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New Approach to the Construction of Multimedia Test Signals

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ABSTRACT

The paper presents a new approach to the construction of test signal generators and test images, for colorimetric evaluation of the quality of functioning of multimedia channels of speech, military, and special purpose. The approach is to use adaptive properties of human vision to determine the number of colors for evaluation in certain adapting parameters. The main criterion for determining the number of colors is the color cut-off threshold. It is proposed to use color sorting capabilities to obtain frequency estimation parameters through a path guiding channel based on transition and ramp signal forms. Empirical expressions are given that allow a priori to estimate the magnitude of the change in the test signal and to model the possible magnitude of the effect on color rendering

Key words: image processing, quality assessment, multimedia tract, test signal, colorimetric evaluation

1. INTRODUCTION

This work is a continuation of research and improvement of signals designed to evaluate and control the quality of digital videotape multimedia systems. The paper [1] published a study of the active signal lines canceled in accordance with the present Recommendation ITU-R BT.801-1.

This paper studies the color band signals identified in Recommendation ITU-R BT.801-1 in order to eliminate the restrictions that existed in the text of this recommendation. Considering that color band signals are most commonly used in test signal sets, and given that they are implemented in widely used industry-standard measuring equipment (Tektronix [2], Rohde & Schwarz [3], DK - Technologies [4]), and that it is desirable to extend the use of color band signals to high definition systems (720 and 1080 active lines) with the ability to vary the encoding bit rate and 4:2:4 or 4:4:4 sampling format.

At the same time, given that the existing test signals, images and tables [5 -13] are composed of colors that correspond to the basic and additional to the basic saturated colors, it should be noted that this set is not enough for a complete evaluation. Therefore, the color set should be supplemented for colorimetric bone and unsaturated colors in the future.

In this work the appropriate analysis and proposed new interfaces adapted to a different set of parameters of colored bands that can be standardized to replace a set of signals that it was defined in Recommendation ITU-R BT.801. The proposed set of parameters is constructed to satisfy the requirement of its compatibility with the parameters of the current test signals.

2. AIM AND GOAL

The purpose is to develop a generator of adaptive test signals for evaluating the quality of color transmission through a multimedia path. Tasks to be solved:

- using the color perception model to get the coordinates of the color points that evenly fill the area of the transmitted colors;
- suggest variants of construction of test images;
- to determine the features of the test signals, their transient characteristics.

3. METHOD

To obtain the results of research, the methods of mathematical modeling, methods of finding extrema are used. This uses the color-coded model of color perception, which is the basis for colorimetric calculations. An expression is used to determine the coordinates of color and fulfilling the condition of its placement in space is the task of finding the lower extremum of functional dependence.

3.1 The general model of functioning

The test signals underlying the test images are constructed using the color coordinates of the image elements (*Yxy*), Fig. 1. Typically, the design uses calculation values that are oriented to specific studio viewing conditions. However, as shown in previous studies [14-16], quantitative and qualitative indicators are primarily influenced by the physical limitations of the system and interference in the communication channel. It is therefore proposed to increase t and set colors for evaluation and to determine its ability to color differentiation. From the above criteria of visibility, 5 CIE units were selected as those that are determined by the average observer - “not noticeable”.

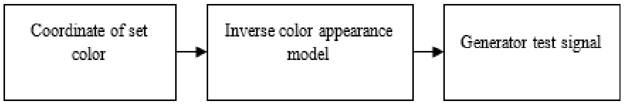

Figure 1: General model of operation of the test signal generator

The distance $\Delta E = 5$ of MCO units was chosen as the initial parameter, and using expression (1), an equidistant grid of color points was constructed in the coordinates of a uniform color space.

$$a'_{M_{(i+1)}} = \Delta E - \sqrt{\left(\Delta J'^2 + \Delta b'^2_M\right)} + a'_{M_i}, \quad (1)$$

where $a'_M \in (-80 : \Delta E : 80)$, $b'_M \in (-80 : \Delta E : 80)$, $J' \in (0 : \Delta E : 100)$ Thus - the coordinates of color a'_M, b'_M, and J' - the parameter of light. To construct the coordinate a'_M, the sum of $J' + b'_M$ is zero.

