computers

Article

Font Design—Shape Processing of Text Information Structures in the Process of Non-Invasive Data Acquisition

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Received: 20 August 2019; Accepted: 17 September 2019; Published: 23 September 2019

Abstract: Computer fonts can be a solution that supports the protection of information against electromagnetic penetration; however, not every font has features that counteract this process. The distinctive features of a font's characters define the font. This article presents two new sets of computer fonts. These fonts are fully usable in everyday work. Additionally, they make it impossible to obtain information using non-invasive methods. The names of these fonts are directly related to the shapes of their characters. Each character in these fonts is built using only vertical and horizontal lines. The differences between the fonts lie in the widths of the vertical lines. The Safe Symmetrical font is built from vertical lines with the same width. The Safe Asymmetrical font is built from vertical lines with two different line widths. However, the appropriate proportions of the widths of the lines and clearances of each character need to be met for the safe fonts. The structures of the characters of the safe fonts ensure a high level of similarity between the characters. Additionally, these fonts do not make it difficult to read text in its primary form. However, sensitive transmissions are free from distinctive features, and the recognition of each character in reconstructed images is very difficult in contrast to traditional fonts, such as the Sang Mun font and Null Pointer font, which have many distinctive features. The usefulness of the computer fonts was assessed by the character error rate (CER); an analysis of this parameter was conducted in this work. The CER obtained very high values for the safe fonts; the values for traditional fonts were much lower. This article aims to presentat of a new solution in the area of protecting information against electromagnetic penetration. This is a new approach that could replace old solutions by incorporating heavy shielding, power and signal filters, and electromagnetic gaskets. Additionally, the application of these new fonts is very easy, as a user only needs to ensure that either the Safe Asymmetrical font or the Safe Symmetrical font is installed on the computer station that processes the text data.

Keywords: computer fonts; graphics; image processing; protection of text information; data acquisition; identification; recognition

1. Introduction

An important element in the daily processing of text information is the use of computers and computer fonts. There are many different computer fonts for a variety of applications. Most often, however, fonts are used to process text information, which is displayed on computer screens and printed. Arial and Times New Roman fonts are the most popular, and almost every text document is processed using these fonts. The characters of these fonts have decorative elements, such as ears, bowls, eyes, serifs, tails, terminals, brackets, and loops [1]. The characters have oval qualities, and the angles between the individual components vary from 90°; in addition, the widths of the line-building characters are variable [2], especially for Times New Roman.

During the processing of text data, each character of a font is represented in the form of an electrical signal. This signal is transmitted from a computer to a screen, or to a printer. The signal becomes a source of electromagnetic emissions, which contain the characteristics of the signal [3–5]. This makes it possible to reconstruct every processed character, and thus, all text displayed on a screen or printed in hard copy.

Side-channel attacks (SCA) play an important role in this process. An SCA is created between the source of the emission (how the electrical signal is transmitted—e.g., by video cables in a video graphics array (VGA), which is still very popular in non-public information systems, where the text information is first processed; digital visual interface (DVI); high-definition multimedia interface (HDMI); or display port standards) and an antenna, which receives these emissions (Figure 1). These are called valuable (sensitive) emissions [6–8].

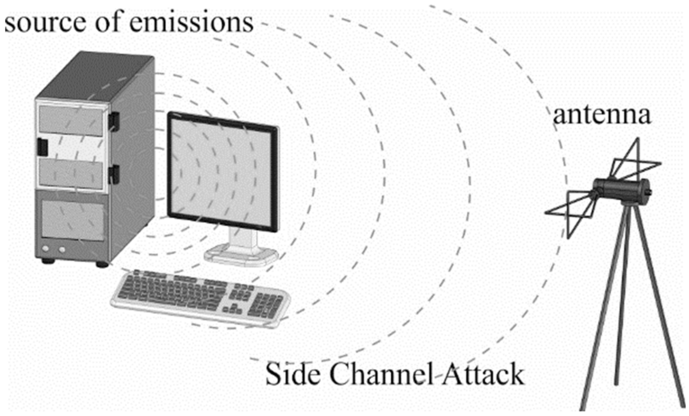
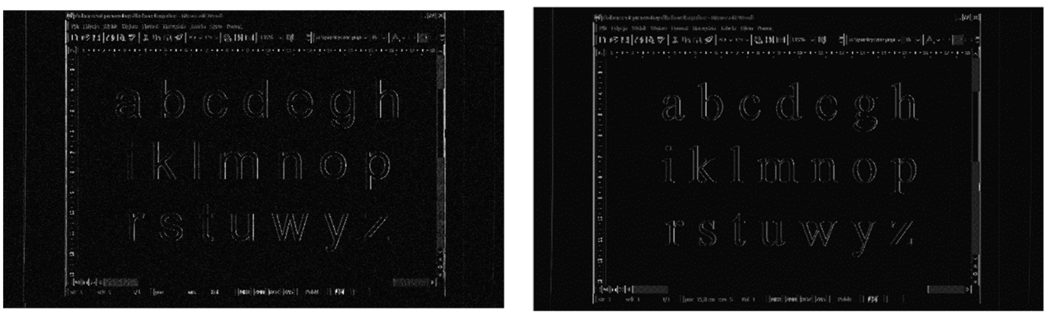


Figure 1. A side-channel attack (SCA).

