Level of electromagnetic safety of graphic digital interface

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***Abstract*—Nowadays, when we have a strong presence of computers in our everyday lives the protection of electronically processed information using digital machines becomes very important. It is related to accidental formation of electromagnetic fields which are correlated with processed information. Although many protective measures are taken a phenomenon of electromagnetic leakage information still poses a great threat. Therefore, methods supporting information protection against the so-called electromagnetic infiltration are still being developed. In addition, these methods would support security of data processing and perhaps replace some of the currently used solutions characterized by high costs of implementation, or a small degree of ergonomics. The article presents the results of the researches of Digital Video Interface from possibilities of manipulating the level of electromagnetic protection point of view using different colors of text and background. There was proposed color method and smoothing mode of edges of graphic characters as a solution supporting electromagnetic protection.**

Keywords—Digital Video Interface; electromagnetic safety; leakage information; electromagnetic eavesdropping; sensitive emission; Side Channel Attack

I. INTRODUCTION

VGA and DVI are video standards currently used among other things in nonpublic information systems. These standards are the object of the research on solutions that effectively protect processed graphical data. Most frequently, the only solutions used for electromagnetic data protection are those design-related which decrease the level of unwanted emissions at a source. Currently there are searched new methods based on software solutions which could change character of radiation source. The methods could be used to support other solution or they could be used alone. One of them are safe fonts so-called TEMPEST font (in the article the Simply Safe font was analyzed, Fig.2). Usefulness of these fonts was confirmed from electromagnetic protection point of view for analog graphic standard (DVI), digital graphic standard (DVI) and laser printers [1,2,3]. The collections of these fonts are resistant to Optical Character Recognize.

Therefore there are conducted additional tests different solutions which could support TEMPEST fonts. The use of several solutions could limit sensitivity of valuable emissions on electromagnetic eavesdropping.

In the article was analyzed two solutions: colors method [4] and smoothing mode of edges of font characters. These solutions directly apply to digital DVI standard which is a source of valuable emissions (Fig.1).

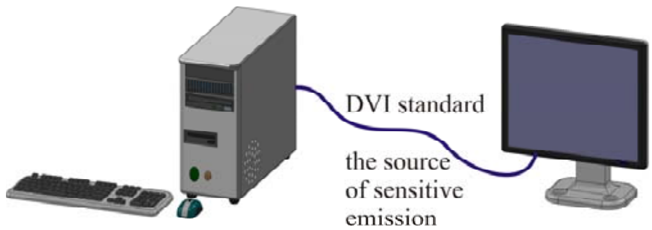


Fig.1. DVI standard as a source of sensitive emission.

The standard uses TMDS encoding method to transmit information about colors of characters and background. The method is effective when one color is used to display on screen each character of letters and one (another than first) is used display a background. About it decides smoothing mode of edges of characters available from level of Windows OS. We could select one of two smoothing mode of edges: Standard smoothing mode and ClearType smoothing mode. These modes are available in Windows 7 OS or newer. In Windows XP OS these modes could be turned off. This possibility is very advantageous from electromagnetic protection of information point of view [5,6].

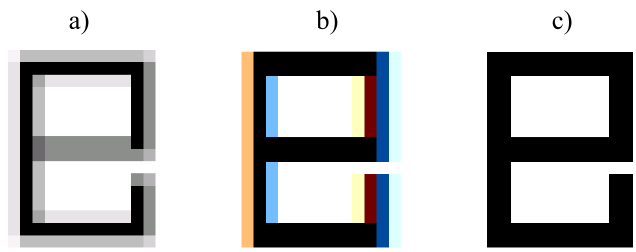


Fig. 2. Examples of smoothing modes of edges available in Windows OS: a) Standard smoothing mode of edges b) ClearType smoothing mode of edges, c) without smoothing mode – character of Simply Safe font.

The Standard smoothing mode smooths both vertical and horizontal edges of characters. Then each character is built from two colors. The main color is black. Between black color and background color (e.g white) additional grey color exists (Fig.2a). This phenomenon increases level of sensitivity of emission source. The ClearType smoothing mode smooths only vertical edges of characters. But the mode uses more colors to realize the smoothing of edges (Fig.2b).

