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Matrix models of bar graph data display for bicyclic excitation of the optoelectronic scale

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Abstract. In this work, being based on the theory of sets and matrix formulation of the information area for a bar graph display the author obtained a matrix description for electric signals necessary to form two variants of bicyclic excitation of the optoelectronic scale elements under dynamic realization of a bar graph information model.

Keywords: bar graph display, information model, matrix description.

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An essential part of modern radioelectronic facilities is oriented to man-controlled interaction. Combination of optical and digital methods for processing signals in these facilities provides a high efficiency of message passing to an operator in such ergatic system [1, 2]. Among various types of means for information display, it is necessary to separate the group of facilities for discrete-analog (scale) data presentation, which possess the best complex of ergonomic characteristics [2-4]. Placed at the heart of their functioning is an information model (IM) that defines the system of rules for coding the messages [5, 6]. Most often, used in serial radioelectronic equipment are two forms of IM for discrete-analog data imaging: positional and additive ones that are synthesized, respectively, from one or set of excited elements inherent to the display information area (IA) [2]. Apparatus realization of IA is some electron-optical image converter (EOIC) providing formation of an optical pattern when exciting respective elements. Most widely used for displaying information in modern radioelectronic equipment are EOICs based on light-emitting diodes, liquid crystals and vacuum cathodoluminescent displays [2, 5, 7].

Reliability of data presentation with a high level of discreteness (more than 20 – 25 meanings), when rigorous limitations of power consumption for imaging are absent, can be functionally reached using a bar graph IM due to its information redundancy [8]. The apparatus component of reliability is provided, first of all, by matrix electric connection of EOIC elements, which allows to essentially shorten the number of scale control lines and respective signals to excite it [7]. However, it is not poissible to simultaneously excite all the elements necessary to form the bar graph IM. Therefore, used is the dynamic regime to form images in IA, which is usually realized by multi-cyclic scanning the matrix along one of its coordinate [5, 9]. As an alternative, developed were bicyclic methods for synthesizing a visual image for discrete-analog presentation of information on the display [10, 11]. Minimization of the number of cycles to excite IA elements considerably increases reliability of data output and lower the level of high-frequency electromagnetic noises caused by EOIC control unit. Thereof, modelling the bicyclic additive discrete-analog data imaging to design highly efficient facilities for information output has a great practical interest.

In this work, being based on the theory of sets and matrix formulation for display IA obtained are analytical models allowing to describe electrical signals necessary to realize two variants for bicyclic excitation of optoelectronic scale elements with dynamic synthesis of imaging the bar graph IM.

The discrete-analog form to code messages assumes that every a_i element of p IA ones has the weight function $\varpi_i = \varpi(a_i)$, the value of which is associated with its space position in IA and is in proportion to its number i in a fully ordered set of $\mathbf{A}$ elements. This can be described as $\mathbf{A} = \{ a_1, a_2, \ldots, a_i, \ldots, a_{p-1}, a_p \}$. Besides, this set is characterized by the condition $\varpi(a_j) < \varpi(a_{j+1})$ at all $j = \overline{1, (p-1)}$. In the heart of this way to code information, there are values of the weight function for IA elements, which are determined relatively to the spatial multi-channel measure [1].

Presentation of messages in IA is realized starting from IM and using the finite set l of $S_{\nu\text{BG}}$ symbols where $\nu = \overline{1, l}$ that form the alphabet of the bar graph model

$\mathbf{\Omega}_{\mathrm{BG}} = \{S_{1\mathrm{BG}}, S_{2\mathrm{BG}}, \ldots, S_{\nu\mathrm{BG}}, \ldots, S_{(l-1)\mathrm{BG}}, S_{l\mathrm{BG}}\}.$

Synthesis of images for alphabet symbols $\mathbf{\Omega}_{\mathrm{BG}}$ takes place in IA. To provide that when exciting EOIC, the subsets $\tilde{\mathbf{A}}_{\nu\mathrm{BG}}$ are formed from the elements of the set IA $\mathbf{A}$, that is for all $\nu = \overline{1, l}$ the condition $\tilde{\mathbf{A}}_{\nu\mathrm{BG}} \subseteq \mathbf{A}$ is fulfilled. As every message should be decoded uniquely, every symbol from $S_{\nu\,\mathrm{BG}} \subset \mathbf{\Omega}_{\mathrm{BG}}$ should be one-to-one corresponded with a_i elements of the subset $\tilde{\mathbf{A}}_{\nu\mathrm{BG}}$ beloning to the set $\mathbf{A}$: $S_{\nu\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}_{\nu\mathrm{BG}}$.

