Maria A. Nazarkevych[1], Ivanna M. Dronyuk[1], Oksana A. Troian[1]

METHOD OF ELECTRONIC AND PRINTED DOCUMENTS PROTECTION ON THE BASIS OF MOIRE EFFECT

The article presents a method of protection based on graphics elements, to build which the moire effect is used. This method can provide high level of information protection in its printed or electronic form leaving out the opportunities for falsification, even by the best of today's copiers. The possibility of using the method offered for protecting information is analyzed.

Keywords: *multimedia technologies; information security; moire effect; printed document; graphic protection.*

Марія А. Назаркевич, Іванна М. Дронюк, Оксана А. Троян

МЕТОД ЗАХИСТУ ЕЛЕКТРОННИХ ТА ДРУКОВАНИХ ДОКУМЕНТІВ НА ОСНОВІ ЕФЕКТУ МУАРУ

У статті розглянуто новий метод захисту на основі графічних елементів, для побудови яких використовується ефект муару. Даний метод зможе забезпечити високий рівень захисту інформації в друкованому або електронному вигляді, не залишаючи можливості для фальсифікації, навіть на кращих сучасних копіювальних пристроях. Проаналізовано можливість використання запропонованого методу для захисту інформації.

Ключові слова: *мультимедійні технології; захист інформації; ефект муар; друкований документ; графічний захист.*

Форм. 14. Рис. 10. Літ. 12.

Мария А. Назаркевич, Иванна М. Дронюк, Оксана А. Троян

МЕТОД ЗАЩИТЫ ЭЛЕКТРОННЫХ И ПЕЧАТНЫХ ДОКУМЕНТОВ НА ОСНОВЕ ЭФФЕКТА МУАРА

В статье рассмотрен новый метод защиты на основе графических элементов, для построения которых используется эффект муара. Данный метод сможет обеспечить высокий уровень защиты информации в печатном или электронном виде, не оставляя возможности для фальсификации даже на лучших современных копировальных устройствах. Проанализирована возможность использования предложенного метода для защиты информации.

Ключевые слова: *мультимедийные технологии; защита информации; эффект муара; печатный документ; графическая защита.*

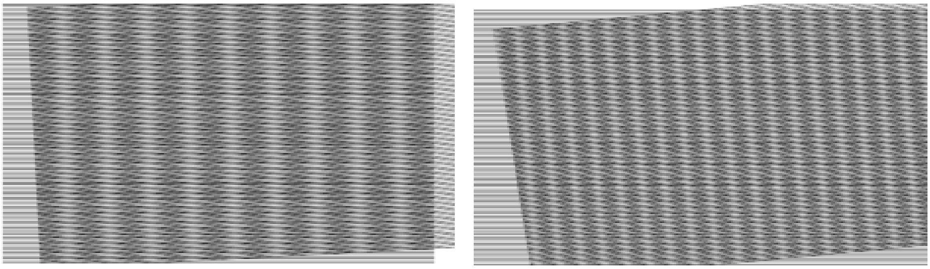
Intoduction. At this stage of society development an urgent problem of protecting electronic documents arises. Analyzing economic losses from falsification of multimedia publications in the Internet, we have concluded that there is a critical need for protection of documents from possible threats by means of moire. The relevance of this study lies in the fact that multimedia technologies (because of their abilities) make it possible to actively use computer, including software, protection. Multimedia technologies may be applied for almost any types of information use in the Internet (ISO 32000-1:2008). Application of multimedia technology makes it possible to obtain a lot of information in an accessible form with minimal resource consumption. Due to this fact multimedia technologies gain more expansion and popularity. This

[1] National University "Lviv Polytechnics", Ukraine.
[2] National University "Lviv Polytechnics", Ukraine.
[3] National University "Lviv Polytechnics", Ukraine.

method is the best one in relation of reliability and efficiency criteria. However, to improve the level of documents protection it is necessary to permanently introduce new methods (Sabanov, 2010), which should take into account the technical characteristics of today's copying machines to make document forgery economically unprofitable. The main objective of this paper is to create the protection method based on graphic elements, to build which, the moire effect is used.

Moire phenomenon occurs when taking digital photography of the originals of printed images with special parallel structures or during their scanning. This phenomenon is quite undesirable in printing reproduction. One struggles with moire in preprinting processing of documents, trying to avoid or reduce it to a minimum. The nature of this phenomenon is optical, moire is a pattern formed by the superposition of several periodic structures (Hersch and Chosson, 2006). Also moire occurs due to improper installation of disposition angles while separated output of films in the processes of formation of a document in color.

