

## PRINCIPLE OF VALIDATION OF MULTILEVEL RGB COLORIMETRIC SYSTEMS OF REMOTE SENSING

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**Abstract.** *The possibility of development of two-level RGB colorimetric systems of remote sensing is analyzed. The principle of validation in multi-level RGB colorimetric systems taking into account the effect of metamerism is formulated.*

**Keywords:** colorimeter; metamerism; multilevel systems; reliability; validation.

### 1. Introduction

As it is marked in work [Colorimetry...], colorimetry is the science and technology used to quantify and describe physically the human color perception. It is similar to spectrophotometry, but is distinguished by its interest in reducing spectra to the physical correlates of color perception, most often the CIE 1931 XYZ color space tristimulus values and related quantities [Krivosheev, Kustarev 1990]. One of principal causes of the limited application of colorimetry in remote sensing is the effect of metamerism. According to the work [Metamerism...], in colorimetry, metamerism is the matching of apparent color of objects with different spectral power distributions. Colors that match this way are called metamers. The physical basis of metamerism infers that human eye contains only three colour receivers perceiving a cumulative energy of radiation in relatively wide band of wavelengths.

Following kinds of metamerism are known as follows:

– metamerism occurred because of distinctions in a light source. The essence of this effect is that the same object is perceived in different colours after the change of light source;

– metamerism occurred because of distinctions of geometrical parameters. The essence of this effect is that two samples are perceived as one-colour at a certain viewing angle, however after the change of viewing angle identity of colour perception of these two objects disappears;

– metamerism occurred because of observer. The essence of this effect is that the properties of colour vision of various observers differ that leads to discrepancy of colour recognition between different observers;

– metamerism occurred because of difference of a field of vision. The essence of this effect is that the properties of cone cells of eye retina change at

displacement from the centre to periphery that finally leads to the dependence of perceived colours from an angle of field of vision of an observer.

As it is underlined in work [Colour...] metamerism is a property of eyesight at which the light of various spectral structures may cause the sensation of same colour. In a narrow sense metamerism is a phenomenon when two painted samples of colour are perceived equally under one source of illumination, but lose similarity under other conditions of illumination.

### 2. Problem statement

Thus, metamerism is could be considered as one of the main causes that limit wide application of RGB colorimetric systems with distributed structure, in the form of spaced RGB colorimetric subsystems functioning in absolutely various conditions of illumination, geometrical parameters, transmission properties of medium and color-sensitive receivers.

Nevertheless, RGB colorimetric systems have quite obvious advantages as small volume of transferred information, possibility to take account of the consumer's individual properties etc. for using as system of remote sensing. At the same time, specificity of remote sensing is that the reliability of the received information should be confirmed by validation.

The specified requirement of classical structures of remote sensing systems leads to necessity of construction of two-level RGB colorimetric systems (Fig. 1).

### 3. Two-level RGB colorimetric system

Let's assume that high-level RGB colorimetric system is mounted onboard of aircraft (satellite, plane, high-altitude unmanned aerial vehicle- UAV, etc.) and low-level RGB colorimetric system is established on the mobile lift or low-altitude UAV or realized in the form of portable manual RGB radiometer.

Let's consider conditions of minimization of negative influence of metamerism on reliability of measurement results by means of two-level colorimetric systems.

Concerning remote sensing from above-stated four kinds of metamerism the most essential is metamerism that occurs because of distinctions in a light source. Other kinds of metamerism are could be easily counted. So, for example, metamerism occurred because of distinctions of geometrical parameters can be eliminated by choosing of identical view angles.

Metamerism emerged because of observer can be neutralised by means of the single-type observers.

Hereby the main kind of metamerism occurs in RGB colorimetric systems because of distinctions in a light source. Thus if assume that a light source for colorimetric measurements for both levels of RGB systems is Sun then the examined kind of metamerism can be formulated as metamerism occurred because of distinctions in transmission of media available between Sun and different levels of RGB systems. Arguing in a similar way for a case of absence of small gas components in atmosphere we can easily come to a conclusion that a principal cause of metamerism in two-level RGB systems is presence of an essential difference between optical thickness of media in distances ( $h_1$ ) between investigated object and RGB system of the first level and ( $h_2$ ) between investigated object and RGB system of the second level (Fig. 2).

Taking into account the above-stated difference in optical thickness on distances  $h_1$  and  $h_2$  we formulate a principle of construction two-level RGB measuring system. A total output signal of RGB system at absence of metamerism could be expressed as follows,

$$U_0 = \int_{\lambda_1}^{\lambda_2} E(\lambda)x(\lambda)d\lambda + \int_{\lambda_3}^{\lambda_4} E(\lambda)y(\lambda)d\lambda + \int_{\lambda_5}^{\lambda_6} E(\lambda)z(\lambda)d\lambda, \quad (1)$$

where  $E(\lambda)$  – intensity of input radiation of RGB system;

$x(\lambda), y(\lambda), z(\lambda)$  – «tristimulus» of function.