II. Transition Minimized Differential Signaling encoding and colors method

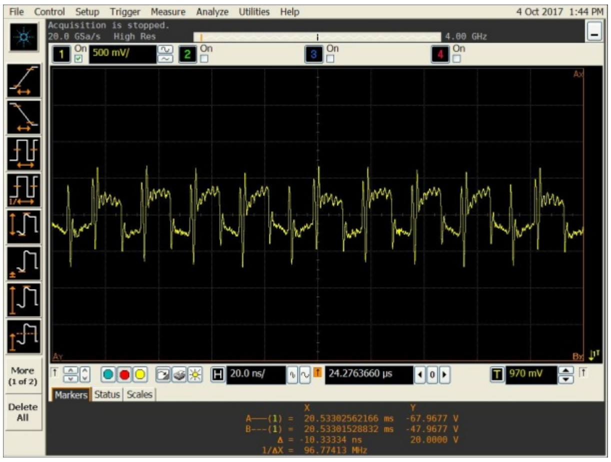
A. Sequence of bits

The TMDS encoding was the object of tests. The algorithm bases on 8-bit word in which the amplitude of pixel is written. Then the 8-bit word is changed into 10-bit word (Table 1, Fig. 3). The sequence of bits is transmitted from PC to a monitor. The process becomes a source of valuable emissions.

TABLE 1. EXAMPLES OF 8-BIT WORDS AND 10-BIT WORDS IN ALGORITHM OF TMDS ENCODING

Amplitude value of pixel	**8-bit word**	**First 10-bit word**	**Second 10-bit word**
0	00000000	0100000000	1111111111
8	00001000	0111111000	1100000111
238	11101110	0011110000	1000001111
255	11111111	0011111111	1000000000

a)



b)

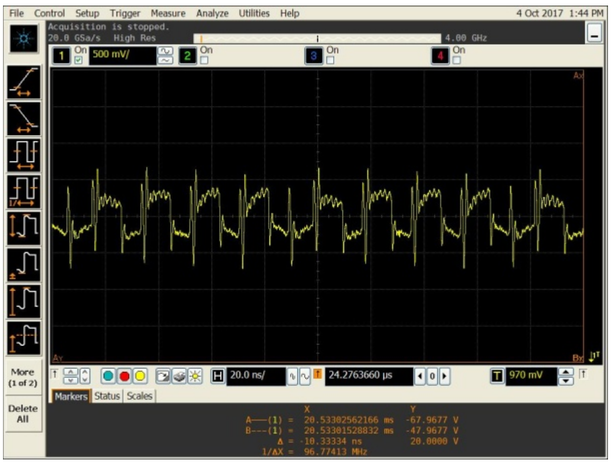


Fig. 3. Examples of bit sequences correspond to amplitude values of pixel equal 0 and 255.

The encoding process isn't very complicated. The main purposes the application of the encoding are limitation of the electromagnetic interference between the wires and increase the resistance of the communication standard to electromagnetic eavesdropping. However the process of data transfer in the form of digital electric signals becomes a source of radiated unwanted emissions. These emissions have features of the processed data, which in many cases allow to reproduce primary information [7]. It isn't possible for all pairs of colors characters and backgrounds.

Earlier was mentioned that the bits sequence is the source of sensitive emissions. When the sequences (color of characters and color of background) differ in properties, reconstructed images from the sensitive emission allow to identify characters on the background. For these pairs of colors the correlation function:

$$R(n)=\frac{\sum_{m=0}^{M-1}\left(y_{a\_(m+n)}-\bar{y}_{a\_n}\right)\cdot\left(y_{b\_m}-\bar{y}_{b}\right)}{\sqrt{\sum_{m=0}^{M-1}\left(y_{a\_(m+n)}-\bar{y}_{a\_n}\right)^{2}\cdot\sum_{m=0}^{M-1}\left(y_{b\_m}-\bar{y}_{b}\right)^{2}}}, \quad (1)$$

where:

$$\bar{y}_b=\frac{1}{M}\sum_{m=0}^{M-1}y_{b\_m}, \quad (2)$$

$$\bar{y}_{a\_n}=\frac{1}{M}\sum_{m=0}^{M-1}y_{a\_(m+n)}, \quad (3)$$

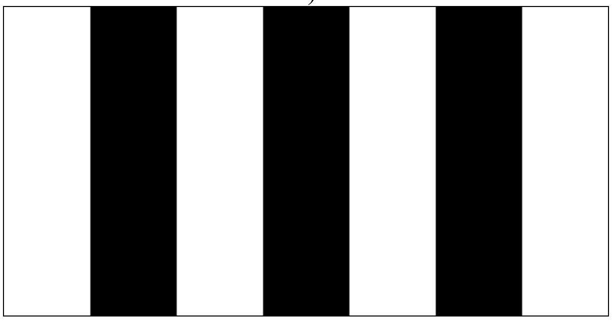
$$n=0,\cdots,2N-1, \quad (4)$$

M – number of bits, y_b – a reference signal (e.g. background), y_a – an analyzed signal, between corresponding bit sequences achieves low values. Taking into account the above we could infer there exist other pairs of colors for which the correlation function between corresponding bit sequences achieves higher values. Then the reading of characters on the background could be very hard. The phenomenon could be used in the process of protection of information against electromagnetic penetration. The only problem is the indication strongly correlated the pairs of colors.

B. Strongly correlated pairs of colors

Sequences of bits corresponding to images including two-color vertical strips (alternated colors) were analyzed (Fig.4). The amplitude values of pixels for these vertical strips were equal 255 and 0 and also 238 and 8. As was mentioned above each amplitude value of pixel is encoding according to TMDS algorithm. On the output of graphic card the sequences of bits exist.

a)



b)

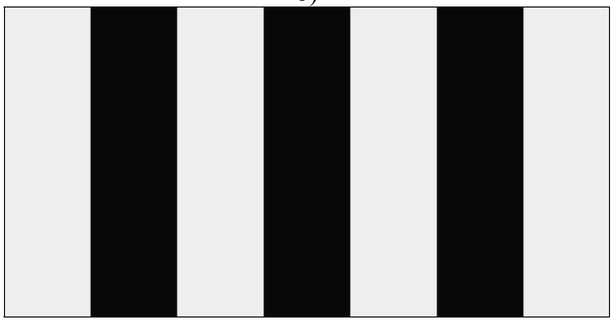
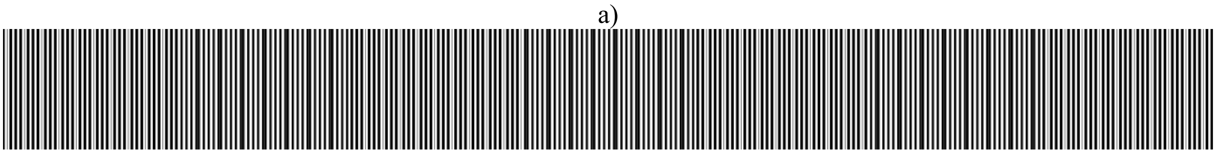


Fig. 4. Images consist on multi-colored lines to calculate correlation coefficients between sequences of bits: a) lines for amplitude values of pixels 255 and 0, b) lines for amplitude values of pixels 238 and 8.

a)



b)

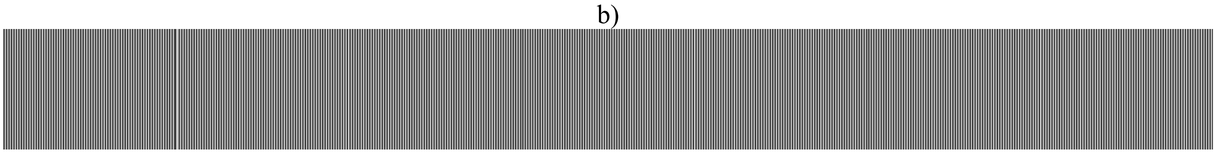
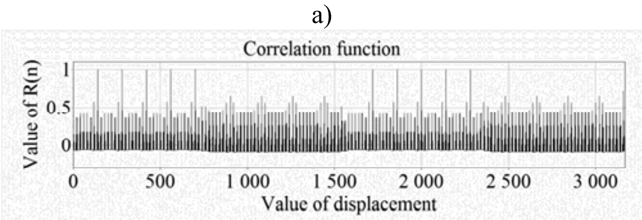


Fig. 5. Examples of bit images for two pairs of colors: a) 255 and 0, b) 238 and 8.