To illustrate the formation of moire we will consider two periodic superimposed on each other structures built in parallel lines of 0.25 pt thickness and distance between the lines of 0.25 pt. We will form moire by turning the upper structure at a specific angle. Figure 1 shows the moire effect formed when imposing the structures described.



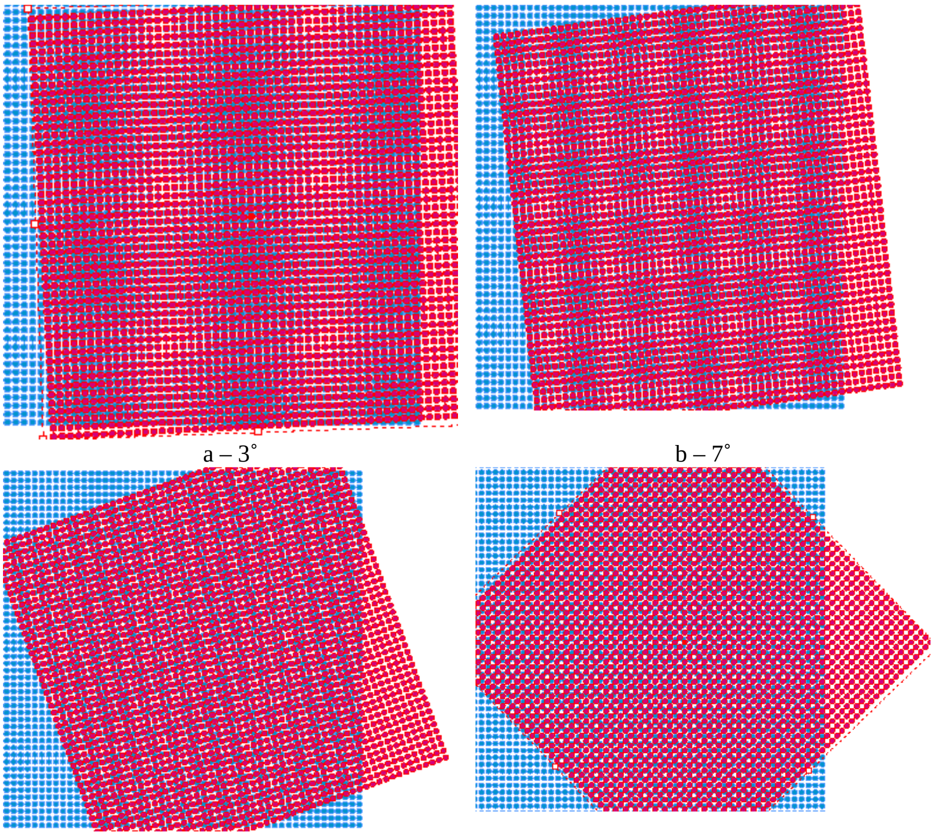
a – 3°　　　　b – 7°

Figure 1. **Moire grids formed while turning the periodic structures,** *developed by the authors*

Moire, as 10 dark areas at the turning of two structures at 3° and when turning at 7° – 20 one dark areas, is observed in Figure 1. With further increase of the angle of rotation, the frequency of repetition of the moire effect increases sharply. The problem of mathematical modelling of a moire effect based on multiple periodic grids is considered in this article. The method of electronic documents protection with multimedia moving of moire image and print documents is built basing on this model.

Figure 2 shows moire formed when two grids overlay, these grids are formed by dots that are close to polygraphic raster. Because while printing documents the image is formed by converting into raster dots that are equidistant from each other in the amplitude modulation or non-equidistant from each other while rasterizing by the stochastic method. The latter case is not considered, since moire is not observed in such rasterizing.

Moire as three dark areas during the displacement of two structures at 30, and when displaced at 70 – 6 dark areas, is observed in Figure 2a. There are several types of moire sockets shown in Figures 2c and 2d.



a – 3° b – 7°

c – 20° d – 45°

Figure 2. **Moire grids formed while turning the periodic structures,** *developed by the authors*

Formulation of the problem. A document that requires protection should contain a large number of fine lines. During this thin parallel lines are built to the thickness of 0.25 mm which considerably complicates copying on the office or scanner machinery (NIST, 2014). When copying such document moire grid is created which distorts the appearance of the document and leads to the distortion of forms or even complete loss of picture elements in the copy. The method of protection that is built on identifying moire effect allows easy distinguishing between the fake copy and the original one. In this regard, printed documents must contain security elements done in thin lines with less optical resolution of repetitions, the value of which will be less than the basic resolution of copying or scanning machinery.