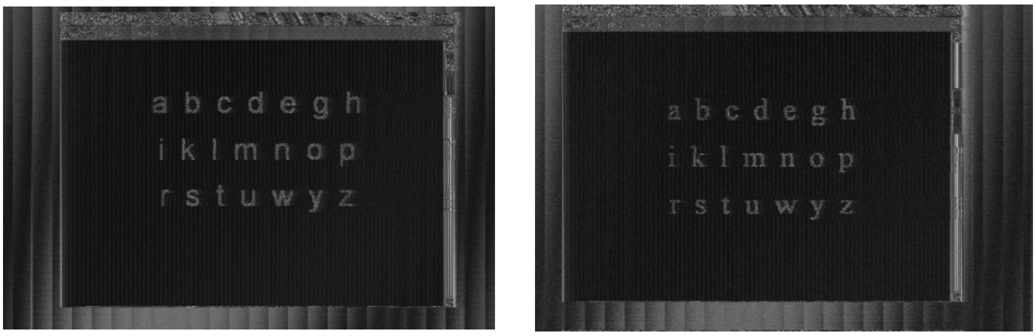
One type of SCA has the characteristics of a high-pass filter, which is an important property from the viewpoint of protecting information against electromagnetic infiltration processes. In the output of an SCA, only vertical and diagonal edges (rising edges and falling edges of electrical video signal pulses) are visible in reconstructed images. There are no visible horizontal edges. In the case of the analog VGA standard, reconstructed characters of fonts are marked by their vertical and diagonal edges. For the digital DVI (HDMI) standard, because of the nature of the transition-minimized differential signaling (TMDS) coding algorithm, character fills appear. This is related to the bit characters (0 and 1) of the electrical signal, and may result in the loss of processed information (Figure 2) [9,10].

The possibility of transferring the paper form of a text document to an electronic version (editable in software such as MS Word) using optical character recognition (OCR) programs is another feature of computer fonts. Not every document should be moved to an editable form. The appropriate characters of the fonts should counteract this process.



(**a**) (**b**)

Figure 2. *Cont.*

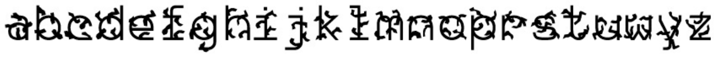


(**c**) (**d**)

Figure 2. Examples of the acquisition of information from sensitive emissions for text data and video graphics array (VGA) and digital visual interface (DVI) (high-definition multimedia interface, HDMI) standards: (**a**) Arial font and VGA standard; (**b**) Times New Roman font and VGA standard; (**c**) Arial font and DVI (HDMI) standard; (**d**) Times New Roman font and DVI (HDMI) standard.

Sang Mun tried to design such fonts. He created three sets of the fonts: Flower, Noise, and Cross (Figure 3). Each font fulfils its role and counteracts the OCR process. One font with features similar to safe fonts is Null Pointer (Figure 3d). The characters of the font do not have diagonal lines, but they have done distinctive features. These features (different widths of vertical and horizontal lines) allow the recognition of each character during the electromagnetic penetration process [11].

(a)



(b)

(c)

(d)

Figure 3. Sang Mun's fonts: (**a**) Flower, (**b**) Noise, (**c**) Cross, and (**d**) Null Pointer font.

Correlation coefficient values were our initial criterion for the assessment of traditional fonts, safe fonts, Sang Mun fonts, and Null Pointer font from the viewpoint of usefulness of the fonts in the process of electromagnetically protecting processed information. This applies to the characters of the fonts in the input of the SCA. Towards this purpose, there were used images containing characters of appropriate fonts (e.g., Figure 3). These images were analyzed. An individual character of each letter was a pattern. In this way, 253 correlation coefficient values were obtained. These values were divided into five similarity level ranges (Table 1). The safe fonts had the most values corresponding to rather strong and very strong relationships. Therefore, these fonts are a solution counteracting the electromagnetic penetration process.

Table 1. The number of relationships between the characters of the fonts in the input of the SCA for which the values of the character correlation coefficient *R* are included in the appropriate ranges of similarity.

Character Correlation Coefficient *R*	Number of Relationships (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$0.0 \leq R^Z < 0.2$ lack relationship	0	0	4	9	1	0	13	89
$0.2 \leq R^Z < 0.4$ weak relationship	1	6	87	98	35	35	167	129
$0.4 \leq R^Z < 0.7$ moderate relationship	78	95	129	129	165	175	73	35
$0.7 \leq R^Z < 0.9$ rather strong relationship	129	111	31	17	44	43	0	0
$0.9 \leq R^Z \leq 1.0$ very strong relationship	45	41	2	0	8	0	0	0

Legend: (1) Safe Asymmetrical font, (2) Safe Symmetrical font, (3) Arial font, (4) Times New Roman font, (5) Null Pointer font, (6) Sang Mun Cross font, (7) Sang Mun Flower font, (8) Sang Mun Noise font.