Let's write expression (1) for RGB system of first and second levels:

$$U_1 = \int_{\lambda_1}^{\lambda_2} E_1(\lambda)x(\lambda)d\lambda + \int_{\lambda_3}^{\lambda_4} E_1(\lambda)y(\lambda)d\lambda + \int_{\lambda_5}^{\lambda_6} E_1(\lambda)z(\lambda)d\lambda,$$

$$U_2 = \int_{\lambda_1}^{\lambda_2} E_2(\lambda)x(\lambda)d\lambda + \int_{\lambda_3}^{\lambda_4} E_2(\lambda)y(\lambda)d\lambda + \int_{\lambda_5}^{\lambda_6} E_2(\lambda)z(\lambda)d\lambda,$$

where  $E_1(\lambda)$  – intensity of input radiation of higher system;

$E_2(\lambda)$  – intensity of input radiation of lower system.

Let's indicate colour errors because of metamerism as  $\Delta R_1, \Delta G_1$  and  $\Delta B_1$  for first system and  $\Delta R_2, \Delta G_2$  and  $\Delta B_2$  for second system. Here we have:

$$U_1 = \left[ \int_{\lambda_1}^{\lambda_2} E_1(\lambda)x(\lambda)d\lambda - \Delta R_1 \right] k_1 + \left[ \int_{\lambda_3}^{\lambda_4} E_1(\lambda)y(\lambda)d\lambda - \Delta G_1 \right] k_2 + \left[ \int_{\lambda_5}^{\lambda_6} E_1(\lambda)z(\lambda)d\lambda - \Delta B_1 \right] k_3, \quad (2)$$

where  $k_1, k_2, k_3$  – input correction coefficients.

For RGB systems of second level we have

$$U_2 = \left[ \int_{\lambda_1}^{\lambda_2} E_2(\lambda)x(\lambda)d\lambda - \Delta R_2 \right] + \left[ \int_{\lambda_3}^{\lambda_4} E_2(\lambda)y(\lambda)d\lambda - \Delta G_2 \right] + \left[ \int_{\lambda_5}^{\lambda_6} E_2(\lambda)z(\lambda)d\lambda - \Delta B_2 \right]. \quad (3)$$

Let's suppose that validation of measurement results is realized by method of correlation. In this case coefficients  $k_1, k_2, k_3$  should be determined as follows

$$k_1 = \frac{\int_{\lambda_1}^{\lambda_2} E_2(\lambda)x(\lambda)d\lambda - \Delta R_2}{\int_{\lambda_1}^{\lambda_2} E_1(\lambda)x(\lambda)d\lambda - \Delta R_1};$$

$$k_2 = \frac{\int_{\lambda_3}^{\lambda_4} E_2(\lambda)y(\lambda)d\lambda - \Delta G_2}{\int_{\lambda_3}^{\lambda_4} E_1(\lambda)y(\lambda)d\lambda - \Delta G_1};$$

$$k_3 = \frac{\int_{\lambda_5}^{\lambda_6} E_2(\lambda)z(\lambda)d\lambda - \Delta B_2}{\int_{\lambda_5}^{\lambda_6} E_1(\lambda)z(\lambda)d\lambda - \Delta B_1};$$