The protection technology involves that the document will be printed in polygraphic method with protective elements. When malefactor tries to forge the document, defensive elements will form the moire (Amidror, 2003). So, using the moire effect printed documents can be protected. But the described method can also be used to form the animated moving image of moire effect while smooth patterns rotation of one structure in relation to the other as described above. Formed animation can be written in the .tiff format and used to create secured multimedia documents.

The essence of the designed method is to create an electronic document with protective elements which are based on the moire effect. Protective elements are created by the vector method and introduced into a file based on the pdf technology. When trying to digitize a printed document and its falsification the moire effect will be formed which is easy to see. For electronic documents security elements are multimedia with moving moire image, a mathematical model of which is obtained in this study.

In general case periodic structures may be identical and different. Mathematical model of moire formation for identical structures is built in (Shevchuk, 2002). This study covers such identical structures with multiple periods, and structures with different line widths are considered.

Recent research and publications analysis. For building technologies to protect documents with the moire formation based on the multiple periodic grids the works of E. Gabrielyan (2007) are used. While (Amidror, 2000) considers the model of moire by building a thin circular curves or lines that while copying form moire and thus protect documents from forgery.

Formulation of the article objectives. The construction of protection method of print and electronic documents based on a mathematical model of moire with multiple or variable thickness periodic grids is a topical task. This technology will protect documents more reliably and efficiently. Multimedia is the merging of text, computer graphics, audio and digitized video which are controlled by interactive software (Sabanov, 2010). Nowadays the world has seen a new phase of computerization of various activities caused by the development of multimedia technologies. Graphics, animation, photo, video, audio, text in the interactive mode of work create integrated information environment in which the user finds new opportunities (Yudin et al., 2009).

The main threats to the systems of electronic document management systems may be classified as follows (Dosmuhamedov, 2009):

- threat to integrity is damage, destruction or distortion of information that can be either unintentional in the cases of errors and failures, or malicious;
- privacy threat is any breach of confidentiality, including theft, interception, changing the route etc.;
- accessibility threat is a threat that gives opportunity for the allowable time to get the right information to side users.

Protection against these threats to some extent should be implemented by a system based on the document protection elements of moire.

The main objective of this paper is to create a protection method based on graphics, to build which the moire effect is used. This method would ensure a high level of protection of information in its printed or electronic forms, leaving out the opportunities for falsification even in the best of modern copiers.

Key research findings.

Technological characteristics of the designed method of protection. To develop protective elements, we will consider the structure of parallel and equidistant lines that form a moire phenomenon when crossing them at an angle. Moire occurs when applying raster periodic structures, resulting in other periodic structure obtained (Korchenko et al., 2010). The formed structure gets its own period different from the period of the raster structure. Formed at a certain angle of forming the lines, moire is noticeable when copying. We consider several known variants (Amidror, 2000) of forming the elements with different slope angles, and slope angle effect on forming the moire. The greater is the angle between two periodic structures, the greater is the period of moire formation. If parallel structures are superimposed onto one another with the angle of 5°, moire becomes well visible, when increasing the angle the moire is even more noticeable, as illustrated in Figure 1.

Moire effect arises from the breach of perception of information and distortion of original image; in particular, uneven changes of shades and colors are received. Obtaining of such moire effects is difficult to predict because the effect depends strongly on specifications and configuration of equipment used for reproduction. We will study moire effect in detail. Moire lines are created by the intersection of the basic and auxiliary layers as shown in Figure 3.

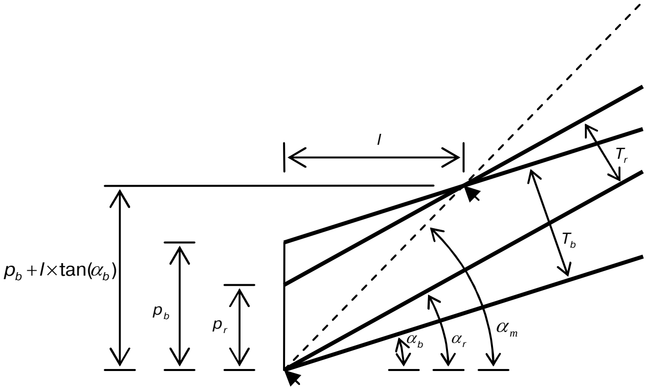


Figure 3. **Scheme of the formation of moire lines depending on the angle** α **of basic and auxiliary layers (Amidror, 2000),** *developed by the authors*

Figure 3 shows that the base layer contains lines equidistant from the period and are at an angle α_r to the beginning of the coordinate system. Auxiliary layer will have a repetition period of the lines T_b and slope α_b. When imposing basic and auxiliary layer moire grid is created as shown by dotted line (Figure 3). The figure also shows that the knots of the moire grid will have length l and will be located at an angle α_m. Projections on the vertical axis of the base and auxiliary layer p_b and p_r.

