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QR Bar-Code Designed Resistant against EM Information Leakage

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Abstract

A threat of eavesdropping display screen image of information device is caused by unintended EM leakage emanation. QR bar-code is capable of error correction, and its information is possibly read from a damaged screen image from EM leakage. A new design of QR bar-code proposed in this paper uses selected colors in consideration of correlation between the EM wave leakage and display color. Proposed design of QR bar-code keeps error correction of displayed image, and makes it difficult to read information on the eavesdropped image.

1 Introduction

The threat of electromagnetic eavesdropping from display screen image of information device has been reported [1], and there is a known threat of information leakage of EM emanation leaked from portable information devices [2].

Such screen image may contain 2-dimensional image information like the QR bar-code which is read by machine. QR bar-code has error correction capability so that it can be read even if the image is damaged. Although a reconstructed image from EM emanation may be damaged, QR bar-code is considered to be possibly read even from an incomplete reconstructed image.

By selecting the display color, the amplitude of the EM emanation can be taken into consideration [3]. This paper proposes a QR bar-code design method that makes EM information leakage difficult by selecting multiple colors of QR bar-code that take into account encoding of display color in transmission protocol.

2 Measures against electromagnetic information leakage by selecting display color

Discussion in this paper focuses on LVDS (Low Voltage Differential Signaling) transmission protocol that is widely used in information devices such as tablets. It is reported that EM emanation from LVDS transmission depends on display color [4].

A normal QR bar-code is composed of two colors, e.g. white and black, and difference of the colors is essential in machine-reading. Evaluation of read performance in QR bar-code in this paper uses the luminance value of human vision (ITU-R BT.601) which is calculated by Equation (1).

$$\mathrm{Y} = 0.299\mathrm{R} + 0.587\mathrm{G} + 0.114\mathrm{B} \quad \dots (1)$$

Magnitude of EM emanation from LVDS depends on number of bit inversions of the color encode in LVDS transmission waveform [3], and luminance of the display color does not directly effect on magnitude of EM emanation. The authors propose to arrange the display colors for QR bar-code by considering EM emanation, or number of bit inversion of LVDS transmission.

Table 1 shows the encoding of four colors which is used in the proposed design of QR bar-code. Two colors with large luminance (bright) values are RGB: (0 192 0) and RGB: (0 192 96), and the rest two colors with small luminance (dark) values are RGB: (0 0 96) and RGB: (96 0 96). The ideal design of colors is that there is little to no difference in the amplitude of EM emanation between white and black parts to hide difference of white and black parts of QR bar-code in the reconstructed image. A pair of colors for white and black were selected to have the same number of bit inversion for each of two images.

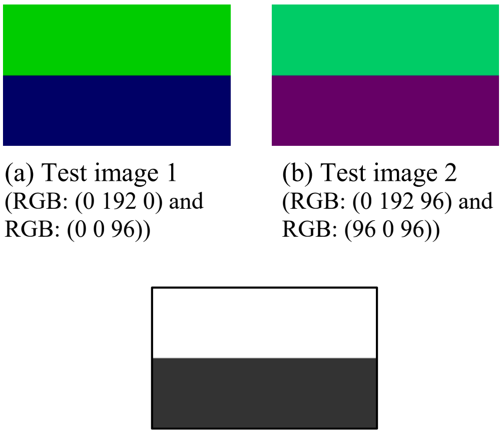
Table1. Color encoding in the proposed design of QR bar-code.

Test in Sect. 2	RGB value / Luminance	LVDS data	Number of bit inversion
Test image 1	0 192 0 / 112.7 (for white)	CH1: 0000000 CH2: 0011000 CH3: xxx0000	Rise 1, Fall 1
	0 0 96 / 10.9 (for black)	CH1: 0000000 CH2: 0000000 CH3: xxx0110	Rise 1, Fall 1
Test image 2	0 192 96 / 123.6 (for white)	CH1: 0000000 CH2: 0011000 CH3: xxx0110	Rise 2, Fall 2
	96 0 96 / 39.6 (for black)	CH1: 0011000 CH2: 0000000 CH3: xxx0110	Rise 2, Fall 2

Figure 1 shows a sample of correlation between an image on display screen and its EM emanation. Evaluation of proposed design is confirmed by amplitude of EM emanation using the test images shown in Fig. 2. The test image in Fig. 2 (a) is combination of two colors for test image 1, and Fig. 2 (b) is made of a pair of colors for test image 2. We also used test image 3 designed in white

(RGB: 255 255 255) and black (RGB: 60 60 60) shown in Fig. 2 (c) as a comparative case. Table 2 shows the encoding of these two colors for Fig. 2 (c).

Figure 1. Display screen and EM emanation.