3.2 Using the color perception model

The grid of colors in the coordinates a'_M, b'_M is the starting point for building the test table. Given that the devices do not work with equally contrasting color coordinates, it is, therefore, necessary to translate to the conventional color coordinates. For this purpose the model used iCAM16 [18, 19], taking into account the properties color perceptual and can be used to account for adapting parameters. A block diagram of the model usage is presented in Fig. 2.

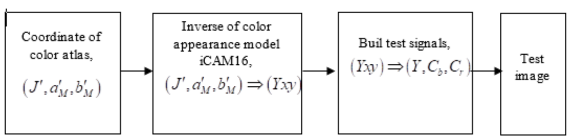

Figure 2: Using the color perception model

Converting raw data to input to the system is using code present in below. Service performed the list of code district at a programming environment Matlab [20].

```
        J = ( J_color ) / (1 + 100 * c1-
J_color * c1);
        M1 = (( aM_color ) ^ 2+ ( bM_color )
^ 2) ^. 5;
        M ( i ) = (exp (c2 * M1)-1) / c2;
        Jj ( i ) = J;
if (( aM_color )> 0)
    h1 = atan ( bM_color / aM_color );
elseif (( bM_color )> 0)
    h1 = atan ( bM_color / aM_color );
elseif ( bM_color == 0) & & ( aM_color == 0)
    h1 = 0;
else
   h1 = atan ( bM_color / aM_color ) -2 *
pi;
end
hr = h1 * (180 / pi);
if    ( aM_color > = 0) && ( bM_color > =
0); h ( i ) = hr ;
elseif ( aM_color < 0) & & ( bM_color > 0);
h ( i ) = hr-180;
elseif ( aM_color < 0) & & ( bM_color <= 0);
h ( i ) = hr + 180;
elseif ( aM_color > = 0) & & ( bM_color <=
0); h ( i ) = hr + 360;
end
 [ X, Y, Z] = I_CAM16 ( Jj (i), M (i), h
(i), XW, YW, ZW, VC, LA);
```

The algorithm in Fig. 2 and the code allows you to retrieve the generated colors in the *XYZ* coordinate system and by converting to get them in the *Yxy* coordinates.

3.3 The composition of the test table

The test table consists of colors that evenly fill the area bounded by the triangle of primary colors. The defined set of colors N can be placed in a single row and used for evaluation. But how colors can be used more than 100 hosted in one line is not possible. It was experimentally determined that the number of colors in a row should not exceed $z_{color} \le 20$. Therefore, the number of rows of test colors will be determined N / z_{color}. The result of this division is not always a multiple residues, so the number of colors, which are not enough in a multiple, are complemented by black. Two approaches can be used in the construction of a test image, the first is when the sorting of the colors obtained is by brightness, and the second is by color. It should be noted that broadcasting and multimedia standards use two components for color rendering, so sorting is blown by one of these components. In fig. 3, 4 depict test images constructed under specified adaptation conditions, and sorting is not performed by any of the above methods. The image in fig. 5-8 also satisfy the set of colors that the system transmits under certain adaptation conditions and are sorted by the luminance signal in descending order.

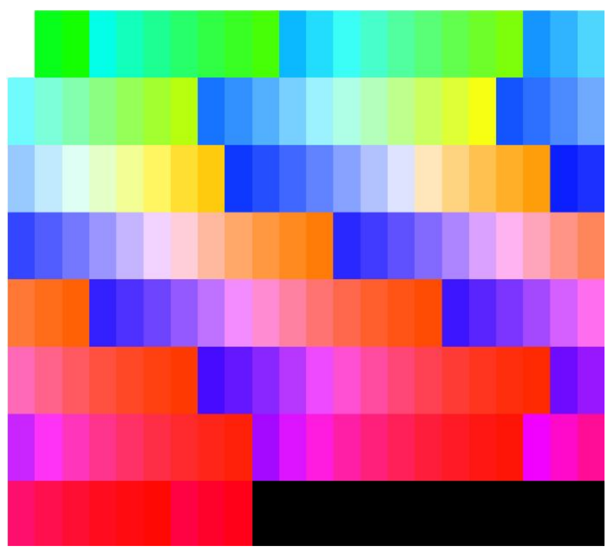

Figure 3: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 50$, meaning adapting parameters $L_A = 50\ cd / m^2$, $VC = average$