The safe fonts have both features. They are resistant to the electromagnetic infiltration process [12] as well as the OCR process.

The main purpose of this article is to show that text data can be protected by the use of special computer fonts. However, such fonts must have appropriate shapes that ensure a high level of similarity between the characters. To prove the usefulness of the safe fonts in the safe processing of text data, many tests were carried out using the safe fonts. The selected characters of these fonts were displayed on an eavesdropping screen. To assess the safe fonts, a visual method and the character error rate (CER) values were used. Reconstructed images from sensitive emissions were the basis for these analyses.

The Materials and Methods section of this article describes the construction principles of the safe fonts. Firstly, the principles apply to the widths of lines that build each character of the safe fonts. These construction requirements influence the high level of similarity between characters (i.e., high values of the character correlation coefficient). The Results section includes the results of tests conducted inside of an anechoic chamber. The tests were carried out on both traditional and safe fonts. The results allowed us to assess the usefulness of the new computer fonts in the safe processing of text data. The Discussion section includes considerations applying to the CER. The analyses were carried out for selected characters of the traditional and safe fonts. Additionally, the Sang Mun fonts and Null Pointer font were analyzed. The high level of similarity among the characters indicates that the Safe Symmetrical and the Safe Asymmetrical fonts could be used in the processing of classified information. The last parts (Patents, Appendix A) of this paper include information about the certificates of the safe fonts.

2. Materials and Methods

2.1. Construction of the Characters of the Safe Symmetrical Font

The Safe Symmetrical font is one of two computer fonts that was designed according to safety criteria [13,14]. This font can be used in the printing process and in computer techniques. This is a typical font used in the processing of text data (i.e., technical documentation, scientific documentation, advertising banners), particularly in the processing of classified data. The characters of the font are devoid of decorative and diagonal elements. The lines that build the characters intersect at right angles. The general contours of the Safe Symmetrical font characters have a rectangle shape. Each character is built from lines of about two widths. The wider lines are the vertical lines of the character, and the horizontal lines are thinner. Additionally, the correct proportions of the line widths and the clearance of each font character are maintained. The corresponding characters have ascenders and descenders. Since the font's characters do not have decorative elements, it means that the characters of the font are similar to each other, with high values of between-character correlation coefficient. Examples of the lowercase letters and numerical digits are shown in Figure 4.

Figure 4. The characters of the Safe Symmetrical font.

The construction of the characters meet the appropriate criteria to ensure protection against the electromagnetic eavesdropping process. These criteria concern the proportions of the line widths, the clearance, and the position of the middle horizontal line. Middle horizontal lines appear in the letters "e", "s", and "z". Details of the construction of the font's characters are shown in Figures 5 and 6. These figures contain basic data regarding the width of the characters, their height, as well as their ascenders and descenders. The important element of the construction affecting the readability of signs is the appropriate space between the lines.

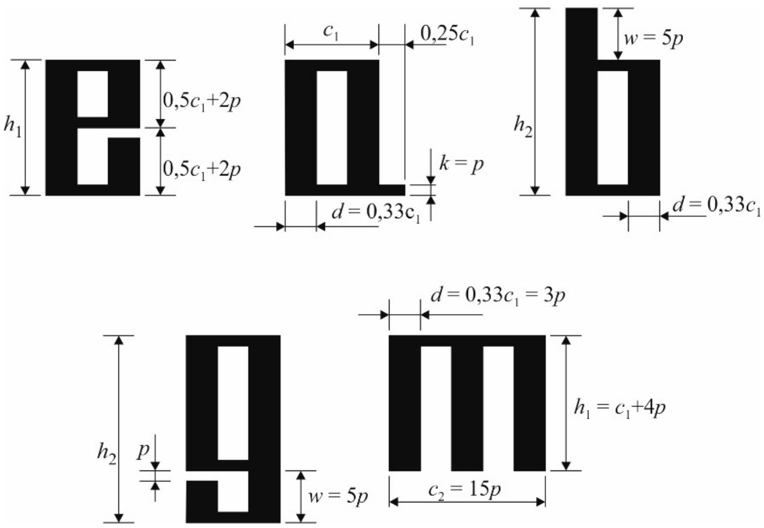


Figure 5. Construction of the lowercase letters of the Safe Symmetrical font.

The characters of the font were constructed with the required proportions of the line widths to the clearances as well as the appropriate position of the middle horizontal lines for characters that have such lines. This applies to the lowercase letters, capital letters, and digits (Figure 7).

