УДК 625.527

INVESTIGATION OF ELECTRIC FIELDS OF ELECTRIC INSTALLATIONS APPLIED IN RADIOELECTRONICS

V.M. Ivanov[1], E.A. Pechagin[1], E.B. Vinokurov[1], A.V. Lanovaya[2]

Departments: «Electrical Equipment and Automation» (1), «Higher Mathematics» (2), TSTU

Represented by a Member of the Editorial Board Professor V.F. Kalinin

Key words and phrases: electron optical moiré effect; moiré pattern.

Abstract: In this article electric field density is measured with the help of electron optical moiré effect. Experimental research was carried out to obtain shadow electron-optical views of uniform and non-uniform extraneous fields, which enable to visualize the topology picture of the given field, whereas deflection amount of distorted grid shadow view on the screen serves as disturbing field measuring value. It was stated out that obtained topological moiré model of investigated fields can be used as measurement assurance in field investigation.

Maxwell method of field addition and subtraction is widely used for solution of some primitive tasks, but it cannot be applied for studying of major field research problems of commercially used electrical installations. In addition the existing methods of electric field simulation are not suitable for analysis of little length fields because the measuring device sensitive element size does not permit precise measurements in rather small volumes. Direct measurement of normal component of field density near the model edge with sample electrode does not permit to obtain precise results because of local field distortions near low-resistance paper strip which serves as conducting medium during simulation.

In this article electric field density is measured with the help of electron optical moire effect based on deflection of electron bunch due to Lorenz force which produces various grid picture shifts on the display. And then the overlapping of distorted and undistorted grids forms moire pattern which reveals the character of field distribution.

The word "moire" comes from the name of silk fabric which folds form moire patterns viewed as collisions of light and dark lines. Moire is rather new method among other experimental techniques. It is one of the most subtle and precise means of displacement measurement based on rather simple physical effect. The importance of this method from technical point of view lies in the opportunity of direct registration of grid plane geometrical changes.

Thus moire effect is called by analogy the occurrence of light and dark bands when two grids overlap under definite conditions. Combining of two periodic phenomena produces the third with a lager period. Interference occurring when two grids overlap is known as moire or moire pattern. [1]. Experiments on studying of uniform electrostatic field moire patterns were carried out on electron-diffractor ЭГ-100А. Uniform electrostatic field was formed between two opposite charged parallel planes. Electron-optical scheme of field observation is presented on Fig. 1.

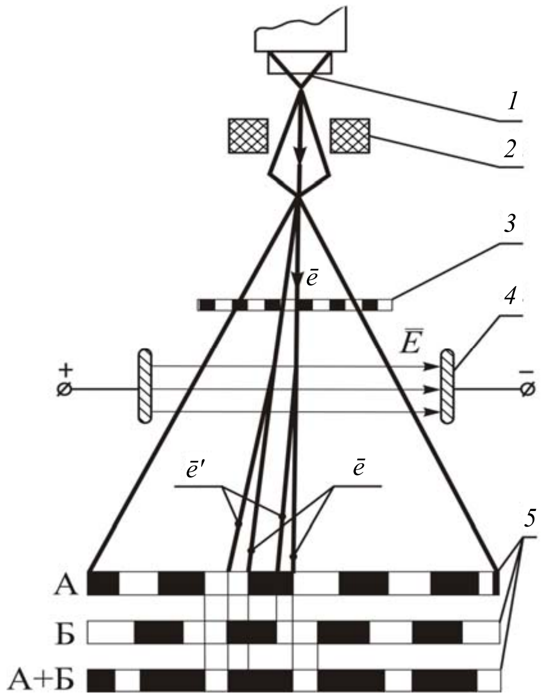

Fig. 1. Electron-optical scheme of field observation:
1 – electron injector; *2* – focusing magnetic lens; *3* – metallic grid 0,075×0,075 mm; *4* – field source (capacitor); *5* – photoplate; А – projective grid view; Б – projective grid view when source is on; А+Б – visualized moire as result of two patterns overlapping

Standard grid view is obtained as a result of electron-optical shaded display of point source. Beam cone appears to be separated on several bunches which cross section is defined by grid cell and shutting geometry. These experiment conditions permit to obtain on the screen fourfold grid magnifying 0,35×0,35 mm.