(a) Test image 1 (RGB: (0 192 0) and RGB: (0 0 96))

(b) Test image 2 (RGB: (0 192 96) and RGB: (96 0 96))

(c) Test image 3 (RGB: (255 255 255) and RGB: (60 60 60))

Figure 2. Test images for measurement of EM emanation.

Table2. Color encode in the QR bar-code for comparison.

	RGB value / Luminance	LVDS data	Number of bit inversion
Test image 3	255 255 255 / 255 (for white)	CH1: 1111111 CH2: 1111111 CH3: xxx1111	Rise 0, Fall 0
	60 60 60 / 60 (for black)	CH1: 1001111 CH2: 1100111 CH3: xxx0011	Rise 3, Fall 2

EM emanation from a tablet device which uses LVDS transmission was measured by using a spectrum analyzer and an EM probe, and the measured result is shown in Fig. 3. The difference in amplitude of the EM emanation of the selected display colors is small for both cases of the (a) test image 1 and (b) 2, while (c) test image 3 shows clear difference. Therefore, the proposed design of a QR bar-code using the colors shown in Table 1 makes it difficult to read information on the reconstructed image.

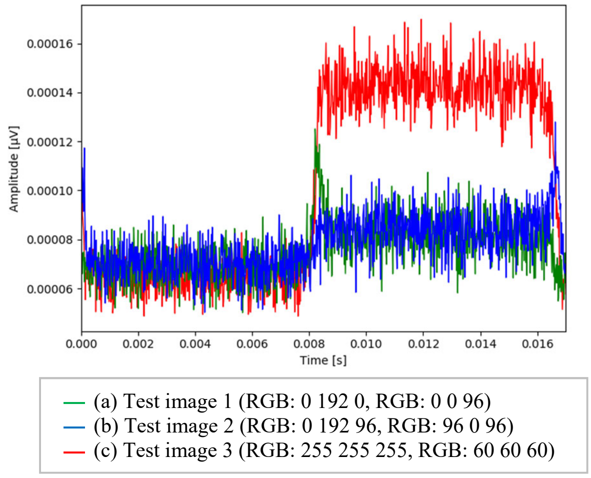


Figure 3. Amplitude of EM emanation in the test image.

3 Design of QR bar-code for resistance against EM Information Leakage

Figure 4 shows a QR bar-code which is based on QR code version 1 (H) and arranged by using the four colors shown in Table 1. Two colors are randomly arranged on both the white or black part of the QR bar-code image. This code contains a text message "True," and is readable by a camera of a smartphone.

Figure 4. QR bar-code by the proposed method.

Figure 5 shows a test image of the designed QR bar-code pasted on a background (RGB: 255 255 255) of 1920 x 1200. QR bar-code image shown in Fig. 6 is a comparative case which uses two colors in Table 2. A border line is added to each of them to indicate the position of the QR bar-code on the reconstructed image.

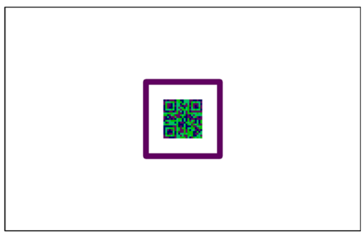


Figure 5. Test image for resistance against EM information leakage.

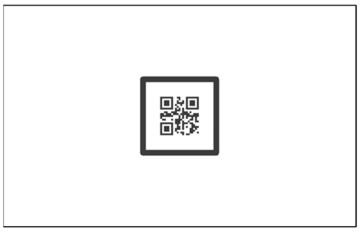


Figure 6. Test image for comparison.

4 Experiment

4.1 Image reconstruction from EM emanation

Figure 7 shows the experimental setup. We observed the EM emanation while displaying the test images shown in Figs. 4 and 5 on the tablet device which uses LVDS transmission protocol. Table 3 shows the specification of the target device. The EM emanation was measured at sampling rate 25MHz, gain 17dB and frequency 653MHz.

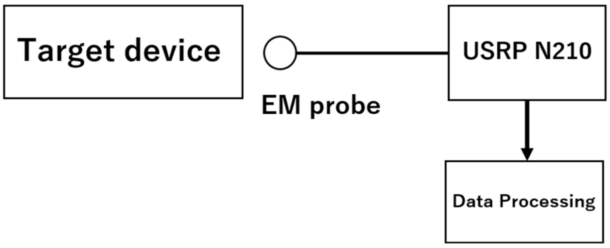


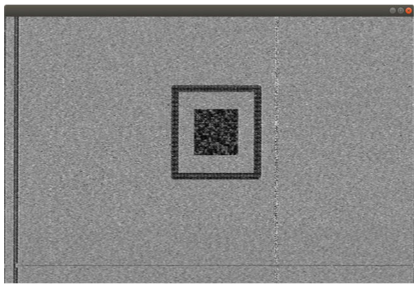
Figure 7. Experimental setup.