The construction parameters of the characters of the Safe Symmetrical font are as follows:

(a) Height of the lowercase characters:

$$h_1 = 13\,p; \tag{1}$$

(b) Height of characters with ascender or descender (as well as the height of digits and capital letters):

$$h_2 = 18\,p; \tag{2}$$

(c) Width of the lowercase letters, capital letters, and digits (with the exception of "m"):

$$c_1 = 9\,p; \tag{3}$$

(d) Width of "m" (lowercase and capital letters):

$$c_2 = 15\,p; \tag{4}$$

(e) Width of vertical lines and the clearance between the vertical lines:

$$d = 3\,p; \tag{5}$$

(f) Width of horizontal lines:

$$k = 1\,p; \tag{6}$$

(g) Width of ascenders and descenders:

$$w = 5\,p. \tag{7}$$

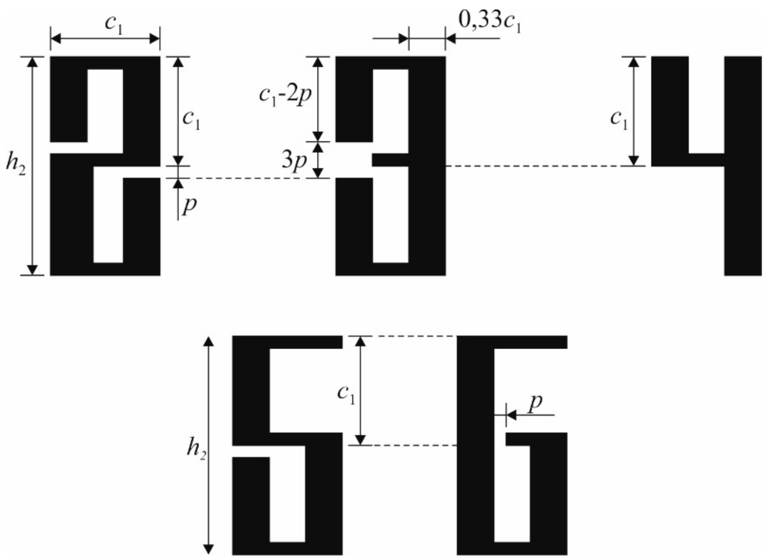


Figure 6. Construction of the digits of the Safe Symmetrical font.

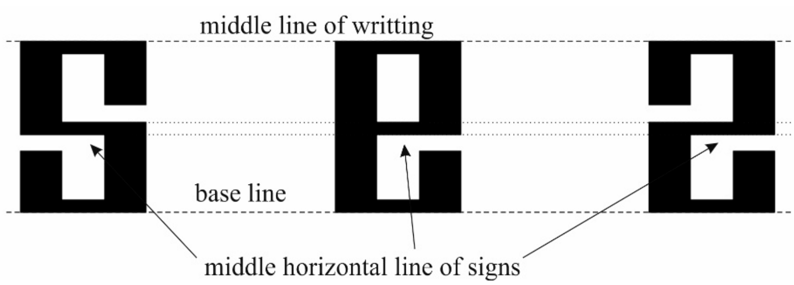


Figure 7. Location of the middle horizontal lines for the lowercase letters and digits of the Safe Symmetrical font.

2.2. Construction of the Characters of the Safe Asymmetrical Font

The Safe Asymmetrical font [13,14] is the second new computer font presented in this paper. Like the Safe Symmetrical font, this font could be used in the printing process and in computer techniques. The characters of the font are devoid of decorative and diagonal elements. The lines that build the characters intersect at right angles. The general contours of the Safe Asymmetrical font characters have a rectangle shape. Each character is built from lines of about two widths. However, the location of these lines in the characters differ from those in the Safe Symmetrical font. The wider lines are the vertical lines, but only on the left part of the characters. The thinner lines appear as the horizontal lines of the characters and as the right elements of the characters (Figure 8). Additionally, the correct proportions of the line widths and the clearance of each character are maintained. The corresponding characters have ascenders and descenders.

Figure 8. Characters of the Safe Asymmetrical font.

Since the characters of this font do not have decorative elements, it means that the characters of the font are similar to each other, with high between-character correlation coefficient values. Examples of the lowercase letters and digits are shown in Figure 8. Similar to the Symmetrical Safe font, the construction of the characters of the Safe Asymmetrical font must meet appropriate criteria (Figures 9 and 10) to ensure protection against the electromagnetic eavesdropping process. These criteria concern the proportions of the line widths, the clearance, and the position of the middle horizontal lines. The middle horizontal lines appear in the letters "e", "s", and "z" (Figure 11).