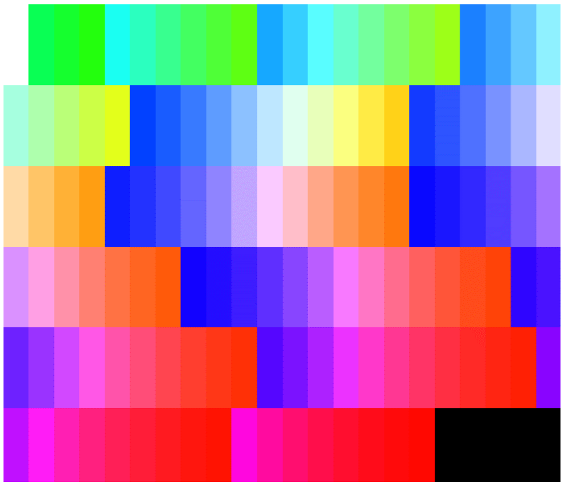

Figure 4: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 50$, meaning adapting parameters $L_A = 50\ cd/m^2$, $VC = dark$

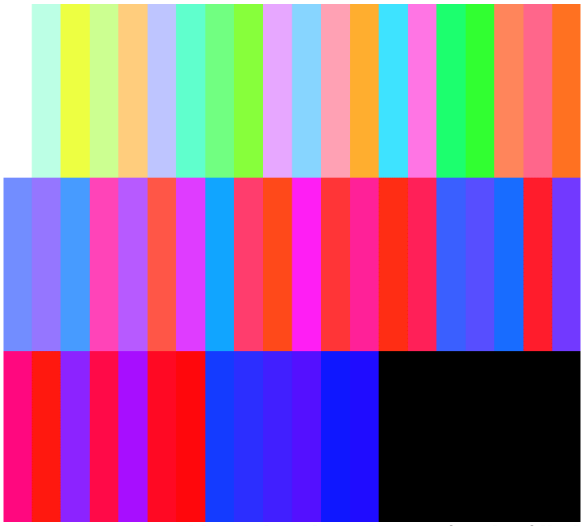

Figure 5: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 20$, meaning adapting parameters $L_A = 50\ cd/m^2$, $VC = dark$

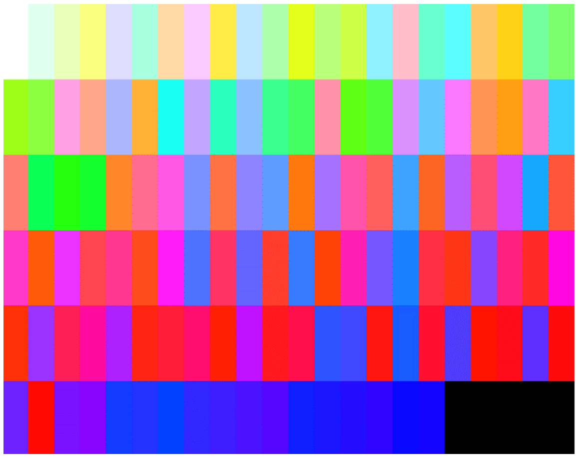

Figure 6: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 50$, meaning adapting parameters $L_A = 50\ cd/m^2$, $VC = dark$

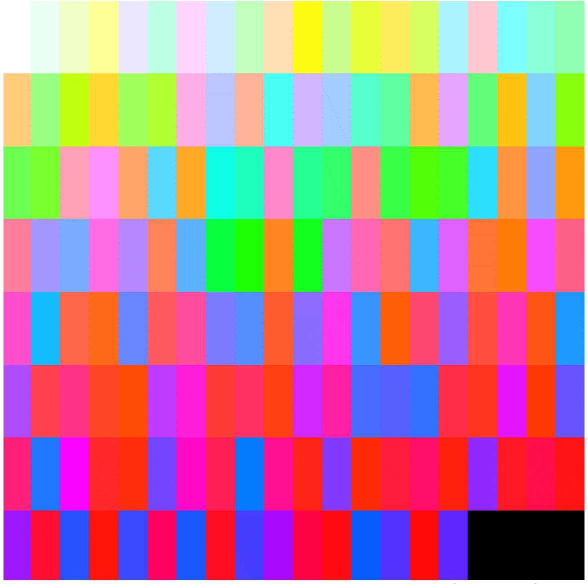

Figure 7: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 70$, meaning adapting parameters $L_A = 50\ cd/m^2$, $VC = dark$