The bar graph form of IM assumes formation of $S_{\nu\mathrm{BG}}$ symbols from a set of a_i elements with serial values of the weight function, originating from its minimum value $\varpi_1 = \varpi(a_1)$ up to the value $\varpi_\nu = \varpi(a_\nu)$ that corresponds to the output information relatively to the spatial measure. These symbols can be described on the set $\mathbf{A}$ as follows

$$S_{\nu\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}_{\nu\mathrm{BG}} = \bigcup_{i=1}^{\nu} a_i = \{a_1, a_2, \ldots, a_i, \ldots, a_{\nu-1}, a_\nu\}. \qquad (1)$$

To increase reliability of the data output facility, one can use an electric organisation of EOIC, when its elements are connected as a two-dimensional matrix from n groups every of m elements where $m \cdot n = p$. Each group contains elements the weight function of which in serial pairs differs by unity. In this case, their common bus is the output termination of one of n high-order bits. Values of the weight function both for each group and for their elements are determined by their position in IA relatively to the spatial multi-channel measure. Joint outputs of all the elements with the same relative value of the weight function inside each group serve as the bus for one of m low-order bits. As a result, EOIC elements form IA consisting of the set $\mathbf{A}_{\mathrm{M}}$ with elements a_{xy} that has the number y in the group of the number x, while $x = \overline{1, n}$ and $y = \overline{1, m}$, that is $\mathbf{A}_{\mathrm{M}} = \{a_{11}, a_{12}, \ldots, a_{xy}, \ldots, a_{n(m-1),} a_{nm}\}$, or in the matrix form

$$\mathbf{A}_{\mathrm{M}} = \left\| \begin{matrix} a_{11} & a_{12} & \cdots & a_{1(y-1)} & a_{1y} & a_{1(y+1)} & \cdots & a_{1(m-1)} & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2(y-1)} & a_{2y} & a_{2(y+1)} & \cdots & a_{2(m-1)} & a_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{(x-1)1} & a_{(x-1)2} & \cdots & a_{(x-1)(y-1)} & a_{(x-1)y_\nu} & a_{(x-1)(y+1)} & \cdots & a_{(x-1)(m-1)} & a_{(x-1)m} \\ a_{x1} & a_{x2} & \cdots & a_{x(y-1)} & a_{xy} & a_{x(y+1)} & \cdots & a_{x(m-1)} & a_{xm} \\ a_{(x+1)1} & a_{(x+1)2} & \cdots & a_{(x+1)(y-1)} & a_{(x+1)y} & a_{(x+1)(y+1)} & \cdots & a_{(x+1)(m-1)} & a_{(x+1)m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{(n-1)1} & a_{(n-1)2} & \cdots & a_{(n-1)(y-1)} & a_{(n-1)y} & a_{(n-1)(y+1)} & \cdots & a_{(n-1)(m-1)} & a_{(n-1)m} \\ a_{n1} & a_{n2} & \cdots & a_{n(y-1)} & a_{ny} & a_{n(y+1)} & \cdots & a_{n(m-1)} & a_{nm} \end{matrix} \right\| \qquad (2)$$

When the number of element is the same, the sets $\mathbf{A}$ and $\mathbf{A}_{\mathrm{M}}$ are equipotent, and there is a one-to-one correspondence between their elements $a_i \Leftrightarrow a_{xy}$. Then, for the elements with the equal value of the weight function $\varpi_\nu = \varpi(a_i) = \varpi(a_{xy})$ one can write that the positional number of the element ν in the set $\mathbf{A}$ is determined by the expression $\nu = m(x-1) + y$, and ν-th element in the set $\mathbf{A}_{\mathrm{M}}$ stands in the matrix as $y_\nu = \nu - m \cdot \mathrm{E}(\nu/m)$ within the group with the number $x_\nu = \mathrm{E}(\nu/m) + 1$, where E is Entier. It is obvious that the subsets $\tilde{\mathbf{A}}_{\nu\mathrm{BG}}$ and $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ ($\tilde{\mathbf{A}}_{\nu\mathrm{BG}} \subseteq \mathbf{A}$, $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} \subseteq \mathbf{A}$) will be equipotent, too, and the symbols $S_{\nu\mathrm{BG}}$ are synthesized from their elements. Then, for the matrix electric connection of EOIC elements the expression (1) can be rewritten in the following form