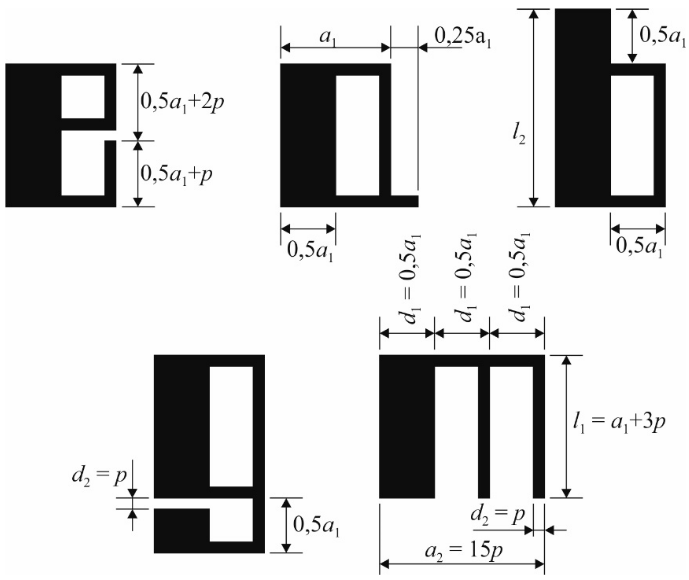


Figure 9. Construction of the lowercase letters of the Safe Asymmetrical font.

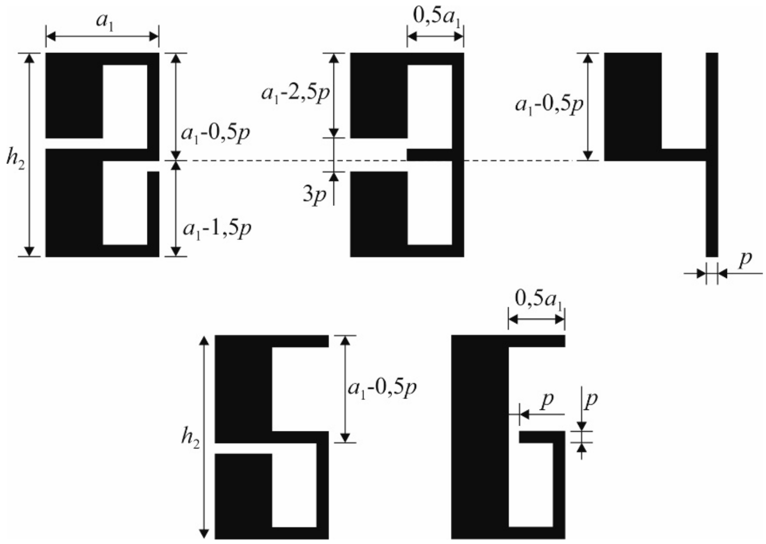


Figure 10. Construction of the digits of the Safe Asymmetrical font.

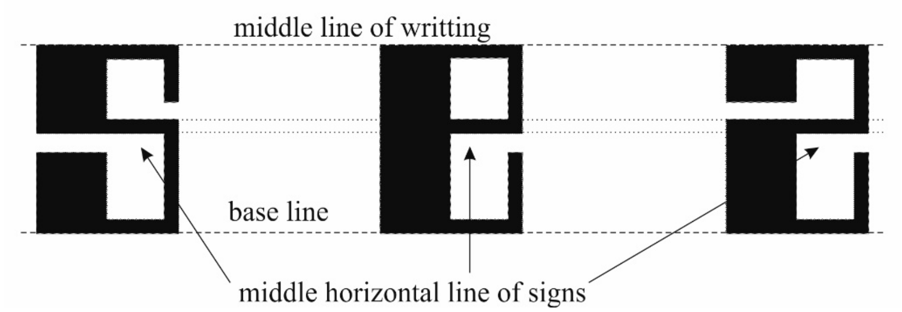


Figure 11. Location of the middle horizontal lines for the lowercase letters and digits of the Safe Asymmetrical font.

The characters of the font were constructed with the required proportions of the line widths to the clearances and the appropriate position of the middle horizontal line for characters that have such lines. This applies to the lowercase letters, capital letters, and digits (Figure 11).

The construction parameters of the characters of the Safe Asymmetrical font are as follows:

(a) Height of the lowercase letters:

$$h_1 = 13\,p; \tag{8}$$

(b) Height of characters with ascenders or descenders (as well as the height of digits and capital letters):

$$h_2 = 18\,p; \tag{9}$$

(c) Width of the lowercase letters, capital letters, and digits (with the exception of "m"):

$$a_1 = 10\,p; \tag{10}$$

(d) Width of "m" (i.e., the lowercase and capital letters):

$$a_2 = 15\,p; \tag{11}$$

(e) Width of the vertical lines (d_1) and the clearance between the vertical lines (d_2):

$$d_1 = 5\,p,\ d_2 = 1\,p; \tag{12}$$

(f) Width of the horizontal lines:

$$k = 1\,p; \tag{13}$$

(g) Width of ascenders and descenders:

$$w = \frac{1}{2}\,a_1 = 5\,p. \tag{14}$$

3. Results

The tests of the safe fonts were carried out in an anechoic chamber (Figure 12). The technical parameters of the chamber (20 m × 16 m × 8 m, length × width × height) as well as the internal conditions of the electromagnetic environment ensured the repeatability of the tests. The external electromagnetic environment did not have an impact on the internal electromagnetic environment. The anechoic chamber was characterized by the required shielding effectiveness—that is, at least 100 dB in the frequency range from 10 kHz to 18 GHz (IEC 61000-5-7, IEEE STD 299). A DSI-1550-A TEMPEST test system (up to 2 GHz), Microwave Downconverter DSI-1580-A (up to 22 GHz), as well as a Rhode and Schwarz antenna (dipole antenna HE527 (200 MHz ÷ 1 GHz)) were used for the tests. The distance of the measuring antenna from the screen (the screen included the characters of the safe fonts, which were the test objects) was 1 meter. The tests were carried out for the frequency range from 200 MHz to 1 GHz. The measured sensitive emissions were recorded and the emissions were used to the reconstruct the primary information in the shape of the images. The rasterization method was used for this process.