From the sequences we could build images (Fig.5). Basing on these images (the images of bits) are assessed similarity between different sequences of bits. Analyzing sequences of bits (Fig.5) we can noticed that for pair of colors 255 and 0 the places of color changes could be pointed very easy [8]. Additionally we see that the bit structures of sequences are very different for colors 255 and 0. For colors 238 and 8 the structures are similar. Therefore we can suppose that the legibility of reconstructed image from sensitive emission could be higher for pair of colors 255 (background) and 0 (text) than for pair of colors 238 (background) and 8 (text). The last pair could be recommended as a solution supporting electromagnetic protection. The values of correlation coefficients $R(n)$ confirm the assumption. According to the relation (1) the values of $R(n)$ were assigned (Fig.6).

a)



b)

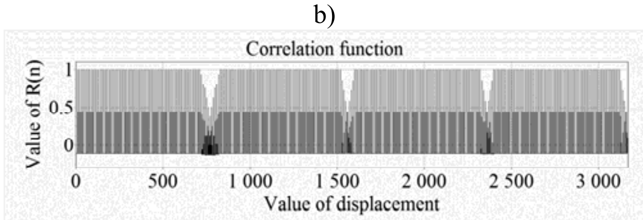
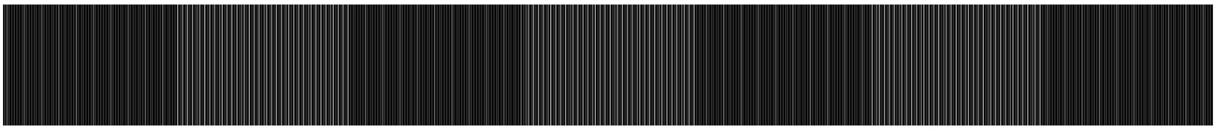


Fig. 6. The values of correlation coefficients $R(n)$ for two pairs of colors: a) 255 and 0, b) 238 and 8.

However from electromagnetic eavesdropping point of view the most important thing is a shape of sensitive emission on the output of Side Channel Attack [9,10]. The shape of the signal depends on SCA which has features of high-pass filter. It means that the signal of sensitive emission consists of impulses connected with pulse start and pulse finish of the signal on the input of SCA. The sequences of bits from Fig.5 take the shape which allow to reconstruct images in form as in Fig.7.

There are carried out a lot of analyses of similarity of bit sequences for more colors than two one. Unfortunately only several pairs of colors (two colors not more) can point for which values of correlation coefficient are very high. It is very important from the use of smoothing mode of edges point of view because the smoothing mode of edges inserts into characters of letter additional colors (Fig.2).

a)



b)

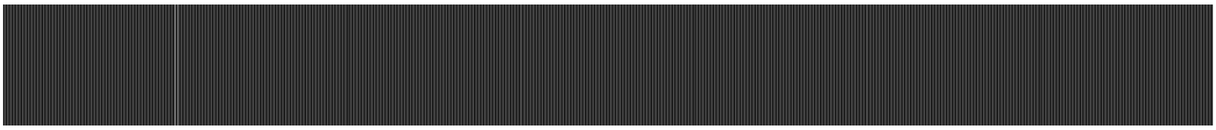
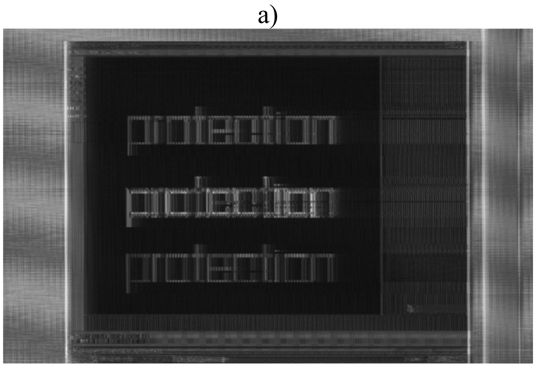


Fig. 7. Examples of bit images for two pairs of colors: a) 255 and 0, b) 238 and 8 which were reconstructed from signals of sensitive emissions on the output of SCA.