The figure described above implies that:

$$\begin{cases} \tan\alpha_m = \dfrac{p_b + l \times \tan\alpha_b}{l} \\ \tan\alpha_r = \dfrac{p_b - p_r + l \times \tan\alpha_b}{l} \end{cases}. \quad (1)$$

Therefore:

$$\tan\alpha_m = \frac{p_b \times \tan\alpha_r - p_r \times \tan\alpha_b}{p_b - p_r}. \quad (2)$$

On trigonometric ratios we have: $T_b = p_b$ x $\cos\alpha_b$; $T_r = p_r$ x $\cos\alpha_r$; $T_m = p_m$ x $\cos\alpha_m$.

Substituting into the formula (2) we obtain:

$$\alpha_m = \arctan\left(\frac{T_b \times \sin\alpha_r - T_r \times \sin\alpha_b}{T_b \times \cos\alpha_r - T_r \times \cos\alpha_b}\right), \quad (3)$$

after some transformations we obtain:

$$T_m = \frac{T_b \times T_r}{\sqrt{T_b^{\ 2} + T_r^{\ 2} - 2 \times T_b \times T_r \times \cos(\alpha_r - \alpha_b)}}. \quad (4)$$

Quality control. For effective information security it is important to ensure high quality of information security. The higher is the degree of protection the harder it would be to forge. Contemporary technologies allow faking almost everything, but there is an issue of economic criteria for creating a fake, that is the cost and the time to create a fake. The main objective of protection is to make counterfeiting unprofitable. Clearly, the increase in quality of documents security leads to increased costs of fraud. Thus, after considering various cases of documents protection one can come to the conclusion that the most secure document can be developed.

Let us consider partial cases of forming moire grids.

Case 1. *Basic and auxiliary layers are built in the same way,* so their periods coincide, that is $T_b = T_r$.

If two grids are identical, then we will justify the formation of moire when basic and auxiliary layer of grids are displaced at a certain angle, and therefore their periods coincide, that is $T_b = T_r$.

Let us consider the case when there are two identical grids which we will rotate at an angle. The first grid will be rotated at the angle α_r, and the second for α_b. If the grids are the same, their repetition period is also the same from where $T_b = T_r$ (Figure 4).

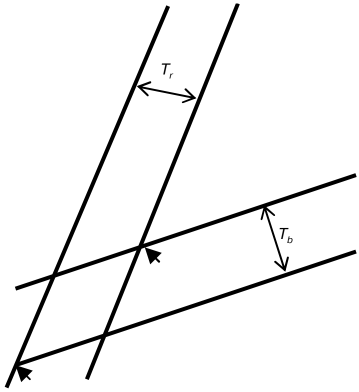


Figure 4. **The case of identical grids,** $T_b = T_r$**,** *developed by the authors*

From the formula (4) we obtain:

$$T_m = \frac{T_b^{\ 2}}{\sqrt{2T_b^{\ 2} - 2 \times T_b^{\ 2} \times \cos(\alpha_r - \alpha_b)}}. \quad (5)$$

Thus, we get:

$$T_m = \frac{T_b}{\sqrt{2\times(1-\cos(\alpha_r - \alpha_b))}}; \tag{6}$$

$$T_m = \frac{T_b}{\sqrt{2\times(\cos\alpha_r \cos\alpha_b + \sin\alpha_r \sin\alpha_b)}}. \tag{7}$$

If we assume that $\alpha_r = 0$, than $\cos\alpha_r = 1$

$$T_m = \frac{T_b}{\sqrt{2\times \cos\alpha_b}}. \tag{8}$$

From the formula (3) with at $\alpha_r = 0$, $T_b = T_r$ it follows that:

$$\alpha_m = \arctan\left(\frac{\sin\alpha_r}{\cos\alpha_r - 1}\right). \tag{9}$$

Let us construct from (9) the dependence of the moire grid angle α_m from the angle of inclination of the basis of the grid α_r. If $\alpha_r = 0$ grids match, than moire is not reproduced.

Let us construct the dependence of the period of the moire grid in case when the period of base and main layer of the grids are identical. This dependence is described by the formula (8).

