires rather reliable grounding for choice of working range of the spectrum. Necessity of increase of expenditure spent on transmission of data to the ground surface and processing means makes the processing of board spectrometric information actual.

If we consider the above-mentioned, the choice of minimum working spectral ranges is important for reducing the surplus from a big volume of information obtained from remote sounding. But at the same time obtaining of full information about studied object must be provided.

n*m number of measuring sets (n – number of channels, m – response ratio of measurements each concerning one channel). We mustn't always expect increase of accuracy during the increase of measuring. We can conclude that too many channel numbers and brilliance level in each spectral range do not make better the classification accuracy. Method of primary components can be used for introduction of data with less information loss in very small measured space [1]. This method is used for exact introduction of data majority and determination of minimum measurement number. Increase of coefficient of spectral luminance (65L) values for spectrum coding can cause not only increase of classification accuracy but also its reduce.

Choice of methodology of ranges' optimal unity based on entropy calculation analyses was suggested by me in the condition of observing of spectral contrasts of natural objects in several sources [1, 2, 7]. The first stage of such methodology is the choice of rather reliable initial data considering the influence of intermediate layer of the atmosphere about the natural objects. For reducing obstacles very narrow spectrum ranges are chosen. For 0,4-0,9 mkm layer 0,54-0,56,0,-66-0,69mkm and 0,72-0,82 mkm ranges are chosen.

Choice of spectral ranges considered for investigation of natural objects becomes complicated because of natural variation of lightning condition, sounding, reflection coefficient and albedo of spectral characteristics of these objects.

It has been known that use of three zones of the spectrum is enough for remote investigation of agricultural plants (corresponding to the maximum reflection in the visible range of green plants λ=550 nm, the second absorption stripe of chordophone λ=670 nm and maximum reflection of green plants in near infrared part of the spectrum λ=800 nm). It has been shown that the value of CSL in these zones and their linear combination (for example, vegetation index I=(CSL 800-SR 670)/(CSL 800+CSL 670) are considered as high informative decoding characteristics in remote investigation of many objects.

That's according to the investigation of several sources we can conclude that in multi-channel spectrometers not all the measuring results of these channels are of informative character, also growth is substituted by stability after definite number of the channels. This causes obtaining of surplus information and doesn't allow to solve appeared problems.

At the same time during multi-channel measurement if we pay attention to the parallel connection of channels (to reduce the whole error), the necessity of carrying out repeated measurements and flight speed of flying device on the measurement system board, we can see that truthfulness of the measurement results will be reduced because of the displacement of obtained results according to the time and place (depending on flight height of sight angle and carrier will cause not required crossing of sight areas but their displacement) and because of non-correspondence of the investigation object to the "point" of measurement:

For example, in order to reduce occasional error in each channel m-layer (m=10) measurement is carried out and following calculations are done according to the average value. Then in common measurement period of system tract will have the following:

$$T_s = t_{OB} + t_M + \\ + n\,m(t_{lf} + t_{pt} + t_{Nt} + t_{CB} + t_{ADC} + t_{MC}) + t_{IMD} + t_{TRD}, \quad (1)$$

(in concrete case

$$T_s = t_{OB} + t_M + \\ + 240(t_{lf} + t_{pt} + t_{Nt} + t_{CB} + t_{ADC} + t_{MC}) + t_{IMD} + t_{TRD},$$

here t_{OB}, t_M, t_{lf}, t_{pt}, t_{Nt}, t_{CB}, t_{ADT}, t_{MC}, t_{IMD}, t_{TRD} are correspondingly overdue or transforming periods, but t_{iE} is the time spent on initial treatment [6].

As the optical-physical features of the ground-based objects, as their luminance and color characteristics are enough reflected with coefficient of spectral luminance (CSL) simplified form of that will be described as following [1]:

$$CSL = F_{SS}\ (R, L, H, x, y, z, \lambda, t) \pm \varepsilon), \quad (2)$$

here R is generalized parameter of external factors influence; L is the input parameter of system; H is generalized parameter of inner parameter of the system and it reflects technical parameters depending on channels number, block data in the system and measurement method; ε is the full error of measurement connected with external factors and usually ε >0.

$$CSL = f(L, H, x, y, z, \lambda, t_0) \pm \varepsilon)$$

$$\text{or}\,|F_{SS}\ (R, L, H, x, y, z, \lambda, t) \pm \varepsilon) - f\,(\ L, H, x, y, z, \lambda, t_0)| < \quad (3)$$

here F_{ss} is the measured value of the investigated objects considering external factors of CSL; f is the real value of that object in the ideal condition of CSL.