$$S_{\nu\,\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}_{\nu\,\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} = \bigcup_{i=1}^{\nu} \left[a_{xy} \Big|_{\substack{x=\mathrm{E}(i/m)+1 \\ y=i-m\cdot\mathrm{E}(i/m)}} \right] = a_{11}, a_{12}, \ldots, a_{xy}, \ldots, a_{x_\nu(y_\nu-1)}, a_{x_\nu y_\nu} \}. \qquad (3)$$

Presentation of $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ as a subset of the set $\mathbf{A}_{\mathrm{M}}$ described with the matrix (where the elements belonging to $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ are marked with tilde) with account of IA matrix description (2) will have the following form

$$\mathbf{A}_{\mathrm{M}} = \\ = \left\| \begin{matrix} \tilde a_{11} & \tilde a_{12} & \cdots & \tilde a_{1(y_\nu-1)} & \tilde a_{1y_\nu} & \tilde a_{1(y_\nu+1)} & \cdots & \tilde a_{1(m-1)} & \tilde a_{1m} \\ \tilde a_{21} & \tilde a_{22} & \cdots & \tilde a_{2(y_\nu-1)} & \tilde a_{2y_\nu} & \tilde a_{2(y_\nu+1)} & \cdots & \tilde a_{2(m-1)} & \tilde a_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde a_{(x_\nu-1)1} & \tilde a_{(x_\nu-1)2} & \cdots & \tilde a_{(x_\nu-1)(y_\nu-1)} & \tilde a_{(x_\nu-1)y_\nu} & \tilde a_{(x_\nu-1)(y_\nu+1)} & \cdots & \tilde a_{(x_\nu-1)(m-1)} & \tilde a_{(x_\nu-1)m} \\ \tilde a_{x_\nu 1} & \tilde a_{x_\nu 2} & \cdots & \tilde a_{x_\nu(y_\nu-1)} & \tilde a_{x_\nu y_\nu} & a_{x_\nu(y_\nu+1)} & \cdots & a_{x_\nu(m-1)} & a_{x_\nu m} \\ a_{(x_\nu+1)1} & a_{(x_\nu+1)2} & \cdots & a_{(x_\nu+1)(y_\nu-1)} & a_{(x_\nu+1)y_\nu} & a_{(x_\nu+1)(y_\nu+1)} & \cdots & a_{(x_\nu+1)(m-1)} & a_{(x_\nu+1)m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{(n-1)1} & a_{(n-1)2} & \cdots & a_{(n-1)(y_\nu-1)} & a_{(n-1)y_\nu} & a_{(n-1)(y_\nu+1)} & \cdots & a_{(n-1)(m-1)} & a_{(n-1)m} \\ a_{n1} & a_{n2} & \cdots & a_{n(y_\nu-1)} & a_{ny_\nu} & a_{n(y_\nu+1)} & \cdots & a_{n(m-1)} & a_{nm} \end{matrix} \right\| \quad (4)$$