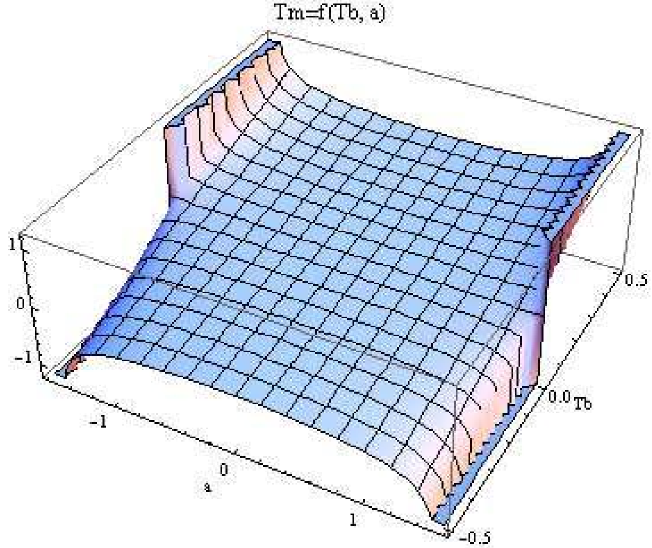


Figure 5. **The dependence of the period of change of moire grid T_m on the angle of inclination of the base layer α_b and the period of the base layer T_b,** *developed by the authors*

Figure 5 shows the dependence of the period changes of the moire grid T_m on the angle of inclination of the base layer grid α_b and the period of the base layer T_b. From the figure it follows that if small changes in the angle of inclination of the base and the main layer, the moire grid dramatically changes its period. In Figure 6 the dependence of the period of moire grid T_m change on the angle of inclination of the grid of base layer α_b and the period of the base layer $T_b \in [0..0{,}01]$ is carried out. The graph shows that the smaller is the grid period of the base layer, the bigger and more noticeable is the size of moire grid, as illustrated in Figure 6. Therefore, the period of change of lines of base layer $T_b \in [0..0{,}01]$ was chosen for further research.

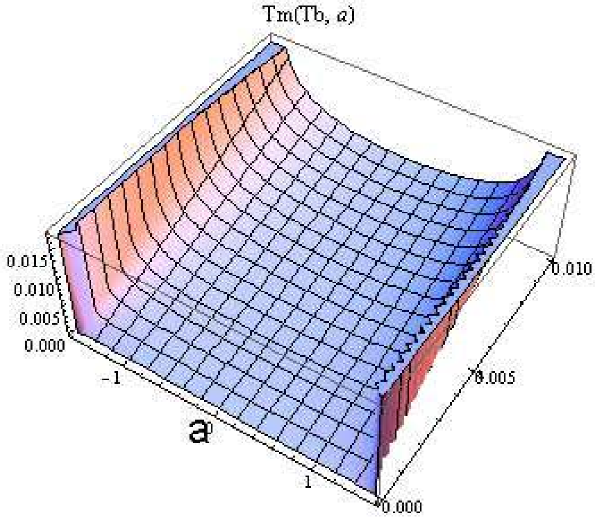


Figure 6. **The dependence of the period of change of the moire grid T_m on the angle of inclination of the grid of base layer α_b and the period of the base layer $T_b \in [0..0{,}01]$,** *developed by the authors*

Case 2. *The auxiliary layer has a period k-times smaller than the period of the base layer*, so $T_b = kT_r$.

If one of the grids has period k-times bigger than the other grid, then we will study a model forming the moire of basic and auxiliary layer. We will consider the case when one of the grids has a period twice bigger in the base layer. We will rotate grids to different angles, the first grid we will rotate at the angle α_r and the other one – at α_b. From (4) we get:

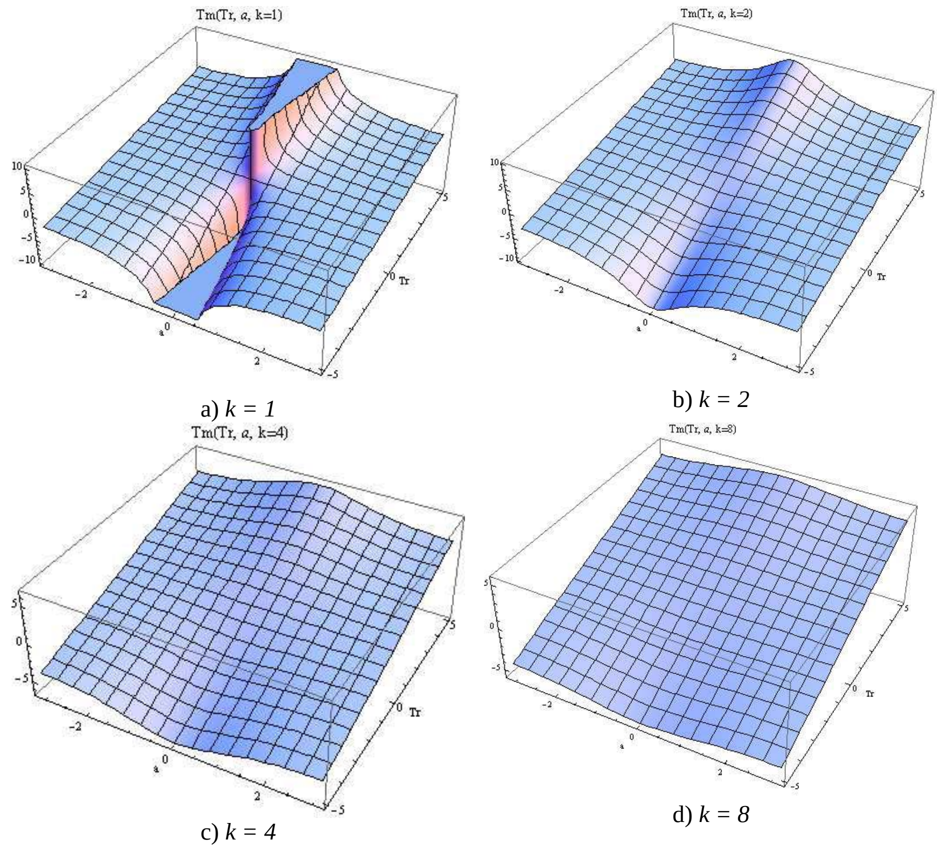
$$T_m = \frac{kT_r^2}{\sqrt{k^2T_r^2 + T_r^2 - 2 \times kT_r^2 \times \cos(\alpha_r - \alpha_b)}}. \quad (10)$$

After transformation it follows:

$$T_m = \frac{kT_r}{\sqrt{k^2 + 1 - 2k\cos(\alpha_r - \alpha_b)}}. \quad (11)$$

Let us construct the dependence of the angle of rotation of basic and auxiliary layer of grids, the period of the auxiliary layer from the period of change of moire grid T_m. The dependences are presented in Figure 7. The study was conducted for 4 cases in which period of the base layer were 1, 2, 4 and 8 times bigger than the auxiliary one.

Accordingly, we received four figures of the period dependence change of the moire grid T_m on the angle of inclination α_b and the period of basic layer T_r.



a) *k = 1*

b) *k = 2*

c) *k = 4*

d) *k = 8*

Figure 7. **Dependence of the period of change of the moire grid T_m on the angle of inclination of the grid of base layer α_b and the period of the base layer** $T_r \in [0..0{,}01]$, *developed by the authors*

Let us consider the case when the periods of base and auxiliary layer are the same (Figure 7a). From the figure it follows that the period of moire increases sharply at small angles of rotation between the base and auxiliary layers. The research continued and found that the period of moire grid Tm changes in the angle of rotation of -200 to + 200, so Figure 7a shows a sharp increase of Tm. Figure 7b shows the case when the auxiliary layer is twice less than the base period. Graph of the dependence has much smoother character. Consequently, the angles of rotation between the base and the auxiliary layers influence less the formation of period of moire grid. Figures 7c and 7d show the cases of even greater change between the periods of the base and auxiliary layers. Graphic representations imply that moire grid period becomes smaller.

Case 3. *The thickness of lines on the base layer l^* is greater than the thickness of auxiliary layer*, so $T_b = T_b + l^*$.

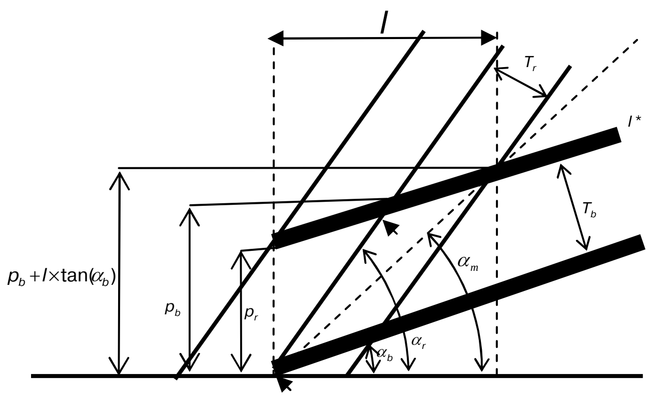


Figure 8. **Scheme of formation of moire lines, depending on the slope angle α of basic and auxiliary layers,** *developed by the authors*

From formulas (1), (2) and $T_b = p_b \times \cos\alpha_b - l^*$; $T_r = p_r \times \cos\alpha_r$; $T_m = p_m \times \cos\alpha_m$.