According to the measurement results of spectrometric measurement system light flux intensity luminance reflected from ground-based objects, space and standard surface CSL it is possible to calculate spectral reflection ability (SRA):

$$CSL(\lambda) = \frac{\mathbf{L}_{ob}(\lambda)}{L_{st}(\lambda)}, \\ SRA_{ob}(\lambda) = \frac{L_{ob}(\lambda)}{L_s(\lambda)}, \quad (4) \\ SRA_{st}(\lambda) = \frac{L_{st}(\lambda)}{L_s(\lambda)},$$

Here $L_{ob}(\lambda)$, $L_{st}(\lambda)$, $L_s(\lambda)$ are spectral luminance's reflected from the object, standard surface and space.

Measuring of the dark current of measurement tract and considering its average value during the measurement in other regimes can cause to some reduce of full error influencing the results. This time measurement results are calculated not by expression (4), but by the following one, and these calculations condition the initial treatment period t_{iE} [6].

$$SBC_{ob}(\lambda_i) = \frac{L_{obav}(\lambda_i) - L_{dcav}}{L_{stav}(\lambda_i) - L_{dcav}}; \quad SRA_{ob}(\lambda_i) = \frac{L_{obav}(\lambda_i) - L_{dcav}}{L_{sav}(\lambda_i) - L_{dcav}};$$

$$SRA_{st}(\lambda_i) = \frac{L_{stav}(\lambda_i) - L_{dcav}}{L_{sav}(\lambda_i) - L_{dcav}}, \quad (i = \overline{1,n}) \quad (5)$$

Here $L_{obav}(\lambda_i)$, $L_{sav}(\lambda_i)$, $L_{stav}\ (\lambda_i)$ and L_{dcav} are correspondingly average values (spectral luminance's) of the measurement results of m=10 layer according to object, space, standard dark currents in λ_i -wave length.

At the same time an electronic part of MCS, that uses the modern element base and high technologies of integral microelectronics and microprocessor engineering, allows easily to minimize weight-size parameters and energy consumption and to provide function economy and reliability. Therefore minimization of OC number of the board MCS allows significantly to decrease the disadvantages shown above.

Two new methods of minimization of board spectrometers OC have been developed by the authors and the patents have been granted [2, 3]. Minimization of OC number reduces to three channels of the basic coolers of visible range of spectrum R (red), G (green), B (blue), realized with the help of three light filters [2].

Each of basic R, G, B has the determined length of wave and they are inter-independent, i.e. none of them can be received by the displacement of two others. Any other colors can be received by the displacement (synthesis) of these three colors R, G, B, taken in the corresponding proportions. The result of such displacement can give a large variety of other color's and their tints. By the mathematical calculations it is possible to determine the results of the shown displacement. Therefore multi-channel synthesis is provided by programming way on the board computer. Thus, instead of N measurements for simple MCS, the offered method allows to fulfill only three channels and calculate a coefficient value spectral luminance (CSL).

The second approach to the solving of the task is based on methodological and structural choice. This time liquid-crystal based block, which allows performing the function of light filters and electron control of the working regimes of the systems is used. As a result based on "guest-host" efficiency wave length flow filtering corresponding to two color's in one channel is carried out and it allows getting some intermediate color's by the introduced method or direct measurement results. Solving of the set up task by device and program means allows to correct the results obtained by calculation and guarantees accuracy of the measurement results. All these play a significant role in true decision making in classification of investigated objects.

At this more effective solution is provided not by usage of any hardware, but application of software [3].

2. Onboard spectrometer with three optical channels

Remote methods of ground objects (GO) research are based on various onboard devices, optoelectronic blocks (OEB) which contain a number of components of various physical nature and action principle. Therefore each of them is characterized by set of various parameters and transformation functions. The increase of OEB components number considerably complicates their design and negatively influences final results.

Because the OEB is on the board flying device, the special attention is paid to its high speed, vibration stability, and also small weight-size characteristics and energy consumption.

Therefore the problem of development of small-size OEB for the control of physical parameters of GO intended for flying devices represents scientific and practical interest. Parameters of the electromagnetic waves reflected from the investigated objects and standard surfaces are measured in the systems of remote sounding.