Let us study the analytical model of electron motion in a uniform transverse field *E* (Fig. 2).

The angle of electron displacement is found from electrostatic field distribution [2]. When leaving field *E* an electron will have the acceleration resulted from electric field

$$a = \frac{eE}{m_e}. \quad (1)$$

Here the velocity on y-line is defined from expression

$$v_y = at = \frac{eEt}{m_e}. \quad (2)$$

Hence the electron exit diffraction angle is found out from the correlation of velocity components on *y* and *x* lines

$$\text{tg}(\varphi) = \frac{v_y}{v_x} = \frac{eEt}{m_e v}, \quad (3)$$

where $v_x = v$ – velocity with which electron enters the field on its high bound.

For experimentally accepted accelerating potential of electron injector 40 kV, electron velocity will be

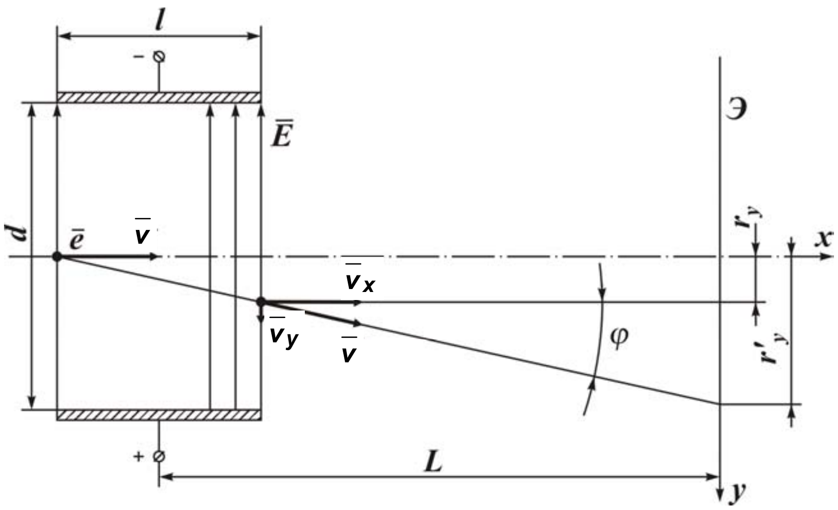

Fig. 2. Analytical model of electron motion in a uniform transverse field:
l – capacitor length; d – distance between plates; L – distance from the capacitor center to the screen; $\bar{v}$ – electron velocity when entering field E; r_y – electron displacement when leaving field E; r'_y – electron displacement observed on the screen

$$v = \sqrt{\frac{2eU}{m_e}} = 1,188 \cdot 10^8 \text{ m/s.} \tag{4}$$

Electron deflection on leaving field E is expressed by the following equation:

$$r_y = \frac{at^2}{2} = \frac{eEt^2}{2m_e}. \tag{5}$$

Leaving the field with l length the electron moves along tangent to the trajectory in point A (x; y), which is on field low bound. On reaching the electron diffractor screen situated on the distance (L – l/2) from field low bound, the particle deflects on the quantity found from

$$r'_y = r_y + \left(L - {l}/{2}\right) \text{tg}(\varphi). \tag{6}$$

Inserting expressions (4), (5) in the equation (6), we obtain

$$r'_y = \frac{eulL}{m_e d v^2}, \tag{7}$$

where $e = 1,6 \cdot 10^{-19}$ C – electron charge; u – voltage between condenser coatings; $l = 0,034$ m – length of condenser plates; $d = 0,0094$ m – distance between condenser plates; $L = 0,7$ m – distance from the condenser centre to the screen; v – electron velocity when entering the electric field.