Two-dimensional matrix electric construction of EOIC superpose some limitations on simultaneous excitation of the set $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ elements that serve to form the image of the symbol $S_{\nu\mathrm{BG}}$. In this case, it is possible to synchronically turn on only all the elements (without exceptions) with arbitrary chosen identical numbers in any set of groups. Therefore, to realize the bicyclic synthesis of an image, the elements of the set $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ described by the matrix (4) with taking this limitation into account are separated in two non-intersecting subsets that are excited in different cycles of $S_{\nu\mathrm{BG}}$ symbol formation

$$\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} = \tilde{\mathbf{A}}^{\mathrm{D}}_{\nu\mathrm{BG}} = \left\{ \tilde{\mathbf{A}}^{\mathrm{D1}}_{\nu\mathrm{BG}}, \tilde{\mathbf{A}}^{\mathrm{D2}}_{\nu\mathrm{BG}} \right\}, \quad (5)$$

where $\tilde{\mathbf{A}}^{\mathrm{D}}_{\nu\mathrm{BG}}$ is the set identical to $\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}}$ and is its dynamic equivalent, $\tilde{\mathbf{A}}^{\mathrm{D1}}_{\nu\mathrm{BG}}$, $\tilde{\mathbf{A}}^{\mathrm{D2}}_{\nu\mathrm{BG}}$ – are the subsets of the set $\tilde{\mathbf{A}}^{\mathrm{D}}_{\nu\mathrm{BG}}$ with elements a_{xy}, and $\tilde{\mathbf{A}}^{\mathrm{D1}}_{\nu\mathrm{BG}} \bigcap \tilde{\mathbf{A}}^{\mathrm{D2}}_{\nu\mathrm{BG}} = \varnothing$.

An obligatory condition to form a persistent sight image of any visual symbol is a relative height of the frequency corresponding to image regeneration $f_S = 1/T_S$ over the critical frequency of flicker fusion [2, 5]. In this case, each group of a_{xy} elements that belongs to the respective subset is excited only one time during every period for symbol regeneration within the time interval $\tau_g = T_S/r$, where r is the number of cycles to synthesize a visual image on the display.

In the case of a two-dimension IA matrix, it is possible to realize two variants of formation of non-intersecting subsets for display elements: using the partition by high-order [10] and low-order [11] bits of the scale. Dynamic joining the elements into groups in accordance with the first version assumes realization of the logic IM in the form [10]

$$S_{\nu\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}^{\mathrm{D}}_{\nu\mathrm{BG}} = \left[\tilde{\mathbf{A}}^{\mathrm{D11}}_{\nu\mathrm{BG}} \bigcup \tilde{\mathbf{A}}^{\mathrm{D21}}_{\nu\mathrm{BG}}\right]\Big|_{T_S} = \\ = \left[\bigcup_{x=1}^{\mathrm{E}\left(\frac{\nu}{m}\right)} \bigcup_{y=1}^{m} a_{xy} \Bigg|_{t=t_S+0}^{t=t_s+\tau_g-0} \right] \bigcup \left[\bigcup_{x=\mathrm{E}\left(\frac{\nu}{m}\right)+1} \bigcup_{y=1}^{\nu-m\mathrm{E}\left(\frac{\nu}{m}\right)} a_{xy} \Bigg|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right], \quad (6)$$

where $\tilde{\mathbf{A}}^{\mathrm{D11}}_{\nu\mathrm{BG}}$, $\tilde{\mathbf{A}}^{\mathrm{D21}}_{\nu\mathrm{BG}}$ are the non-intersecting subsets of a_{xy} elements; t – current time of image dynamic synthesis; t_S – onset of the period of $S_{\nu\mathrm{BG}}$ symbol formation in IA.

It is seen that, in accord with this type of logic IM (6), synthesis of the $S_{\nu\mathrm{BG}}$ symbol in IA is realized in the dynamic bicyclic regime, and two groups of IA elements are separated in this case. During the first time interval $t_s < t < t_s + \tau_g$, excited are all m elements of all high-order bits from the first up to E(ν/m)-th one. The second interval $t_s + \tau_g < t < t_s + 2\tau_g$ corresponds to formation of a visual signal by using [$\nu - m$E(ν/m)] elements of one [E(ν/m) + 1]-th IA order. Obtaining the extended visual image in IA that corresponds to the symbol $S_{\nu\mathrm{BG}}$ is provided by inertial properties of a human sight analyzer when excitation of scale elements in two groups is repeated by cycles with the frequency exceeding that of flicker fusion.