Spectral reflective properties are the basic attributes of GO which can be expressed through a CSL. CSL is defined by measured values of color intensity (luminance) and contains data about intensity and color characteristics of the investigated objects. It is sensitive to spatial changes of these characteristics and influences of external factors.

In many spectrometers decomposition of a spectrum with the help of narrow-band (a pass band 5-10 microns) interference optical filters are used. However, to receive the spectral characteristic with high reliability rather a large number of optical filters are required. As a result, hardware expenses of spectrometer increase and speed decreases.

Therefore adequate reception of spectral characteristics with the help of minimal number of channels by measured values completely reflecting a state of researched object is an actual problem of spectrometric measurements.

At spectrometric measurements in a visible range of spectrum according to the received data on intensity of radiations from the sky, object and standard, coordinates of color are defined by calculations. Thus color is considered as received one in addition to monochromatic spectral color's set.

Any color of object Fob with complex distribution of radiation is the sum of monochromatic components $\Delta F(\lambda_i)$, in other words [4]:

$$F = \sum_{i=1}^{n} \Delta F(\lambda_i). \quad (6)$$

Components $\Delta F(\lambda_i)$, can be received under the first law of displacement with the help of three primary color's of visible range of spectrum (R, G, B):

$$\Delta F(\lambda_i) = r'(\lambda_i)R + g'(\lambda_i)G + b'(\lambda_i)B, \quad (7)$$

Where $r'(\lambda_i)$, $g'(\lambda_i)$, $b'(\lambda_i)$ are corresponding coordinates of color $\Delta F(\lambda_i)$. As it is known, in addition to color's their luminance is added, which can be expressed by the formula as following:

$$L = \sum_{i=1}^{n} \Delta L(\lambda_i), \quad (8)$$

Where $\Delta L(\lambda_i)$ – luminance of i-th component of color's with luminance L.

For the object and standard the formula will be as:

$$L_{ob} = \sum_{i=1}^{n} \Delta L_{ob}(\lambda_i), \; L_{st} = \sum_{i=1}^{n} \Delta L_{st}(\lambda_i) \quad (9)$$

where L_{ob}, L_{st} – spectral luminance values of the object and standard accordingly:

$\Delta L_{ob}(\lambda_i)$ and $\Delta L_{st}(\lambda_i)$, spectral luminance of i-th component of the object and standard

Spectral luminance L_{ob} and L_{st} – can be represented by the following formula:

$$L_{ob} = L_{Rob} + L_{Gob} + L_{Bob};$$

$$L_{st} = L_{Rst} + L_{Gst} + L_{Bst}; \quad (10)$$

or $L_{ob} = r'_{ob}(\lambda_i)L_{(R)ob} + g'_{ob}(\lambda_i)L_{(G)ob} + b'_{ob}(\lambda_i)L_{(B)ob}$;

$$L_{st} = r'_{st}(\lambda_i)L_{(R)st} + g'_{st}(\lambda_i)L_{(G)st} + b'_{st}(\lambda_i)L_{(B)st}, \quad (11)$$

where $r'_{ob}(\lambda_i), g'_{ob}(\lambda_i), b'_{ob}(\lambda_i)$ and $r'_{st}(\lambda_i), g'_{st}(\lambda_i), b'_{st}(\lambda_i)$ coordinates of color and standard accordingly:

$L_{(R)ob}, L_{(G)ob}, L_{(B)ob}$ and $L_{(R)st}, L_{(G)st}, L_{(B)st}$ - spectral luminance of unit values of basic components of the object and standard. Last values of L_{ob} and L_{st} let to determine the CSL:

$$CSL_\lambda = L_{ob}\Delta\lambda / L_{st}. \quad (12)$$

The three-channel spectrometer realizing above-stated method, meets the basic requirements showed in onboard devices intended for small-size pilot and pilotless flying devices.

