Evaluation of Conductive Inks for Anti-Counterfeiting Deterrents

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Abstract

When using security printing for product protection, deploying magnetic or conductive inks can increase the number of ways in which the printed information on a package or label can be authenticated. This approach is commonly used with bank checks, where the routing and account numbers are printed at the bottom of the check in MICR (magnetic ink character recognition) ink and can be authenticated both visually using OCR (optical character recognition) and magnetically via an electronic check reader. As improved conductive inks are developed for use in inkjet printing, additional approaches may be deployed in which two or more methods can be used to authenticate printed information.

In this paper we examine the print quality of MICR ink and a new silver-based conductive ink. We use the 2D DataMatrix bar code as a test vehicle for verifying print quality. We also implement structural pre-compensation to increase the range of module sizes which authenticate. We then examine the feasibility and difficulty of counterfeiting a personal bank check and discuss the issues surrounding authentication approaches.

Introduction

The use of magnetic and conductive ink-jettable inks offer an opportunity to increase the complexity of the information printed on to a package or a label. In addition to visually replicating the printed security deterrent, a would-be-counterfeiter must also match the electromagnetic properties of the inks used. Failure to correctly match these properties will result in "reading" failure during authentication. We define authentication of a security deterrent by two or more different means as *multi-modal* authentication.

Prior to deploying an ink designed for multi-modal use, the ink must be qualified. While an ink may contain novel properties not possessed by more commonly used commercial thermal inkjet (TIJ) inks, if the formulation of the ink is such that it has diminished print quality (e.g. increased mottle or bleed), deployment of the ink will be limited.

In this paper we examine a straightforward approach to examining and qualifying multi-modal inks. We also show that there are limitations to multi-modal deployment by counterfeiting a personal check and attempting to authenticate it through a commercial off the shelf check reader.

Experiments Performed

Two sets of experiments were performed in conducting our research. The first set of experiments examined printability and readability of inks using 2D bar codes and commercial 2D bar code reading software. The second set of experiments examined the feasibility of counterfeiting personal checks with respect to readability of the routing, account, and check numbers of the E13B MICR font numbers at the bottom of a check.

In our first experiment we used two types of inks; VersaInk black MICR ink manufactured by G7 Productivity Systems [1] and a silver based nano ink manufactured by Methode Electronics, Inc. [2]. Test pages were printed using an HP 6127 deskjet TIJ printer on HP office paper and Teslin [3]. 2D bar codes were printed in module sizes 10 through 30 using the 2D DataMatrix symbology with two different ink volume settings; normal and heavy. (These settings are directly accessible in Windows XP by accessing the printing preferences of the 6127 through the control panel.) Due to the number of bar codes requiring authentication, five samples were printed for each combination of paper, ink volume, compensation mode, and module size. All prints were produced from the same digital raster images. Authentication was performed with a SR IT4600 model InData Systems handheld reader using a 405 nm optic [4].

In previous works [5, 6] we demonstrated the effectiveness of using structural pre-compensation for increasing the authentication rates of 2D DataMatrix symbols. Briefly, the approach is to decrease the size of each individual black square in the symbol to reduce the effects of ink spread and bleed. Since one of the objectives of this body of work is to verify the print quality of the inks, we chose also to examine if adding structural pre-compensation in the print process increased the read rate as it had with standard HP black ink [5]. Figure 1 depicts, side-by-side, an uncompensated and a pre-compensated DataMatrix symbol with a module size of 20 mils.

The second experiment performed involved attempting to replicate a personal check. Taking the approach of a would-be-counterfeiter, we chose to utilize equipment and software that is readily available off the shelf or via the internet. To that end, we used an HP 8350 Scanjet flatbed scanner to scan an existing check. We then performed minor image cleanup using a readily available open source image processing application called *The GNU Image Manipulation Software (GIMP)* [7], followed by printing of the replicated check using VersaInk [1] with an HP 6127 deskjet. For authentication we used a MagTek MICR Mini USB 3TK model check reader [8]. All prints were performed on HP office paper.

Figure 1: Sample 2D DataMatrix bar codes each with a module size of 20 mils. The left bar code is structurally uncompensated while the right bar code is structurally pre-compensated.