It follows that:

$$\tan\alpha_m = \frac{(T_b + l^*) \times \sin\alpha_r - T_r \times \sin\alpha_b}{(T_b + l^*) \times \cos\alpha_r - T_r \times \cos\alpha_b}. \quad (12)$$

It is known from (Amidror, 2000): $p_m = (p_b \times p_r) / (p_b - p_r)$.

From here:

$$T_m = \frac{(T_b + l^*) \times T_r \times \cos\alpha_m}{(T_b + l^*) \times \cos\alpha_r - T_r \times \cos\alpha_b}. \quad (13)$$

We know that:

$$\cos\alpha_m = \frac{1}{\sqrt{1 + tg^2\alpha_m}}.$$

Substituting into the formula (12) we obtain:

$$\cos\alpha_m = \sqrt{\frac{(T_b + l^*) - T_r}{(T_b + l^*)(\cos\alpha_r - \sin\alpha_r) - T_b}}$$

Hence it follows that:

$$T_{m=} \frac{(T_b + l^*) \times T_r \times \sqrt{\frac{(T_b + l^*) - T_r}{(T_b + l^*)(\cos\alpha_r - \sin\alpha_r) - T_b}}}{(T_b + l^*) \times \cos\alpha_r - T_r}. \quad (14)$$

The essence of the given model is to create an electronic document which will be protected by multimedia element created by the program PostScript, which creates 99 basic element layers +1 base layer that provides the reliability and efficiency of protection for a document in cyberspace. The next step is the generation of a text document in Word and the creation of a multimedia element in PostScript (Byram-Wigfield, 2010).

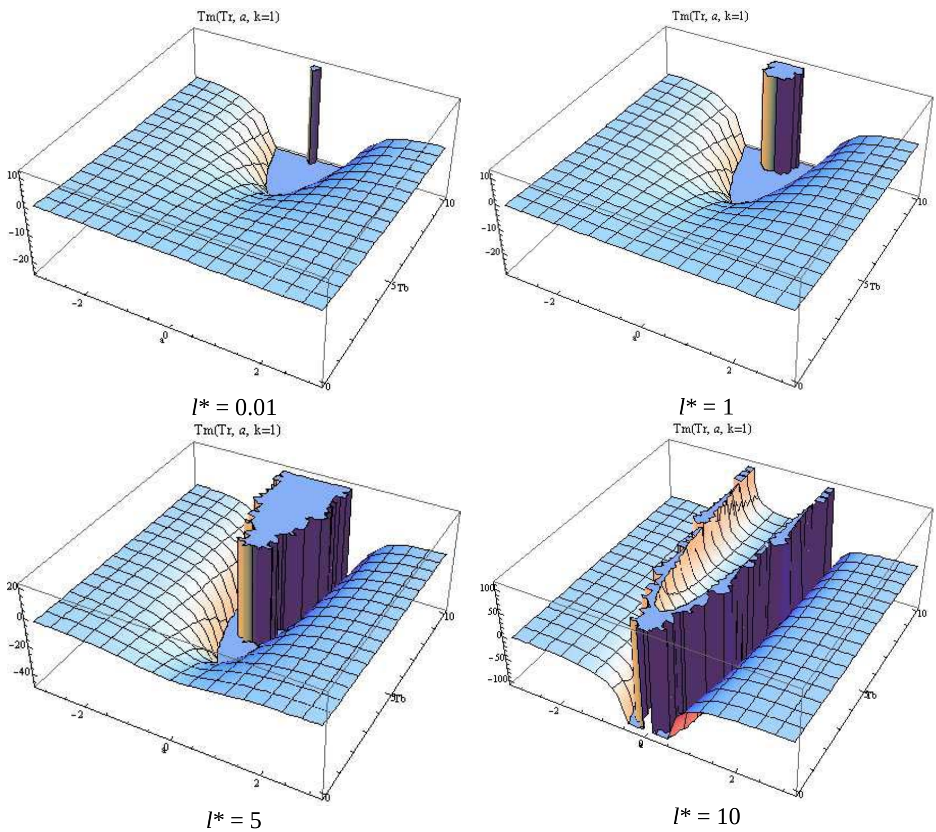


Figure 9. **Dependence of the period of change of moire grid on the angle of the base layer and the period of the base layer** $T_b \in [0,10]$, *developed by the authors*

The resulting document stored in the database will be protected from threats of hacking and fraud, so that the program cannot generate multimedia element while copying in another environment which would indicate fraud.

Figure 10 shows the example of the formation of multimedia mobile element on the basis of moire effect.