The OEB of three-channel spectrometer as against existing similar devices instead of N optical filters and photo-electric converters contains only three optical filters, passing three primary color's of visible range of spectrum R, G, B

$$CSL_{\lambda i} = F_{ss}\left[L_{ob}(\lambda_i), L_{st}(\lambda_i), \overline{R_{ob}}(\lambda_i), \overline{G_{ob}}(\lambda_i), \overline{B_{ob}}(\lambda_i), \overline{R_{st}}(\lambda_i), \overline{G_{st}}(\lambda_i), \overline{B_{st}}(\lambda_i)\right].$$

It is considered here that $L_{ob(et)}$ is found on the basis of measurement results L_{Rob}, L_{Gob}, L_{Bob}, L_{Rst}, L_{Gst}, L_{Bst}, that's $L_{ob(st)} = L_{Rob(st)} + L_{Gob(st)} + L_{Bob(et)}$, $L_{ob}(\lambda_i)$ and $L_{st}(\lambda_1)$ are calculated by both measurement results and accepted special coefficients [2]:

$$\overline{R}_{ob}(\lambda_i) = \frac{\bar{r}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda}{\sum_1^n \bar{r}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda};$$

$$\overline{G}_{ob}(\lambda_i) = \frac{\bar{g}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda}{\sum_1^n \bar{g}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda};$$

$$\overline{B}_{ob}(\lambda_i) = \frac{\bar{b}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda}{\sum_1^n \bar{b}(\lambda_i)I(\lambda_i)\rho_{ob}(\lambda_i)\Delta\lambda}; \quad (13)$$

$$SBC_{\lambda_i} = \frac{\overline{R}_{ob}(\lambda_i)L_{Rob} + \overline{G}_{ob}(\lambda_i)L_{Gob} + \overline{B}_{ob}(\lambda_i)L_{Bob}}{\overline{R}_{st}(\lambda_i)L_{Rst} + \overline{G}_{ob}(\lambda_i)L_{Gst} + \overline{B}_{st}(\lambda_i)L_{Bst}}, \quad (14)$$

where ($\bar{r} = (\lambda_i)$) is coordinate of the color corresponding to i wave length and values in the sources are given as a table form, $I(\lambda_i)$ is the organizer light flow intensity from the space; $\rho_{ob}(\lambda_i)$ is reflecting coefficient of the object in i wave length.

It is known from the changing character of optical-physical parameters of ground based objects in the visible range that during the investigation of these objects measured quantities have constant average value and very small incline in the repeated measurements. In these systems occasional processes can be shown as a stationary and occasional (ergodic) processes. In both cases it will provide minimization of the difference of the errors got during restoring of intermediate results in the measurement range. During carrying out measurements only in three channels tenfold measurement has been done and treatment and storage in memory have been realized during initial treatment according to expressions (5). In this case the expression (1) will be received as following:

$$T_{s3} = t_{OB} + t_M + n \cdot m(t_{lf} + t_{pt} + t_{Nt} + t_{MC}) + t_{IMD3} + t_{TRD},$$

(in concrete case

$$T_{s3} = t_{OB} + t_M + 30(t_{lf} + t_{pt} + t_{Nt} + t_{MC}) + t_{IMD3} + t_{TRD} \quad . (15)$$

If we consider t_{IMD3} and t_{TRD} correspondingly are the time spent on writing of measurement results on three channels to IMD and initial treatment, then t_{IMD3} is several times smaller than t_{IMD} and t_{iE} then t_{iE} and here $t_{CB} + t_{ADT}$ doesn't take part, at this time from the comparison of expressions (1) and (15) it is seen that T_{s3} is several times smaller than T_s.

This time three channel OECB of the spectrometric system will have structure scheme shown in Fig. 2.

As it is seen from the figure, OECB being unlike OECB in fig. 1 will have only three measurement channels instead of N measurement channels.

Thus introduced spectrometric system allows realizing measurement with high quickness.

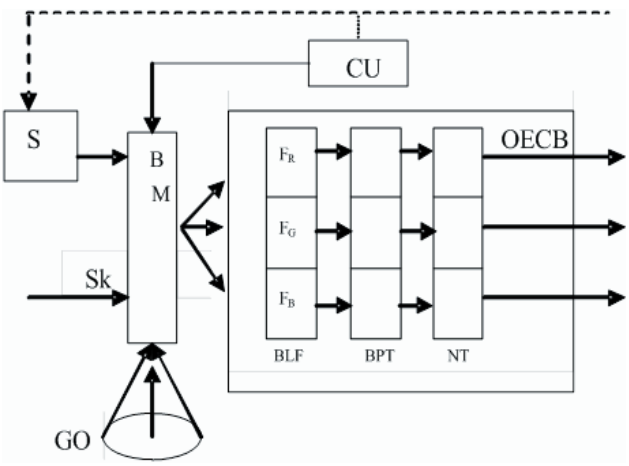


Fig 2. The block diagram of three-channel OEB

In its turn it helps to renew sliding according to time and place causing reduce of measurement results accuracy, corresponding reduce stored information volume and as a result to use board memory more effectively that plays significant role during investigation of ground-based objects and also investigation of environment by the pilotless plane.