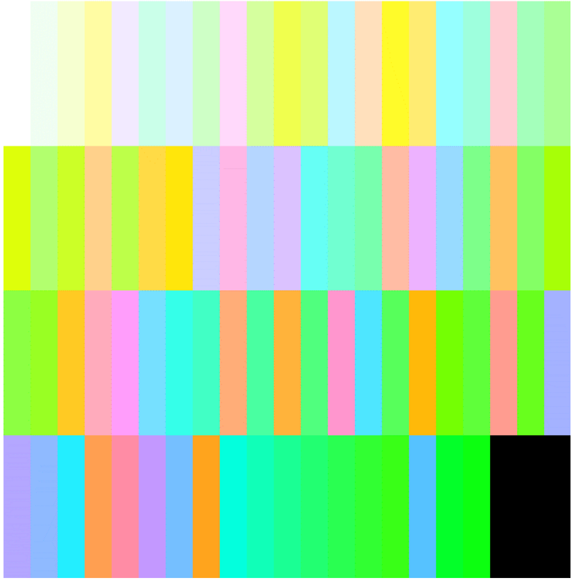

Figure 8: Test table with colors that uniformly fill the color range in increments of $\Delta E = 5$ units CIE and for the level lightness $J' = 90$, meaning adapting parameters $L_A = 50\ cd/m^2$, $VC = dark$

It should be noted that fig. 3-8 is also represented by a multimedia track or paper display system and may be distorted. Therefore, spectral distributions or color coordinates should be used to perform the optical test image. In the absence of the need for an optical image, use a test image generator or arrays of generated signal levels. It is not possible to represent arrays of all possible variants in this work, so it is recommended to use a test set to debug a projected test signal generator. The value is presented in Table l.

Table 1: Validation values for debugging the algorithm of the test signal generator