Now, let us proceed from set logic presentation of IM (6) to the matrix one by using the respective form (4) to describe the excited IA when forming the symbol $S_{\nu\mathrm{BG}}$. As a result, we obtain the matrix of $n\times m$ dimensions:

$$\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} = \tilde{\mathbf{A}}^{\mathrm{DM}}_{\nu\mathrm{BG}} =$$
$$= \left\| \begin{matrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1(y_\nu-1)} & \tilde{a}_{1y_\nu} & \tilde{a}_{1(y_\nu+1)} & \dots & \tilde{a}_{1(m-1)} & \tilde{a}_{1m} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2(y_\nu-1)} & \tilde{a}_{2y_\nu} & \tilde{a}_{2(y_\nu+1)} & \dots & \tilde{a}_{2(m-1)} & \tilde{a}_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{(x_\nu-1)1} & \tilde{a}_{(x_\nu-1)2} & \dots & \tilde{a}_{(x_\nu-1)(y_\nu-1)} & \tilde{a}_{(x_\nu-1)y_\nu} & \tilde{a}_{(x_\nu-1)(y_\nu+1)} & \dots & \tilde{a}_{(x_\nu-1)(m-1)} & \tilde{a}_{(x_\nu-1)m} \\ \tilde{a}_{x_\nu 1} & \tilde{a}_{x_\nu 2} & \dots & \tilde{a}_{x_\nu(y_\nu-1)} & \tilde{a}_{x_\nu y_\nu} & 0 & \dots & 0 & 0 \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \end{matrix} \right\|; \qquad (7)$$

If using the considered logic IM, the searched description of subsets $\tilde{\mathbf{A}}^{\mathrm{DM11}}_{\nu\mathrm{BG}}$ and $\tilde{\mathbf{A}}^{\mathrm{DM21}}_{\nu\mathrm{BG}}$ can be deduced from the matrix (7) with taking account of the operator (6) in the form of matrixes with the dimension $n\times m$

$$\tilde{\mathbf{A}}^{\mathrm{DM11}}_{\nu\mathrm{BG}} =$$
$$= \left\| \begin{matrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1(y_\nu-1)} & \tilde{a}_{1y_\nu} & \tilde{a}_{1(y_\nu+1)} & \dots & \tilde{a}_{1(m-1)} & \tilde{a}_{1m} \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2(y_\nu-1)} & \tilde{a}_{2y_\nu} & \tilde{a}_{2(y_\nu+1)} & \dots & \tilde{a}_{2(m-1)} & \tilde{a}_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{(x_\nu-1)1} & \tilde{a}_{(x_\nu-1)2} & \dots & \tilde{a}_{(x_\nu-1)(y_\nu-1)} & \tilde{a}_{(x_\nu-1)y_\nu} & \tilde{a}_{(x_\nu-1)(y_\nu+1)} & \dots & \tilde{a}_{(x_\nu-1)(m-1)} & \tilde{a}_{(x_\nu-1)m} \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 & 0 \end{matrix} \right\|, \qquad (8)$$

$$\tilde{\mathbf{A}}^{\mathrm{DM21}}_{\nu\mathrm{BG}} = \left\| \begin{matrix} 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ \tilde{a}_{x_\nu 1} & \tilde{a}_{x_\nu 2} & \dots & \tilde{a}_{x_\nu(y_\nu-1)} & \tilde{a}_{x_\nu y_\nu} & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \end{matrix} \right\|. \qquad (9)$$

With account of the matrixes (7)-(9), for non-intersecting subsets in the framework of this bicyclic logic IM, the following equality is valid:

$$\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} = \tilde{\mathbf{A}}^{\mathrm{DM}}_{\nu\mathrm{BG}} = \tilde{\mathbf{A}}^{\mathrm{DM11}}_{\nu\mathrm{BG}} + \tilde{\mathbf{A}}^{\mathrm{DM21}}_{\nu\mathrm{BG}}. \qquad (10)$$