The construction of the characters of the Safe Symmetrical and the Safe Asymmetrical fonts has the effect of generating a high level of similarity between the characters. Because the SCA, due to its properties, additionally eliminates some construction elements of the characters, it becomes impossible to identify the characters [15–17]. In the reconstructed images from the sensitive emissions, almost all characters (depending on the degree of similarity and the correlation coefficient value) were identified as the same character [18–21]. In this situation, the reading of the text data was impossible (Figure 13, Figure 14, and Figure 15). This means that the safe fonts are useful not only in the typical processing of the text data. These fonts effectively counteract the process of electromagnetic infiltration.

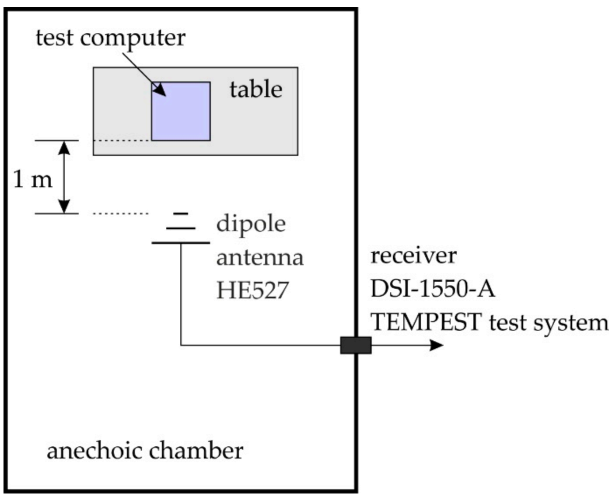
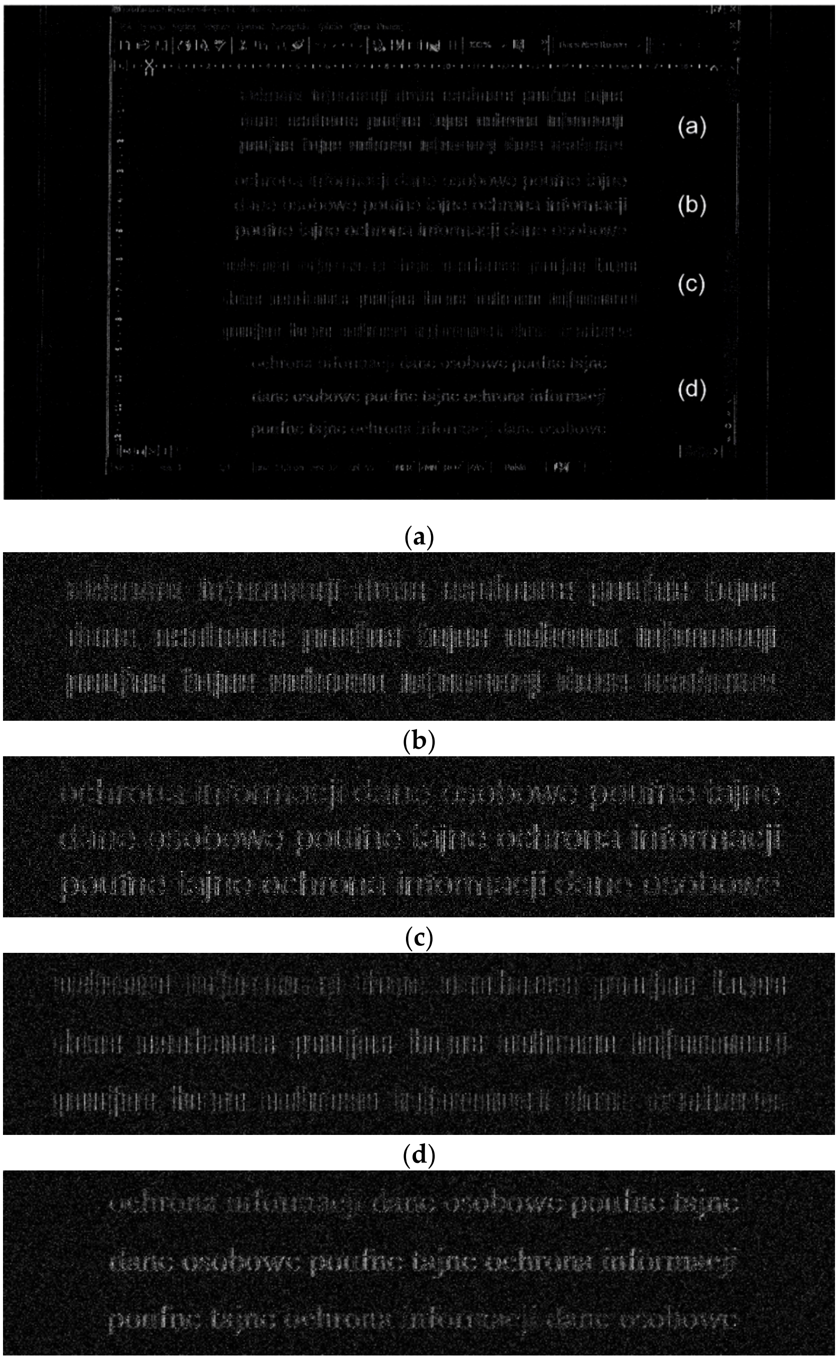