R	*G*	*B*	*Y*	*Cr*	*Cb*
1,0000	1,0000	1,0000	235	128	128
0,8706	1,0000	0,9529	225	114	128
0,8980	1,0000	0,7843	223	121	108
0,9529	1,0000	0,5843	222	130	83
1,0000	0,9059	0,7333	216	142	105
1,0000	0,9647	0,3804	215	143	61
0,6863	1,0000	0,9059	212	95	129
0,8706	0,8902	1,0000	212	124	141
0,7098	1,0000	0,7412	210	100	110
0,9686	1,0000	0,0706	210	141	25
0,7608	0,9176	1,0000	209	109	143
0,9490	0,8275	1,0000	209	138	143
0,5804	0,9922	1,0000	207	82	144
0,7451	1,0000	0,5569	207	108	88
0,8745	1,0000	0,2118	207	128	44
1,0000	0,8078	0,8510	207	149	126
0,8000	1,0000	0,3765	206	117	66
0,6118	0,9490	1,0000	203	89	146
1,0000	0,8314	0,5020	201	153	85
1,0000	0,8784	0,1961	199	154	47
0,4902	1,0000	0,8510	198	74	131
0,4392	0,9882	1,0000	197	66	150
0,5176	1,0000	0,6863	196	80	111
0,6980	0,8431	1,0000	195	109	151
1,0000	0,7020	0,9412	195	157	144
0,5490	1,0000	0,5137	193	86	91
0,7176	1,0000	0,0588	193	114	33
R	*G*	*B*	*Y*	*Cr*	*Cb*
0,5882	1,0000	0,3451	192	94	70
0,6431	1,0000	0,1922	191	103	51
1,0000	0,7255	0,6196	190	161	106
1,0000	0,7569	0,3098	187	163	69
0,4824	0,8784	1,0000	185	81	157
1,0000	0,7961	0,0588	185	164	38
0,2314	1,0000	0,9647	184	43	153
0,6941	0,7608	1,0000	184	116	157
0,2824	1,0000	0,7961	183	51	132
1,0000	0,6471	0,7333	183	166	124
0,5961	0,7922	1,0000	182	102	159
0,7725	0,7059	1,0000	182	130	158
0,3176	1,0000	0,6314	181	58	113
0,3490	1,0000	0,4667	179	65	93
1,0000	0,5725	0,9490	179	169	154
0,3882	1,0000	0,3098	178	72	74
0,4902	1,0000	0,0471	178	88	41
0,8549	0,6314	1,0000	178	146	161
0,4314	1,0000	0,1686	177	79	56
1,0000	0,6588	0,4157	177	171	88
0,4667	0,8157	1,0000	176	86	162
1,0000	0,6392	0,5137	176	171	100
0,5804	0,7490	1,0000	175	105	162
1,0000	0,6863	0,1569	174	173	57
0,9529	0,5490	1,0000	174	165	163
1,0000	0,5451	0,8235	172	174	142
0,3098	0,8392	1,0000	169	66	166
R	*G*	*B*	*Y*	*Cr*	*Cb*
1,0000	0,5804	0,5294	169	176	106
1,0000	0,6039	0,4078	169	176	91
0,0745	1,0000	0,7373	168	29	134
0,1176	1,0000	0,5765	167	37	114
0,1529	1,0000	0,4196	165	44	95
0,1882	1,0000	0,2706	164	50	77
1,0000	0,5961	0,2510	164	180	74
0,2784	1,0000	0,0275	163	65	46
1,0000	0,6196	0,0431	162	181	49
1,0000	0,5059	0,6314	162	181	123
0,1373	0,8667	1,0000	161	44	171
1,0000	0,4314	0,9333	160	183	163
0,5294	0,6353	1,0000	157	109	173
1,0000	0,5216	0,3529	157	185	91
0,6039	0,5843	1,0000	156	123	174
0,4392	0,6667	1,0000	155	96	174
1,0000	0,5412	0,1255	154	187	64
0,6745	0,5216	1,0000	152	136	176
0,3255	0,6902	1,0000	151	82	176
1,0000	0,4549	0,4510	151	189	107
0,0784	1,0000	0,0078	150	43	52
0,0314	1,0000	0,1098	149	36	65
1,0000	0,4706	0,2118	147	192	79
0,7490	0,4471	1,0000	147	152	179
1,0000	0,4863	0,0353	145	194	58
0,1882	0,7059	1,0000	144	65	181
0,8353	0,3725	1,0000	144	168	181
0,8431	0,3569	1,0000	142	171	182
1,0000	0,4078	0,2980	141	196	93
1,0000	0,4235	0,1020	138	198	70
0,0392	0,7255	1,0000	137	46	185
1,0000	0,2863	0,6902	136	201	146
1,0000	0,3686	0,1765	133	202	83
1,0000	0,2941	0,5686	133	202	132
1,0000	0,2941	0,5686	133	202	132
0,3804	0,5137	1,0000	132	104	188
0,2980	0,5451	1,0000	131	92	188
0,4510	0,4706	1,0000	131	116	188
1,0000	0,3804	0,0235	131	204	65
1,0000	0,2000	0,9647	131	204	183
0,5137	0,4157	1,0000	128	128	190
0,1961	0,5686	1,0000	127	78	190
1,0000	0,2078	0,7333	127	207	157
0,4039	0,4549	1,0000	126	112	191
1,0000	0,3294	0,0824	126	208	75
0,5804	0,3529	1,0000	124	142	192
1,0000	0,2039	0,5529	122	211	137
0,0824	0,5843	1,0000	121	64	194
1,0000	0,2980	0,0157	120	212	70
0,6471	0,2863	1,0000	120	155	194
1,0000	0,1098	0,8706	117	214	180
1,0000	0,1922	0,4039	116	215	121
0,3333	0,3922	1,0000	113	110	198
1,0000	0,1216	0,6549	113	217	155
1,0000	0,1804	0,2784	112	218	108
0,7922	0,1451	1,0000	111	185	199