To realize IM, when using dynamic formation of subsets for IA elements by separation of groups by low-order bits of the display matrix, analytic presentation of image synthesis can be written in the form [11]

$$S_{\nu\mathrm{BG}} \Leftrightarrow \tilde{\mathbf{A}}^{\mathrm{D}}_{\nu\mathrm{BG}} = \left[\tilde{\mathbf{A}}^{\mathrm{D12}}_{\nu\mathrm{BG}} \bigcup \tilde{\mathbf{A}}^{\mathrm{D22}}_{\nu\mathrm{BG}}\right]\Big|_{T_S} =$$
$$= \left\{ \bigcup_{y=1}^{\nu - m\mathrm{E}\left(\frac{\nu}{m}\right)} \left[\bigcup_{x=1}^{\mathrm{E}\left(\frac{\nu}{m}\right)+1} a_{xy} \Bigg|_{t=t_s+0}^{t=t_s+\tau_g-0} \right] \right\} \bigcup \left\{ \bigcup_{y=\nu - m\mathrm{E}\left(\frac{\nu}{m}\right)+1}^{m} \left[\bigcup_{x=1}^{\mathrm{E}\left(\frac{\nu}{m}\right)} a_{xy} \Bigg|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right] \right\}. \qquad (11)$$

This operator describes formation of the symbol $S_{\nu\mathrm{BG}}$ in the dynamic bicyclic regime and defines two sets of IA elements. During the first time interval $t_s < t < t_s + \tau_g$ excited are $[\nu - m\mathrm{E}(\nu/m)]$ low-order elements of all

[E(ν/m) + 1] matrix low-order bits. The second interval $t_s + \tau_g < t < t_s + 2\tau_g$ corresponds to formation of a visual signal by using {m [E(ν/m) + 1] – ν} high-order elements of E(ν/m) IA low-order bits. Due to the lag effect of human sight analyzer, the repeated cyclic excitation of elements in these two groups allows to form an extended visual image corresponding to the symbol $S_{\nu \mathrm{BG}}$.

Changeover from IM set logic presentation (11) to the matrix one is realized in the identical manner said above for the model (6) by using the respective form (4) describing the excited IA when forming the symbol $S_{\nu \mathrm{BG}}$. It is obvious that the matrix (7) is valid for this type of IM, too. Consequently, the subsets $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM12}}$ and $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM22}}$ can be deduced from the matrix (7) with account for the operator (11) in the form of matrixes with the dimension $n \times m$

$$\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM12}} = \begin{Vmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \dots & \tilde{a}_{1(y_\nu-1)} & \tilde{a}_{1y_\nu} & 0 & \dots & 0 \\ \tilde{a}_{21} & \tilde{a}_{22} & \dots & \tilde{a}_{2(y_\nu-1)} & \tilde{a}_{2y_\nu} & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ \tilde{a}_{(x_\nu-1)1} & \tilde{a}_{(x_\nu-1)2} & \dots & \tilde{a}_{(x_\nu-1)(y_\nu-1)} & \tilde{a}_{(x_\nu-1)y_\nu} & 0 & \dots & 0 \\ \tilde{a}_{x_\nu 1} & \tilde{a}_{x_\nu 2} & \dots & \tilde{a}_{x_\nu (y_\nu-1)} & \tilde{a}_{x_\nu y_\nu} & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \dots & 0 & 0 & 0 & \dots & 0 \end{Vmatrix}, \tag{12}$$

$$\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM22}} = \begin{Vmatrix} 0 & \dots & 0 & \tilde{a}_{1(y_\nu+1)} & \dots & \tilde{a}_{1(m-1)} & \tilde{a}_{1m} \\ 0 & \dots & 0 & \tilde{a}_{2(y_\nu+1)} & \dots & \tilde{a}_{2(m-1)} & \tilde{a}_{2m} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \dots & 0 & \tilde{a}_{(x_\nu-1)(y_\nu+1)} & \dots & \tilde{a}_{(x_\nu-1)(m-1)} & \tilde{a}_{(x_\nu-1)m} \\ 0 & \dots & 0 & 0 & \dots & 0 & \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 & \end{Vmatrix}. \tag{13}$$

Analysis of the matrixes (7), (12) and (13) shows that for non-intersecting subsets in the case of bicyclic logic IM with separation of IA elements into groups by low-order bits one can write

$$\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{M}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM12}} + \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM22}}. \tag{14}$$

From the expressions (10) and (14) as well as analysis of all four subsets of elements $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM11}}$, $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM21}}$, $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM12}}$, $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM22}}$ used to form the $S_{\nu \mathrm{BG}}$ symbol image, one can write the respective sums of matrixes for every synthesis way

$$\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{M}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM11}} + \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM21}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM12}} + \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM22}}. \tag{15}$$