Figure 12. Schematic of the anechoic chamber.



(**a**)

(**b**)

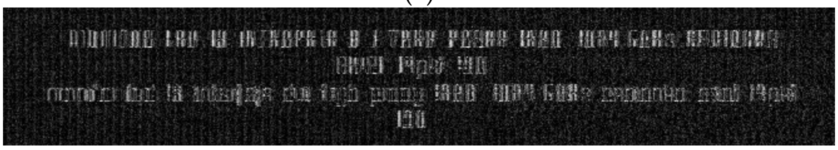
(**c**)

(**d**)

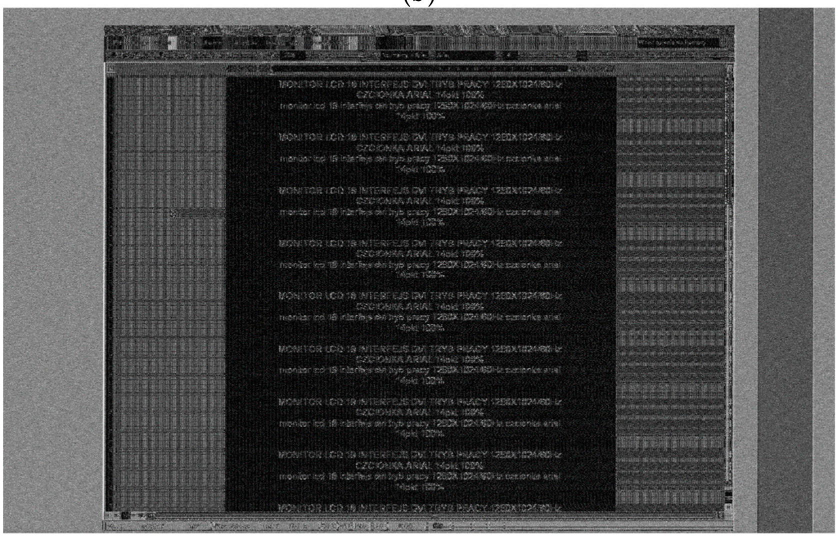
(**e**)

Figure 13. (**a**) Example of a reconstructed image with the text data for four different fonts (from the top: The Safe Symmetrical font, the Arial font, the Safe Asymmetrical font, and the Times New Roman font). Magnifications of the parts of the image: (**b**) the Safe Symmetrical font; (**c**) the Arial font; (**d**) the Safe Asymmetrical font; (**e**) the Times New Roman font (frequency of the appearance of the valuable emission f_0 = 740 MHz; BW = 50 MHz; size of the characters: 14 p; VGA standard was the source of the valuable emission).

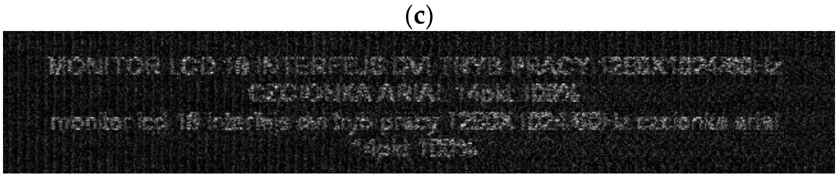
(**a**)



(**b**)



(**c**)



(**d**)

Figure 14. Examples of reconstructed images with the text data: (**a**) the Safe Symmetrical font, (**c**) the Arial font. Magnifications of parts of these images are in (**b**) and (**d**), respectively (frequency of the appearance of the valuable emission f_0 = 1730 MHz; BW = 100 MHz; size of the characters: 14 p; DVI (HDMI) standard was the source of the valuable emission).