The main advantage of the method offered is the possibility of implementing multimedia or mobile security elements with the use of standard hardware and software.

The method is economically viable and reliable. Protective moving elements are formed on the basis of moire effect, formed by two structures of parallel lines. Even more difficult to counterfeit and therefore more reliable are multimedia security elements formed by combining two parallel structures of lines while moving in a circle with changing slope angles, thus moire images are formed. When forging, created hidden security elements become visible and thus we can identify a fake. The developed method of protection is effective and difficult to forge as hidden image becomes visible in the process of creating copies of a document.

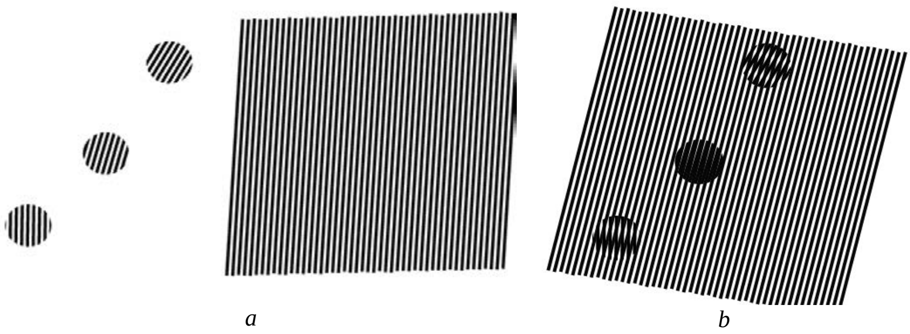


Figure 10. **Example of moire multimedia image that "moves" while superpositioning the layer at an angle,** *developed by the authors*

The results of the study can be used to protect printed documents that require effective protection and identification, and also for information protection in its electronic form by multimedia security elements.

Conclusions. A method providing reliable data protection in electronic and printed documents is created. The essence of the method is to design the elements of graphic protection, namely security elements based on moire in hidden elements. The method of document protection that improves the efficiency of protection based on moire effect is designed. Since introduction and implementation of this method does not require large financial costs, the developed method can be widely used to protect various documents.

The main advantage of the designed method is the possibility of implementation using standard hardware and software tools. The method is economically viable and reliable. Protective elements are created on the basis of moire which is formed by two structures of parallel lines. The method of protection, when two structures are combined at the angle and thus moire image is formed, is even more difficult to forge, and therefore more reliable. Created hidden security elements become visible while forging and thus a fake can be detected. The developed method of protection is effective and difficult to forge as hidden image becomes visible in the process of creating copies.

This study is of significant importance as scientific and technological development in the field of graphic information security. Our results can be used to develop protective elements of securities, accounting documents and other printed documents which need effective protection and identification and also for the protection of information in electronic form.

References:

Досмухамедов Б.Р. Анализ угроз информации систем электронного документооборота // Компьютерное обеспечение и вычислительная техника.– 2009.– №6. – С. 140–143.

Сабанов А.А. Некоторые аспекты защиты электронного документооборота // Мир связи.– 2010.– №7. – С. 62–64.

Шевчук А.В., Музика В.П. Система захисту цінних паперів та документів суворого обліку – наукоємна проблема державного масштабу // Друкарство.– 2002.– №4. – С. 72–74.

Юдін О.К., Конахович Г.Ф., Корченко О.Г. Захист інформації в мережах передачі даних. – К.: DIRECTLINE, 2009. – 714 с.

Amidror, I. (2000). The Theory of the Moire Phenomenon. Kluwer Academic Publisher.

Amidror, I. (2003). Glass patterns in the superposition of random line gratings. Journal of Optics A: Pure and Applied Optics, 28 March: 205–215.

Byram-Wigfield, D. (2010). Practical PostScript. A Guide to Digital Typesetting // www.computer-books.us.

Gabrielyan, E. (2007). Moire pointer for measurement instruments. Switzernet Research Reports, 4 August 2007.

Hersch, R.D., Chosson, S. (2006). Model-based synthesis of band moire images for authenticating security documents and valuable products. Published US Patent Application No. 2006/0003295.

ISO 32000-1:2008 – Document management – Portable document format – Part 1: PDF 1.7 // www.iso.org.

Korchenko, O., Vasiliu, Y., Gnatyuk, S. (2010). Modern quantum technologies of information security against cyberterrorist attacks. Aviation (Vilnius: Technika), 14(2): 58–69.

National Institute of Standards and Technology (NIST). Latent Interoperability Transmission Specification. NIST Special Publication 1152, January 2013 // nvlpubs.nist.gov.

Стаття надійшла до редакції 26.11.2015.