It is seen that the bicyclic synthesis of symbols $S_{\nu \mathrm{BG}}$ is invariant relatively to the choice of the principle for partition of the set $\tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{M}} = \tilde{\mathbf{A}}_{\nu \mathrm{BG}}^{\mathrm{DM}}$ by two subsets when exciting the visual images of the bar graph IM on the IA element matrix. In each of these image synthesis modifications, IA elements with the same numbers in the respective group set are switched on simultaneously, which does not contradict to the imposed limitations for synchronical controlling the electric matrix of elements.

Formation of IA element subsets belonging to the expression (15) is realized with electric signals generated by the display driver in the dynamic regime. To synthesize an image in IA for every time moment, the respective group $\tilde{\mathbf{A}}_{\nu}^{q}$ of scale matrix elements is excited, which, as shown in [12], is described by the vector product

$$\tilde{\mathbf{A}}_{\nu}^{q} = \vec{\mathbf{E}}_{\nu}^{\mathrm{L}\,q} \times \vec{\mathbf{E}}_{\nu}^{\mathrm{H}\,q} \quad , \tag{16}$$

where $\vec{\mathbf{E}}_{\nu}^{\mathrm{L}\,q}$, $\vec{\mathbf{E}}_{\nu}^{\mathrm{H}\,q}$ are *m*- and *n*-dimensional vectors of electric signals that control low- and high-order bits of the matrix, respectively. The elements of vectors are defined as e_{li} and e_{hj}, where $i = \overline{1,\ m}$, $j = \overline{1,\ n}$, and their values are equal to e_L and e_H for buses of display low- and high-order bits excited at this moment. Here, $\vec{\mathbf{E}}_{\nu}^{\mathrm{L}\,q}$ presents a row matrix, while $\vec{\mathbf{E}}_{\nu}^{\mathrm{H}\,q}$ does the column one. The group $\tilde{\mathbf{A}}_{\nu}^{q}$ consists of elements placed at the intersection of buses with applied electric stimuli e_{li} and e_{hj} corresponding to respected voltage levels or currents with necessary directions, in the dependence on the used IA type.

As a result, realization of a bar graph IM with bicyclic image formation by separation groups in high-order bits of display matrix, if starting from (10) and taking into account the matrix (8) and (9) as well as the expression (16), can be provided by electrical signals of the following form

$$\tilde{\mathbf{A}}_{\nu\mathrm{BG}}^{\mathrm{M}} = \tilde{\mathbf{A}}_{\nu\mathrm{BG}}^{\mathrm{DM}} = \left[\tilde{\mathbf{A}}_{\nu\mathrm{BG}}^{\mathrm{DM11}} + \tilde{\mathbf{A}}_{\nu\mathrm{BG}}^{\mathrm{DM21}}\right]\Big\|_{T_s} =$$

$$= \left\{ \left[\vec{\mathbf{E}}_{\nu\mathrm{BG}}^{\mathrm{L11}} \times \vec{\mathbf{E}}_{\nu\mathrm{BG}}^{\mathrm{H11}}\right]\Big\|_{t=t_s+0}^{t=t_s+\tau_g-0} \right\} \bigcup \left\{ \left[\vec{\mathbf{E}}_{\nu\mathrm{BG}}^{\mathrm{L21}} \times \vec{\mathbf{E}}_{\nu\mathrm{BG}}^{\mathrm{H21}}\right]\Big\|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right\} =$$

$$= \left\{ \left[\left\| e_{l1} \quad e_{l2} \quad \ldots \quad e_{l(i-1)} \quad e_{li} \quad e_{l(i+1)} \quad \ldots \quad e_{l(m-1)} \quad e_{lm} \right\| \times \right.\right.$$

$$\left.\left. \times \begin{Vmatrix} e_{h1} \\ e_{h2} \\ \vdots \\ e_{h(x_\nu-2)} \\ e_{h(x_\nu-1)} \\ 0 \\ \vdots \\ 0 \\ 0 \end{Vmatrix} \right] \Bigg|_{t=t_s+0}^{t=t_s+\tau_g-0} \right\} \cup \left\{ \left[\left\| e_{l1} \quad e_{l2} \quad \ldots \quad e_{l(y_\nu-1)} \quad e_{l\,y_\nu} \quad 0 \quad \ldots \quad 0 \quad 0 \right\| \times \right.\right. \tag{17}$$

$$\left.\left. \times \begin{Vmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ e_{h\,x_\nu} \\ 0 \\ \vdots \\ 0 \\ 0 \end{Vmatrix} \right] \Bigg|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right\} .$$