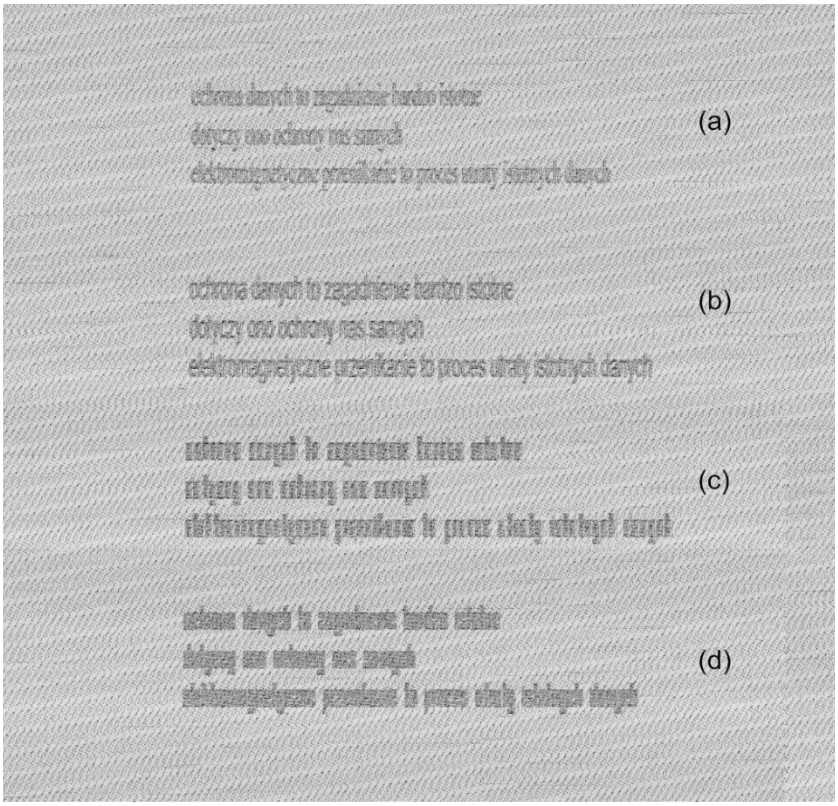


Figure 15. Example of a reconstructed image with the text data for four different fonts: (**a**) the Times New Roman font, (**b**) the Arial font, (**c**) the Safe Asymmetrical font, (**d**) the Safe Symmetrical font (frequency of the appearance of the valuable emission f_0 = 750 MHz; BW = 30 MHz; printing resolution (with character size of 14 p): 600 dpi × 600 dpi; laser printer was the source of the valuable emission).

4. Discussion

The effectiveness of the safe fonts in the protection of information was confirmed by the very large CER values (Table 2) that were calculated according to the equation below:

$$CER = \frac{m+k}{q} = \frac{m+(u-n)}{q}, \tag{15}$$

where u is the number of characters searched in the analyzed image, m is the number of incorrectly recognized characters, n is the number of correctly recognized characters, k is the number of unrecognized but searched characters in the analyzed image ($k = u - n$), q is the number of all characters in the analyzed image. This means that many mistakes were made during the reconstruction of the letters and digits [22,23]. This applied to the lowercase letters, capital letters, and the digits (Figures 13–15).

The safe fonts are fully functional computer fonts, and can be used in the processing of the text information. The feature that distinguishes these fonts from traditional Arial or Times New Roman fonts is the high level of similarity between the characters. This was achieved by eliminating the decorative elements and diagonal lines that build the characters of the fonts. This means that the characters of the safe fonts have unique shapes that are not similar to other existing characters of computer fonts.

The unique characters of the safe fonts give them significant features related to protection against electromagnetic penetration. In contrast to the traditional fonts, the indication of specific characters in reconstructed images from sensitive emissions is very difficult. This applies to the sources of the unwanted emissions in the form of analog and digital graphic standards [24]. Additionally, the safe fonts are resistant to optical character recognition—this type of software cannot correctly recognize the letters and digits.

Table 2. The character error rate (CER) values for the traditional and safe fonts [23].

Character	Arial Font	Times New Roman Font	Safe Symmetrical Font	Safe Asymmetrical Font
VGA Standard				
a	1	2	1	4
c	3	5	7	350
h	51	0	310	6
n	31	39	283	183
s	1	3	40	204
DVI (HDMI) Standard				
a	1	4	91	21
c	3	11	97	509
h	3	4	50	60
n	7	6	431	80
s	1	1	156	70
Laser Printer (Double-Diode System, Resolution: 600 dpi × 600 dpi)				
a	3	5	3	122
c	0	5	19	98
h	5	0	20	95
n	3	10	73	104
s	2	3	3	75

5. Patents

The Safe Symmetrical and the Safe Asymmetrical fonts are new computer fonts. Due to the universality of their use and the acceptance of the potential users, works on improving the shapes of the characters are still being continued. Despite the high level of similarity between the characters, each safe font can be used in the secure processing of information. These fonts have obtained the protection of the Polish Patent Office in the form of Industrial Design (No. 24487, Figure A1a) [13] and Patent (No. P.408372, Figure A1b) [14].

Funding: This research received no external funding.

Conflicts of Interest: The author declares no conflict of interest.

Appendix A

(**a**) (**b**)

Figure A1. Certificates of (**a**) the Industrial Design and (**b**) the Patent for the safe fonts.

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