R	*G*	*B*	*Y*	*Cr*	*Cb*
1,0000	0,1255	0,4863	110	219	135
0,2510	0,4039	1,0000	109	100	201
0,3176	0,3647	1,0000	109	111	201
0,1765	0,4353	1,0000	108	89	201
0,8667	0,0784	1,0000	108	199	201
1,0000	0,1647	0,1765	107	221	98
0,3765	0,3176	1,0000	106	122	202
1,0000	0,1216	0,3490	106	222	120
1,0000	0,0353	0,7922	106	222	176
0,0863	0,4549	1,0000	105	77	203
0,9451	0,0078	1,0000	104	215	204
0,4314	0,2667	1,0000	103	133	204
1,0000	0,1451	0,0980	103	225	90
1,0000	0,0510	0,5882	103	225	152
1,0000	0,1137	0,2353	102	225	108
0,4863	0,2078	1,0000	100	145	206
1,0000	0,0588	0,4275	100	227	134
1,0000	0,0588	0,4275	100	227	134
1,0000	0,1294	0,0392	99	227	85
1,0000	0,1020	0,1490	98	228	99
1,0000	0,0588	0,3020	97	229	120
1,0000	0,0588	0,3020	97	229	120
1,0000	0,0902	0,0784	95	230	92
1,0000	0,0549	0,2039	94	231	109
1,0000	0,0549	0,2039	94	231	109
1,0000	0,0784	0,0314	92	232	88
1,0000	0,0510	0,1216	91	233	100
1,0000	0,0510	0,1216	91	233	100
0,1451	0,3059	1,0000	90	97	212
0,2039	0,2745	1,0000	90	107	212
1,0000	0,0431	0,0627	89	235	94
1,0000	0,0078	0,2627	89	234	119
1,0000	0,0431	0,0627	89	235	94
1,0000	0,0078	0,2627	89	234	119
0,0784	0,3294	1,0000	88	88	213
0,6471	0,0353	1,0000	88	179	213
0,2549	0,2314	1,0000	87	117	213
1,0000	0,0353	0,0196	87	236	90
1,0000	0,0078	0,1725	87	236	109
1,0000	0,0353	0,0196	87	236	90
1,0000	0,0078	0,1725	87	236	109
0,3059	0,1882	1,0000	85	126	214
1,0000	0,0078	0,1020	85	237	101
1,0000	0,0078	0,1020	85	237	101
0,3529	0,1412	1,0000	82	136	216
0,0588	0,2196	1,0000	73	96	221
0,1098	0,1922	1,0000	73	104	222
0,1608	0,1569	1,0000	72	113	222
0,2510	0,2510	0,2510	71	128	128
0,2510	0,2510	0,2510	71	128	128
0,2039	0,1216	1,0000	70	121	223
0,2431	0,0824	1,0000	67	129	225
0,0431	0,1216	1,0000	59	103	229
0,0000	0,0000	0,0000	16	128	128

3.4 Features of the test table signals

This section provides formulas for a generic description of signal elements that can be used to analyze the characteristics of these signals. This paper presents a study of the characteristics of signals with numbers 1–14. The numbering of the signal readings corresponds to that defined in Recommendations ITU - R BT. 656-5 and ITU - R BT. 1120-7.

The temporal characteristics of the signals are determined so that their use is free from distortions that may occur in the system with the sampling of the signal. The blurring of transients with the impulse response $g(\xi)$, described by the Blackman window function, was used for this purpose.

This impulse response can generally be described by the formula

$$g_{\alpha\zeta}(\xi)=\begin{cases}\frac{1}{\pi(1-2\alpha)}\left(\cos^2\frac{\pi\xi}{2\zeta\Delta\xi}-2\alpha\cdot\sin^2\frac{\pi\xi}{\zeta\Delta\xi}\right) & \text{for } |\xi|<\zeta\Delta\xi\\ 0 & \text{for } |\xi|>\zeta\Delta\xi,\end{cases}$$

where ξ - the time coordinate or the associated coordinate in the horizontal plane of the image $\Delta\xi$ - the step of sampling in coordinate ξ; ζ - duration of impulse response, expressed as the number of sampling steps, which is equal in Recommendation ITU - R BT .801-1 $\zeta=3$, α - Blackman function parameter , which is equal to 0.08 in Recommendation ITU - R BT .801-1.

When $\Delta\xi=1$ a coordinate ξ is a reference number $i=\xi\in\overline{0,N_a-1}$ whose signal is the signal brightness (color) of the corresponding image element in the active part of the line, which varies in the interval $\overline{0,N_a-1}$, were N_a – number of image elements in the active part of the line in the system with the number of active lines Z_a .