For shooting conditions accepted in the experiment we obtain the rated dependence connecting the quantity of electron bunch deflection and electric field provoking it

$$r'_y = 0,631 \cdot 10^{-4} u. \tag{8}$$

Experimental results were processed with optical microscope with magnifying up to 100 times. Moire pattern is presented on Fig. 3.

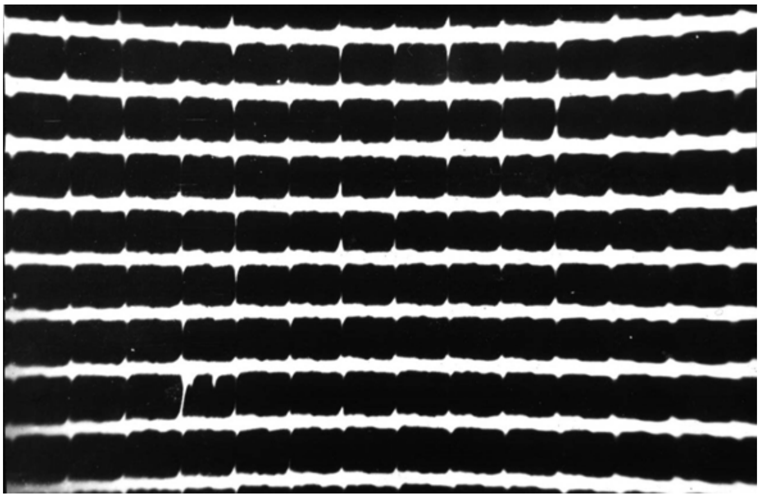

Fig. 3. Moire pattern on capacitor electric field

Quantity of bunch deflection is found as

$$r'_y = n - k\,, \tag{9}$$

where k – the size of rated grid view; n – the size of grid view along electric field tension lines when some voltage is supplied to capacitor plates.

For instance, when intensity is 300 V/m, electron bunch deflection will amount

$$r'_y = 525 - 350 = 175 \cdot 10^{-6}\,. \tag{10}$$

Fig. 4 shows the dependence of electron bunch deflection value on intensity of plane capacitor electric field. Experimentally found dependence is compared to theoretically probable obtained from equation (8). From comparison of theoretical and experimental data became obvious that deviation amounts not more than 10 % in the whole investigated interval.

For example, to find the distribution of electric component of electromagnetic extraneous field in a sound head, let us use one of Maxwell equations

$$\mathrm{rot}E = -\mu_0 \frac{\partial H}{\partial t}\,, \tag{11}$$

where

$$\frac{\partial E_y}{\partial x} = -\mu_0 \frac{\partial H_z}{\partial t}\,. \tag{12}$$

Due to the fact that alternating voltage is fed to sound head coil the magnetic field Hz in specific gap area can be presented with an amplitude changing according to harmonic law [3]

$$H_z = \frac{H_0 \sin\omega t}{\pi}\left(\mathrm{arctg}\frac{z+2hs}{x} - \mathrm{arctg}\frac{z-2hs}{x}\right). \tag{13}$$

Having integrated two parts of expression (12) on dx and taken into account dependence (14), we obtain expression for intensity component of electric field E_y:

$$E_y = \frac{\mu_0 \omega H_0 \cos\omega t}{\pi}\int\left(\mathrm{arctg}\frac{z+2hs}{x} - \mathrm{arctg}\frac{z-2hs}{x}\right)dx\,. \tag{14}$$

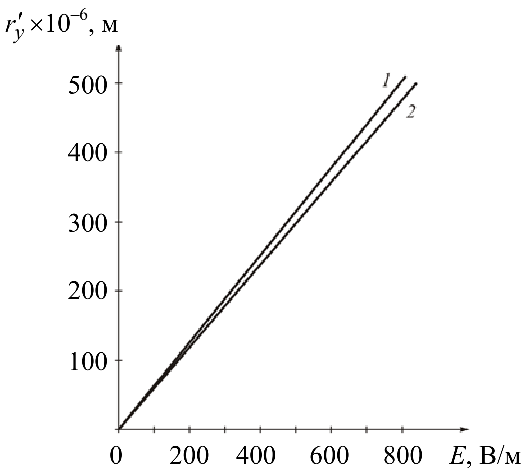

Fig. 4. Dependence of electron jet deflection value on various quantities of electric field intensity:
1 – experimental; *2* – theoretical