III. TESTS RESULTS

To tests were used Simply Safe font. The source of sensitive emissions was digital DVI standard. During the tests on the screen were displayed three words. For the first word (from the top) the smoothing mode of edges wasn't used. The edges of the second word were smoothing by Standard smoothing mode. The edges of characters of last word were smoothing by ClearType soothing mode. All tests were carried out inside of anechoic chamber. The signal of valuable emissions were measured on frequency 642 MHz [11]. In based on the emissions images were reconstructed (Fig.8).

a)



b)

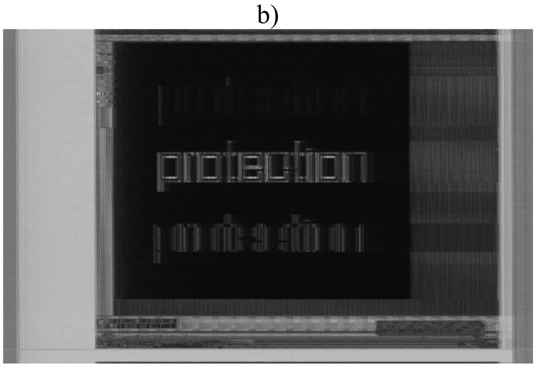


Fig. 8. Images (Simply Safe font) based on the reveal emission signals (BW = 100 MHz, signal frequency: f_o = 642 MHz): a) pair of colors 255 and 0, b) pair of colors 238 and 8 (there were used three smoothing modes of edges, from the top: without smoothing mode of edges, Standard smoothing mode of edges, ClerType smoothing mode of edges).

We see that for the pair of colors 238 and 8 and without smoothing mode of edges the signal of sensitive emission hasn't distinctive features which would allow to reconstruct primary information. For others smoothing modes the distinctive features exist. This is caused by presence of more than two colors of text and background.

However, we have to note that the phenomenon could not appear on the other frequencies. For example on frequency 591 MHz the word without smoothing mode of edges exists although the pair of colors 238 and 8 was used (Fig.9). Therefore the solution binding both colors method and smoothing mode of edges doesn't eliminate sensitive emissions [12,13]. The solution can limit number of frequencies on which valuable emissions could appear but only for case without of smoothing mode of edges.

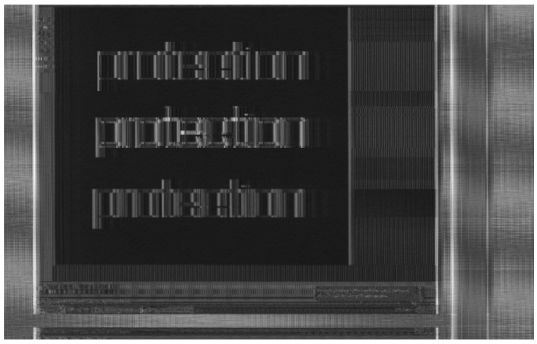


Fig. 9. Image (Simply Safe font) based on the reveal emission signal (BW = 100 MHz, signal frequency: f_o = 591 MHz) – pair of colors 238 and 8.

The colors method is very significant from electromagnetic eavesdropping point of view. As we know comparable colors (grey scale) e.g. 245 and 255 can't be used to process information. In this case the text data wouldn't be visible (245 color) on the background (255 color) or the reading of the data would be very hard (Fig.10). However the sensitive emission for this pair of color is very valuable. The using the reveal emission the text data could be reconstructed and the data are very well legible (Fig.11). It is differently from VGA

Fig.10. Image displayed in screen including text data in color 245 on the background in color 255 – invisible data.

Fig.11. The reconstruct image in base on theoretical sensitive emission corresponds to displayed image from Fig.10 (DVI standard as a source of emission, ClearType smoothing mode of edges).

standard. A low difference between amplitude values of text color and background color is very advantageous from protection of information point of view in area of VGA standard.

IV. CONCLUSIONS

In the article was carried out the analysis of the possibilities to use the available software solutions in the protection of information against the electromagnetic infiltration. The so-called colours method and smoothing mode of edges (especially the mode without smoothing edges) available in the Windows system were analysed. Each of the method can be used in the protection of information without reducing the quality and readability of characters shown on the computer screen. The Simply Safe font increases the level of protection of information. The most effective method is mode without smoothing edges and the pair of colours 238 and 8 (and also pairs 216 and 19, 210 and 22, 246 and 16, 232 and 44). However colours method doesn't reduce the sensitivity of DVI standard to electromagnetic eavesdropping. The method limits number of frequencies occurrence of sensitive emissions. In spite of all this phenomenon is very important from electromagnetic penetration point of view [14].

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