3. Board spectrometric complex with liquid crystalic deflector and filter

In the introduced system in the optic electron converter block liquid crystalic filters and deflectors which have more effective spectral characteristics as well as the signal/noise comparison, as opposed to interference light filters, are used. Half band-width of these filters are controlled. Liquid crystalic deflectors, as opposed to the electromechanical modulators, carry out electronic control of choice of the system's operation regime [6]. Thus such devices allow reducing measurement-weight parameters of OES and its energy consumption, to replace mechanical control by electronic control. But we must note that this period is based on application of "guest- host" efficiency (the host is liquid crystal and the guest is the imager according to one of basic color's), giving a signal frequency which corresponds to one of the basic color's. Then the liquid crystal has the corresponding color and allows light flow of the wave length of same color to pass (fig. 3).

At the same time by the application of two "guest-painters" in each channel instead one allows to get measurement result corresponding to two wave lengths. That's using three of double frequency liquid-crystalic filters; direct measurement result corresponding to six colors will be obtained.

For example, in the wave lengths corresponding to the color's received from the pairs of RGB color's in the visible range from the working range of the system or in the wave lengths considered as informative by the investigators.

As a result with three channels we can get measurement results corresponding directly to six color wave lengths instead of three ones.

Application of liquid-crystals as deflectors in the optic receiver and modulator block of the introduced spectrometric complex allows carrying out electronic control of working regimes of the complex according to the working program written in MKM that can remove the negative influences affected on the measurement results of the mechanical modulators.

The block diagram of three-channel liquid crystalic application of onboard spectrometer is shown on Fig 3.

Here: S – the standard, S_k – the sky, OWBM – the block of the optical wireless and radiations modulator, BLCF – the block of liquid crystalic filters LCF_P, $LCF_Э$, LCF3, BPC – the block of photo-electric converters, BNC – the block of normalizing converters, OCM – onboard computers module (which has inner K EC – the electronic commutator or ADC – the analogue-to-digital converter), MU – the memory unit, EM – an external memory, DIT – the device of information transfer to the center on ground, FB – feed block, KB1, KB2, KB3 – control blocks of LCD1, LCD2 and BLCF.

At the same time, a rational distribution of fulfilled functions between the hardware and software has a great meaning. Measurements made in modes "the object", "the standard", "the sky" and "the dark current" are periodically updated by program way. The software contains programs of

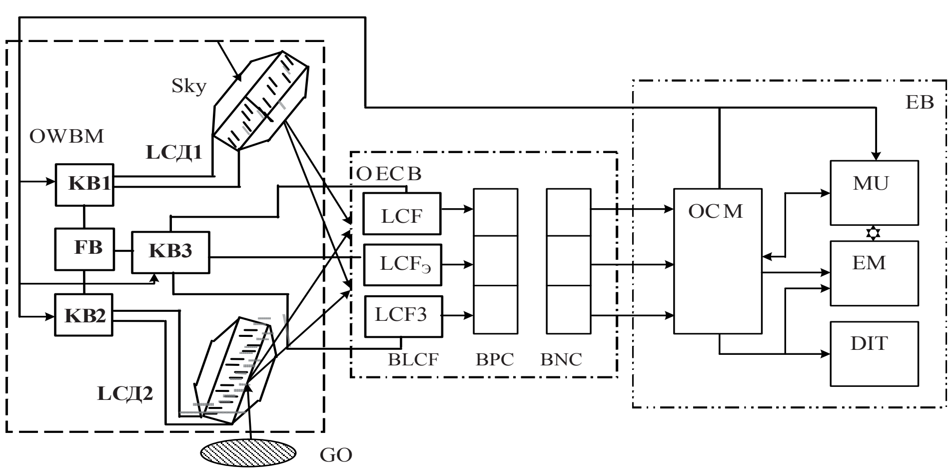


Fig. 3. The block diagram of three-channel onboard spectrometer

data acquisition, preliminary and full processing and record of end results to the external memory.

Liquid-crystalic deflectors LCD1 and LCD2 allow substituting mechanical control of system regimes introduced in figure 1 by electronic control [3]. It allows removing influence of mechanical modulator on measurement results.