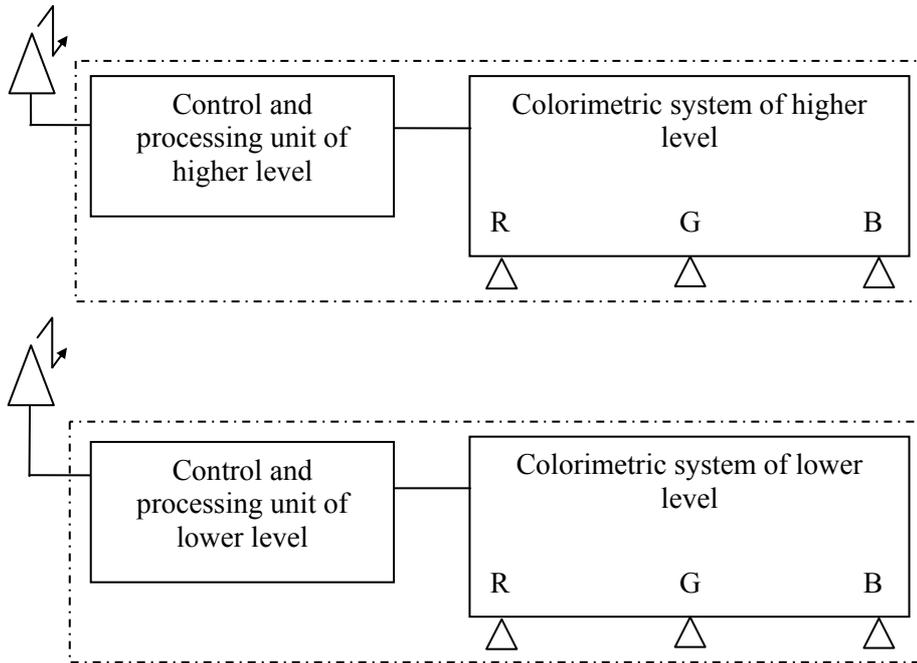


Fig. 1. Block-scheme of two-level RGB colorimetric system

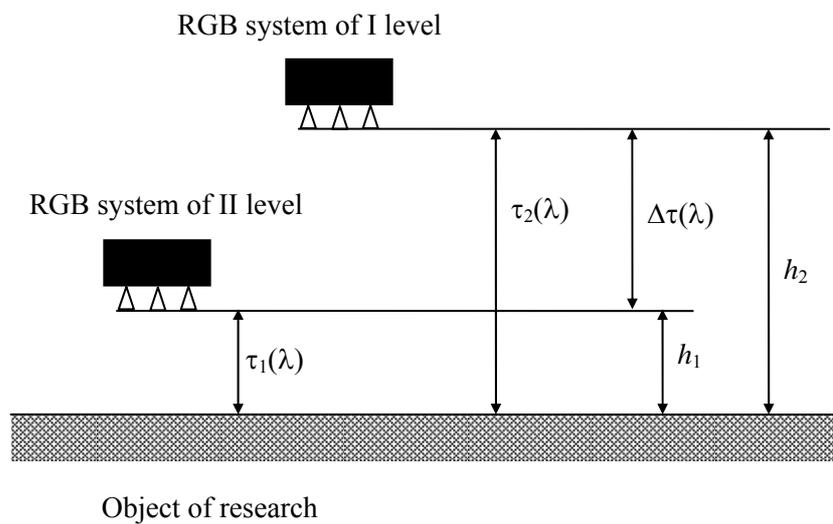


Fig. 2. Conditional graphic interpretation of distinctions of RGB systems' parameters of the first and second levels

$$k_3 = \frac{\int_{\lambda_5}^{\lambda_6} E_2(\lambda) x(\lambda) d\lambda - \Delta B_2}{\int_{\lambda_5}^{\lambda_6} E_1(\lambda) x(\lambda) d\lambda - \Delta B_1}$$

In case of absence of correction, i.e. at  $k_1 = k_2 = k_3 = 1$  it is possible to receive following conditions results' validation two-level RGB measurements from expression (2) and (3)

$$\left. \begin{aligned} \int_{\lambda_1}^{\lambda_2} [E_1(\lambda) - E_2(\lambda)] x(\lambda) d\lambda &= \Delta R_1 - \Delta R_2, \\ \int_{\lambda_3}^{\lambda_4} [E_1(\lambda) - E_2(\lambda)] y(\lambda) d\lambda &= \Delta G_1 - \Delta G_2, \\ \int_{\lambda_5}^{\lambda_6} [E_1(\lambda) - E_2(\lambda)] z(\lambda) d\lambda &= \Delta B_1 - \Delta B_2. \end{aligned} \right\} \quad (4)$$

In case of  $h_1 \rightarrow 0$ , i.e. at terrestrial functioning of RGB system of the second level the system (4) has the following appearance

$$\left. \begin{aligned} \int_{\lambda_1}^{\lambda_2} [E_1(\lambda) - E_2(\lambda)] x(\lambda) d\lambda &= \Delta R_1, \\ \int_{\lambda_3}^{\lambda_4} [E_1(\lambda) - E_2(\lambda)] y(\lambda) d\lambda &= \Delta G_1, \\ \int_{\lambda_5}^{\lambda_6} [E_2(\lambda) - E_0(\lambda)] z(\lambda) d\lambda &= \Delta B_1. \end{aligned} \right\} \quad (5)$$

The condition (5) shows a possibility in principle construction of two-level RGB colorimetric systems with authentic validation as it allows to estimate errors of playback of R, G, B colours, occurred because of metamerism.

#### 4. Conclusions

On the basis of the above-stated, the principle of two-level RGB colorimetric can be formulated as follows: Validation of RGB colorimetric data of high level RGB system can be carried out by supplementation with system of the second (terrestrial) level during organization of a correlation method of R, G, B components' verification. Meanwhile in the presence of the information on spectral radiation on inputs of RGB radiometers, values of the colour errors  $\Delta R, \Delta G, \Delta B$  occurring because of metamerism could be defined on maximization of output of correlation calculator which is carrying out validation of data.

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#### Бекірова Лала Рустам кизи. Принцип валідації багаторівневих RGB колориметричних систем дистанційного зондування

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Проаналізовано можливість побудови дворівневих RGB колориметричних систем дистанційного зондування. Сформульовано принцип валідації в багаторівневих RGB колориметричних системах з урахуванням ефекту метамерії.

**Ключові слова:** багаторівневі системи; валідація; достовірність; колориметр; метамерія.

#### Бекірова Лала Рустам кызы. Принцип валидации многоуровневых RGB колориметрических систем дистанционного зондирования

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Проанализирована возможность построения двухуровневых RGB колориметрических систем дистанционного зондирования. Сформулирован принцип валидации в многоуровневых RGB колориметрических системах с учетом эффекта метамерии.

**Ключевые слова:** валидация; достоверность; колориметр; метамерия; многоуровневые системы.

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