Table 3. Specification of target device.

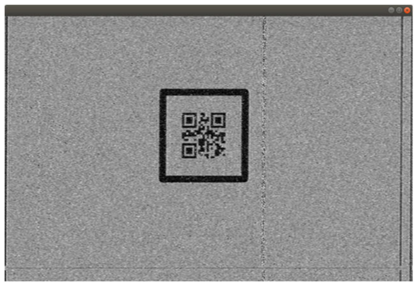
Resolution	1920 × 1200
Refresh rate	60 Hz

Figure 8 shows the reconstructed images derived from EM emanation for test images of Figs. 5 and 6. Figure 9 shows images cut out by extracting the border on the reconstructed image by image processing. The cropped images were read with a smartphone camera by using a standard camera app on an iOS 12 smartphone.

The text information could not be obtained from Fig. 9 (a), but the text information "True" could be obtained in Fig. 9 (b). Therefore, the information stored in the QR bar-code image can be leaked if any countermeasure against EM emanation is not considered, and the proposed design is effective as a countermeasure against EM information leakage from the reconstructed image.

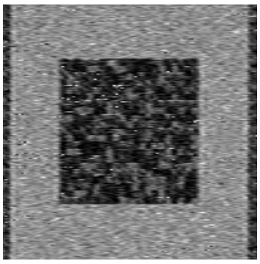


(a) Proposed countermeasure

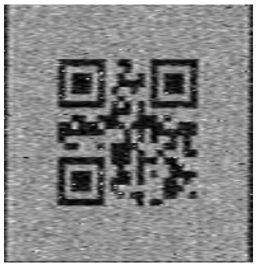


(b) No countermeasure

Figure 8. Reconstructed image from EM emanation.



(a) Proposed countermeasure



(b) No countermeasure

Figure 9. Image cropped at the border.

4.2 Shape restoration by image binarization

Next experiment is to observe whether the shape of the QR bar-code could be restored by discriminating the QR bar-code on the reconstructed image into two colors. The part of QR bar-code was extracted from the reconstructed image in Fig. 9, and then each pixel in the image was converted to grayscale value Y from 0 to 255 by applying Equation 2.

$$Y = (R + G + B)/3 \quad \ldots (2)$$

Each pixel value Y was binarized by flowchart shown in Fig. 10. When a pixel value was smaller than a threshold value t, the pixel was classified as black (RGB: 0 0 0)), and when larger than t, white (RGB: 255 255 255). The binarized image was pasted on a white background image of 1920 × 1200, and readability was tested using cv2.QRCodeDetector () of the OpenCV library for image processing.

Figure 11 shows samples of the processed QR bar-code images at t = 96/255. The QR bar-code image (a) from the proposed countermeasure could not obtain the stored information. The QR bar-code image (b) that did not take countermeasure against EM emanation was able to obtain the stored text information "True" for conditions the threshold value t = 96/255, 97/255, or 98/255. Therefore, it was shown that it is difficult to obtain the information in a QR bar-code by taking countermeasure against EM emanation by the proposed method.

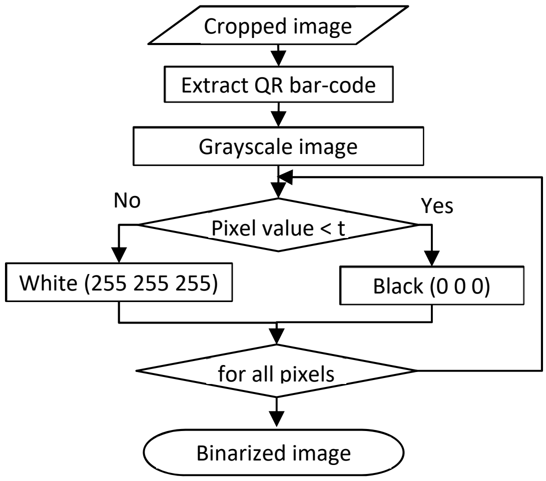


Figure 10. Flowchart for binarized image.

(a) Proposed countermeasure (b) No countermeasure

Figure 11. Binarized images at t = 96.

5 Conclusion

This paper discussed on design of multicolor QR bar-code that makes EM information leakage difficult in consideration of the encoding of LVDS transmission signal. Experiments on reconstructed image from EM emanation showed that it is difficult to obtain the information in the designed QR bar-code. If the QR bar-code takes countermeasure against EM emanation by the proposed method, we can design QR bar-code which is resistant against EM information leakage.

6 Acknowledgements

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7 References

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