Thus was worked out the technique of obtaining shadow moire patterns on electric field due to overlapping of distorted and undistorted grid views resulted from their successive exposure on one and the same photo plate. Experimental research was carried out to obtain shadow electron-optical views of uniform and non-uniform extraneous fields. They enable to visualize the topology picture of the given field, whereas deflection amount of distorted grid shadow view on the screen serves as disturbing field measuring value. It was stated out that obtained topological moire model of investigated fields can be used as measurement assurance in field investigation as deviation from theoretical calculations amounts not more than 5% in the investigated range.

The main technique advantage is the visualization opportunity of any electric field sophisticated distribution as well as the possibility to observe electric field lines and their quantitative evaluation in small volumes.

References

1. Дюрелли, А. Анализ деформаций с использованием муара / А. Дюрелли, В. Паркс. – М. : Мир, 1974. – 356 с.

2. Арцимович, Л.А. Движение заряженных частиц в электрических и магнитных полях / Л.А. Арцимович, С.Ю. Лукьянов. – М. : Наука, 1972. – 220 с.

3. Гитлиц, М.В. Магнитная запись сигналов / М.В. Гитлиц. – М. : Радио и связь, 1990. – 232 с.

Исследование электрических полей электрооборудования радиоэлектроники

В.М. Иванов[1], Е.А. Печагин[1], Е.Б. Винокуров[1], А.В. Лановая[2]

Кафедры: Электрооборудование и автоматизация» (1), «Высшая математика» (2), ГОУ ВПО «ТГТУ»

Ключевые слова и фразы: муаровый узор; электронно-оптический муаровый эффект.

Аннотация: Предложена методика измерения напряженности электрического поля с помощью электронно-оптического муарового эффекта. Проведены экспериментальные исследования по получению теневых электронно-оптических изображений однородного и неоднородного электрических полей рассеяния, позволяющие наблюдать топологическую картину данного поля, при этом величина смещения теневого изображения искаженной сетки на экране электронографа служит мерой величины возмущающего поля. Установлено, что полученная топологическая муаровая модель исследуемых полей может быть использована в качестве метрологического обеспечения при анализе данных полей.

Forschung der elektrischen Felder der elektrischen Ausrüstung der Radioelektronik

Zusammenfassung: Es ist die Methodik der Messung der Gespannheit des elektrischen Feldes mit Hilfe des elektronenoptischen geflammten Effektes angeboten. Es sind die experimentalen Forschungen nach dem Erhalten der schattigen elektronenoptischen Darstellungen der gleichartigen und ungleichartigen elektrischen Felder des Zerstreuens, die das topologische Bild des gegebenen Feldes zu beobachten zulassen, durchgeführt. Dabei dient die Größe der Verschiebung der schattigen Darstellung des verzerrten Netzes am Bildschirm des Elektronographs zum Maß der Größe des empörenden Feldes. Es ist festgestellt, dass das bekommene topologische geflammte Modell der untersuchten Felder als metrologische Versorgung bei der Analyse der gegebenen Felder verwendet sein kann.

Etude des champs électriques de l'équipement électrique de la radioélectronique

Résumé: Est proposée la méthode de la mesure de la tension du champs électrique à l'aide de l'effet électronique optique de moire. Sont effectuées les études expérimentales pour obtenir des images électroniques et optiques ombragées des champs électriques homogènes et hétérogènes de dispersion permettant d'observer l'image topologique de ce champs, la grandeur du décalage de l'image ombragée du réseau altéré sur l'écran de l'oscillographe servant de la mesure de la grandeur du champs perturbé. Est établi que le modèle topologique de moire obtenu peut être utilisé en qualité de l'approvisionnement métrologique lors de l'analyse de ces champs.