During the use of liquid-crystalic filters instead of light filters in optical block, according to the working program written to MKM, definite frequency control corresponding to three primary color's gives tension from the power source to one of IB MKB. It must be mentioned that according to "guest-host" efficiency MKF-s are colored in conformity with 2 color's by the help of special paints.

Each of MKF filters separates out monochromatic ray having wave length corresponding to one of the primary colors or intermediate color and directs the received monochromatic ray to the photoreceiver.

Measurements can be organized according not to three, but six wave lengths in each structure set up in two frequency modifications of each MKF. It allows getting measurement results according to three primary color's both by indirect calculation and direct measurement and it makes possible to determine accuracy of the obtained data according to the introduced method.

It is seen from the structure scheme introduced in fig. 3, calculation results of equivalent (14) can be corrected to the experimental results carried out by two-colored variant. Considering corrected results in calculation of next measurement results the errors can be minimized.

For this: in the introduced structure scheme information according to intermediate color's (or in the informative zones) together with the primary colors of the investigated object is stored and data base is formed; data base concerning investigation object by equivalence (14); dependence between these two data bases is found (neuron model, genetic algorithms, classic solution and etc.).

4. Numerical and experimental comparison

Let's make up the distribution curve of CSL of ground-based wheat field on the basis of metering results of multichannel spectrometric system and offered structure and methodology, and analyze them comparatively. The goal is to obtain necessary results in the chosen informative ranges applying computer technologies in ground center theoretically according to the equations both with the special coefficients and experimental (metering) results and necessary to restore the intermediate colors. As it is noticed in the article let us choose standard surface. As a standard of communication, asphalt surface has been chosen. The reflection coefficient of this surface is known: $\rho_{as} = 0,07$ [4]. In [4] metering results of multichannel system and the CSL of wheat field on the basis of these results as well as its graphical distribution have been represented. As the experimental result of standard surface, the curve of CSL_{as} has been also represented here. Intensity of light flux from the space has been measured in "space" regime of $I_s(\lambda_i)$ ($I(\lambda_i)$ of equations (13) and (14)) and saved in the memory. For various wave lengths corresponding to R, G, B in the equations color coordinates ($\bar{r}(\lambda_i), \bar{g}(\lambda_i), \bar{b}(\lambda_i)$) have been taken from [4]. Consequently, metering results for object and standard in B(435.8), G(546.1) and R(700) nm wave lengths L_{Rob} , L_{Gob} , L_{Bob} and L_{Rst} , L_{Gst} , L_{Bst} are mentioned and saved in the memory. As three-channel system introduced in the article gives an opportunity to obtain metering results in more three intermediate color's, these results are input to memory (It should be mentioned that chosen intermediate colors are taken from sub ranges considered as informative). According to these data the value of ρ_{ob} is found.

According to initial data and metering results, calculations have been carried out by equations (13) – (14) and CSL results obtained by offered correction method have been compared with corresponding curve of CSL of wheat field represented in [8] (diagram 1). The comparison results are shown in the table 1. The number of intermediate values of λ selecting from the informative sections of the electromagnetic spectrum, where the data are recovered, can be increased on-demand of classification of the object.

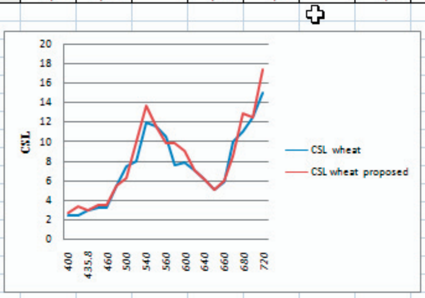
As it is seen from the table, the error is in permissible limit and its reduction can be provided by repeating the offered correction method. At the same time metering error can be reduced, considering average statistic values of the errors calculated on the basis of a prior measurement and stored in data base.