By analogy, we can obtain an analytic description for synthesis of a bar graph IM with bicyclic image formation by using separation of groups by low-order bits of the display matrix. In this case, we shall start from (14) with account of the matrixes (12) and (13) as well as the expression (16), which allows to represent the necessary electric signals in the form

$$
\begin{aligned}
&\tilde{\mathbf{A}}^{\mathrm{M}}_{\nu\mathrm{BG}} = \tilde{\mathbf{A}}^{\mathrm{DM}}_{\nu\mathrm{BG}} = \left[\tilde{\mathbf{A}}^{\mathrm{DM12}}_{\nu\mathrm{BG}} + \tilde{\mathbf{A}}^{\mathrm{DM22}}_{\nu\mathrm{BG}}\right]\Big|_{T_s} = \\
&= \left\{ \left[\vec{\mathbf{E}}^{\mathrm{L12}}_{\nu\mathrm{BG}} \times \vec{\mathbf{E}}^{\mathrm{H12}}_{\nu\mathrm{BG}}\right]\Big|_{t=t_s+0}^{t=t_s+\tau_g-0} \right\} \bigcup \left\{ \left[\vec{\mathbf{E}}^{\mathrm{L22}}_{\nu\mathrm{BG}} \times \vec{\mathbf{E}}^{\mathrm{H22}}_{\nu\mathrm{BG}}\right]\Big|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right\} = \\
&= \left\{ \left[\begin{Vmatrix} e_{l1} & e_{l2} & \dots & e_{l(y_\nu-1)} & e_{l y_\nu} & 0 & \dots & 0 & 0 \end{Vmatrix} \times \begin{Vmatrix} e_{h1} \\ e_{h2} \\ \vdots \\ e_{h(x_\nu-1)} \\ e_{h x_\nu} \\ 0 \\ \vdots \\ 0 \\ 0 \end{Vmatrix} \right]\Bigg|_{t=t_s+0}^{t=t_s+\tau_g-0} \right\} \cup \qquad (18) \\
&\cup \left\{ \left[\begin{Vmatrix} 0 & 0 & \dots & 0 & e_{l(y_\nu+1)} & e_{l(y_\nu+2)} & \dots & e_{l(m-1)} & e_{lm} \end{Vmatrix} \times \begin{Vmatrix} e_{h1} \\ e_{h2} \\ \vdots \\ e_{h(x_\nu-2)} \\ e_{h(x_\nu-1)} \\ 0 \\ \vdots \\ 0 \\ 0 \end{Vmatrix} \right]\Bigg|_{t=t_s+\tau_g+0}^{t=t_s+2\tau_g-0} \right\}.
\end{aligned}
$$

These analytic expressions obtained in the matrix form describe the process of dynamic bicyclic image synthesis for bar graph IM on the scale of matrix electric connection of elements. Analyzed and represented are both possible variants for IM of this type: with partition of IA elements onto groups by low- and high-order bits of the display matrix.

Considered are information conversion stages the most interesting from a practical viewpoint and those requiring to be modelled, starting from formation of electric signals controlling the display and finishing with formation of visual images in IA. The analytic expressions obtained possess good layout and are convenient for computer modelling the radioelectronic facilities.

The results presented above create an analytical base extremely necessary in designing, investigation and complex optimization of functional, structural and circuitry solutions for information display facilities aimed at radioelectronic equipment of various purposes. This equipment can be used both in mobile objects and information-measuring as well as controlling systems exploited mainly in complex conditions. It serves also as a base for efficient solution of the task to increase the level of technical-and-economical performances of serial and specialized products as well as to simplify their integration into perspective automated control means for complex objects and processes.

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