The impulse response (2) corresponds to a transient response describing the law of change in the transitions of the signals presented in table 1, which is described by the formula:

$$h_{\alpha\zeta}(\xi)=\begin{cases}0 & \text{for } \xi<-\zeta\,\Delta\xi\\ \frac{1}{2\pi}\left\{\frac{\pi\xi}{\zeta\,\Delta\xi}+\pi+\frac{\sin\frac{\pi\xi}{\zeta\,\Delta\xi}-\alpha\sin\frac{2\pi\xi}{\zeta\,\Delta\xi}}{1-2\alpha}\right\} & \text{for } -\zeta\,\Delta\xi<\theta<\zeta\,\Delta\xi\\ 1 & \text{for } \theta>\zeta\,\Delta\xi\end{cases} \quad (2)$$

The digital representation of signals is related to the quantization of their levels, which can be expressed by the formula:

$$\mathrm{Round}(x)=\mathrm{Sign}(x)\times\mathrm{Floor}\left(|x|\times D+0,5\right)/D$$

where $D=2^{m-8}$, where m is the number of bits of binary signal coding x.

The digital representation is such that the eight highest digits form a whole part of the signal samples, and the digits younger than the eighth form a fractional part.

4. RESEARCH RESULTS

The signals resulting from the constructed images can also be represented as line drawings of that image. These figures can be used as test signals when testing through paths. An example of signals is shown in fig. 9 to conditions adaptation when the trench is lightness $J' = 90$, as mentioned adapting parameters $L_A = 50\,cd/m^2$, $VC = dark$.

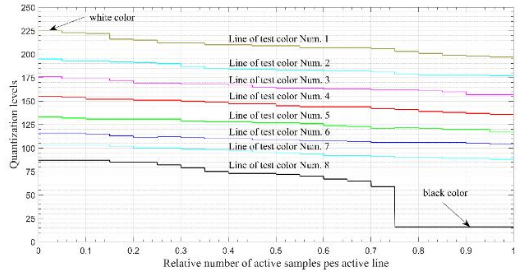

Figure 9: Line drawings of the test image

The data presented can be used to construct test signal generators, but in each case when the magnitude of the adaptive values will differ, the shape of the signal will also differ.

The use of images sorted by brightness or color makes it possible to evaluate not only the transients between neighboring colors but also the law of change of the step-like saw signal, which can be seen in Fig. Transients and sawtooth test signal changes require description taking into account the physical capabilities of the equipment. Therefore, considerations such as generator frequency and bit rate should be considered.

4.1 About the negotiation of results

The use of color perception not only in adapting the transmitted or reproduced image but also in the construction of the test image generator is a new step in the progress of multimedia measurements. Due to the change in the magnitude of the adaptive parameters, the color rendering area changes and so does the area to be evaluated. The paper proposes a new approach to evaluating not only saturated colors but all colors transmitted by the system. This is achieved by generating an orthogonal color grid within the system transmission area in increments of 5 CIE units, fig. 3-8. Thus, the proposed algorithm will determine interference occurring in through path, and such effect lighting sources that are different from the studio and other. His use of this method in assessing the quality received color rendering in telemedicine with remote initial examination and detection applications in rehabilitation and loss of color vision.

By represented in the results include analytical expressions (1-3), which for include value of real physical equipment, such as clock speed and bit coding. So no less than 6 clock samples should be selected for the transient process, and the transient process should be described by Blackman's filter. This statement makes it possible to realize the compatibility between existing facilities and potential and but new and improve existing fleet of equipment. The paper presents sample test signals of the generated sequence of test colors, fig. 9. It should be noted that transients are described by expression (1) and sawtooth (2). Determination of signal levels is performed using expression (3).

5. CONCLUSION

The paper proposes the implementation of a test signal generator that implements images of a set of test colors that uniformly fill the area of the transmitted colors. This generator can be used to evaluate the quality of functioning of television, multimedia, and other special-purpose tracts.
During the implementation of the generator, the experience of creating mathematical models describing the color perception of a person and applying it to the algorithm of operation of the generator was used. The paper offers several test signal and image configurations that extend the ability to evaluate three-color image transmission channels.

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