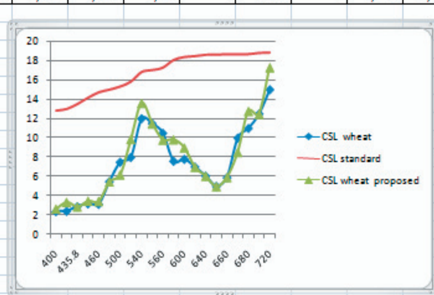
Table 1

Диаграмма 7

λ	400	420	435.8	440	460	480	500	520	540	546,1
CSL wheat	2,4	2,43	2,9	3,2	3,15	5,5	7,5	8	12	11,5
CSL standard	12,8	12,98	13,5	14,15	14,71	14,98	15,3	15,81	16,8	17,01
L sky	1,1664	3,5232	4,228225	4,7388	6,661	7,6712	8,1882	9,249	10,091	10,26555
CSL wheat proposed	2,688	3,3748	2,9	3,4957	3,477	5,5	6,211	9,89	13,62	11,5
absolute error	0,288	0,9448	0	0,2957	0,327	0	1,289	1,89	1,62	0

λ	560	580	600	620	640	650	660	675	680	700	720
CSL wheat	10,5	7,6	7,8	7	6,0739	5	5,9	10	11	12,5	15
CSL standard	17,26	18,05	18,357	18,45	18,59	18,61	18,64	18,65	18,66	18,78	18,82
L sky	10,4215	9,6628	9,2421	10,1478	9,9701	9,679	9,948	10,7406	10,9097	10,6144	12,6009
CSL wheat proposed	9,8137	9,8508	9,005	7	6,074	5	5,9511	8,5385	12,7894	12,5	17,3234
absolute error	0,6863	2,2508	1,205	0	1E-04	0	0,0511	1,4615	1,7894	0	2,3234





According to the fulfilled comparative analyses, we can mention that the offered structural and methodological solution of the system gives an opportunity to restore the intermediate results in the chosen sub ranges considered as informative and as a result to except the negative properties of the multi-channel system.

5. Conclusion

The great of the article is to obtain necessary results in the informative ranges chosen by the applications of computer technologies on the ground center theoretically according to the equalities using experimental (measurement) results and special coefficients important for restoring of intermediate colours. That is of a little part of the measurement results as direct measurement results, the other part as a calculation method and by application of computer technologies allows to solve technical problems causing errors in the classification. Specialists can use these results and modern information technologies in projecting and making remote sounding of ground based objects.

In the article two more structural model have been introduced to provide the accuracy of intermediate results obtained by calculation using computer technologies. Models allow to obtain chosen intermediate results by calculation method ($L_{c\lambda_i}$). And it allows to carry out automatic corrections by program way during restoring of intermediate results according to the introduced equality. And it not only proves the possibility of realization of the main idea but also server to the improvement of direct measurement results ($L_{m\lambda_i}$) is obtained theoretically (mathematical set up of the increase of the accuracy: $\| L_{c\lambda_i}$ - $L_{m\lambda_i} \|$ min).

In mathematical processing of the results application of up-to date information technologies allow both to get results quickly and to raise number of intermediate results in restoring of intermediate results.

In one of the structures constructed on two-frequency modification of each MKF-s, measurements can be made according to not three, but six wave lengths. It allows getting measurement results on the basis of three primary colors by calculation indirectly and by measurement directly and at the same time it allows to determine accuracy of received data according to the introduced method. Also measurement result in conformity with three primary colors and information measurement result in conformity with total light flux are obtained.

Considering these results in the equivalences introduced in (16) we can make corrections in measurement results. All these allow minimizing errors during the restore of intermediate results by calculation way (fig. 4).

Here A_p and P_r are correspondingly device program realizaton means; A-key, CB-comparison block; C and AMB are blocks of correction and automatic manaplments. As the measurement results concerning total light flux received by direct measurement are used directly in the equivalences of restoring of intermediate color's and considering statistic primary treatment of measurement results required in the existing structure to be the source of additional time and error, for comparison we can say that the introduced structure allows to work out primary treatment on board by minimum measurement channel.

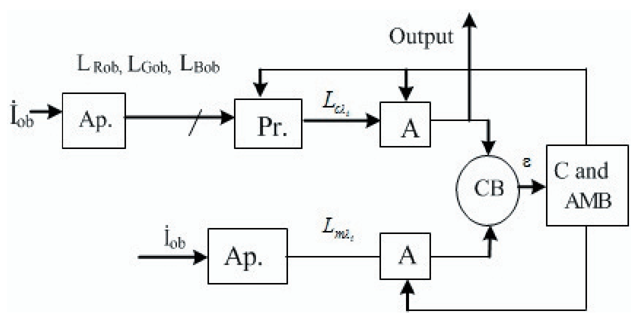


Fig. 4. Structural model of the correction of calculation results

Together with the improvement of the shown parameter it allows systematically to use memory of the board system that means increase of the experiment period.

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