Results

DataMatrix Authentication

The results of the VersaInk are summarized in Table 1. Because VersaInk is a commercially available ink which has been formulated both for its magnetic properties as well as its legibility, 2D DataMatrix authentication results were very good. Accuracies of 100% were attained for sizes 21 to 30 mils on HP office paper with normal ink volumes. Implementing structural pre-compensation on the barcode raster images before printing significantly enhanced the readability of the symbols—allowing authentication at a module size of 11 mils or higher. When the ink volume setting was increased to heavy, results for uncompensated symbols shifted upwards and 100% accuracy was only attained for modules sized 24 to 30 mils. Adding pre-compensation significantly boosted the read rate for the MICR ink with a heavy ink volume, and 100% read accuracy was observed starting at the smallest (10 mils) size.

Table 1: Authentication Results for 2D DataMatrix symbols using VersaInk on HP office paper. (UC = Uncompensated, PC = Precompensated)

Mode	Ink Volume	Size (mils)	Read Rate(%)
UC	Normal	10-19 20 21-30	0 80 100
PC	Normal	10 11-27 28 29-30	20 100 80 100
UC	Heavy	10-23 24-30	0 100
PC	Heavy	10-28 29 30	100 40 0

Since the Nano-Ag Methode ink is not currently a commercially available ink—having been only recently developed Methode--considerably less was known about ink print quality before the print tests were performed. The results summarized in Table 2 show that the Nano-Ag ink provides good authentication performance—at least comparable to the VersaInk—on HP office paper. In trends similar to that of the MICR ink on office paper, adding pre-compensation to the symbols prior to printing significantly increases the range of sizes which can be authenticated by the handheld bar code reader.

The results of the Nano-Ag ink on Teslin differed considerably from the results on the HP office paper. Examination of the results in Table 3 indicate that the read rate is considerably more erratic and do not follow the general upwards trends of authentication as the size of the symbol is increased. We believe that the differences of the read rate between Teslin and standard office paper are due in part to the fact that Teslin is a non-porous substrate. Rather than absorbing into the fibers, the ink rests and dries on the surface of the substrate after printing. In this case, structural pre-compensation does not function as expected since bleed does not occur on Teslin.

Table 2: Authentication Results for 2D DataMatrix symbols using Methode Nano-Ag ink on HP office paper. (UC = Uncompensated, PC = Precompensated)

Mode	Ink Volume	Size (mils)	Read Rate(%)
UC	Normal	10-18 19 20-30	0 80 100
PC	Normal	10 11-28 29 30	0 100 60 0
UC	Heavy	10-18 19-30	0 100
PC	Heavy	10 11-27 28 29 30	0 100 80 20 0

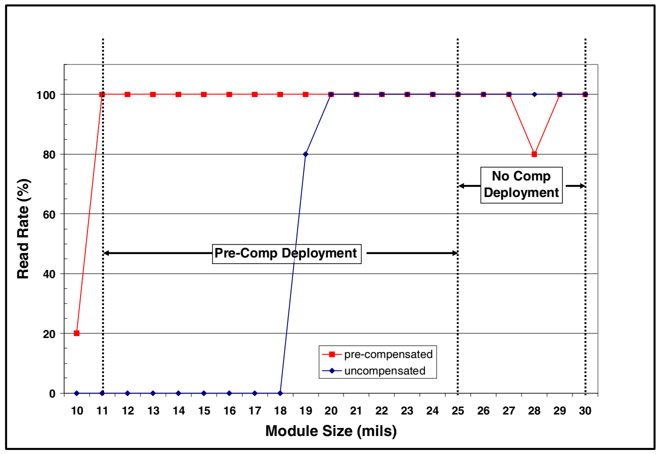

Figure 2: Read Rate of VersaInk on HP office paper printed with normal ink volume. The black dotted vertical lines demark the preferred deployment ranges for pre-compensated and uncompensated module sizes.

The authentication trends are used to determine the optimal deployment of symbols printed with pre-compensation versus symbols printed without compensation. For VersaInk on HP office paper printed with normal ink volume, pre-compensation is recommended for module sizes 11 through 25. Module sizes 26 through 30 are recommended to be printed uncompensated. In this example, the module size for transitioning from pre-compensated to uncompensated modules is determined by taking the midpoint between the point where uncompensated modules authenticate at 100% (size 20) and where pre-compensated modules cease to authenticate at 100% (size 30). Figure 2 plots the read rates of VersaInk on HP office paper.

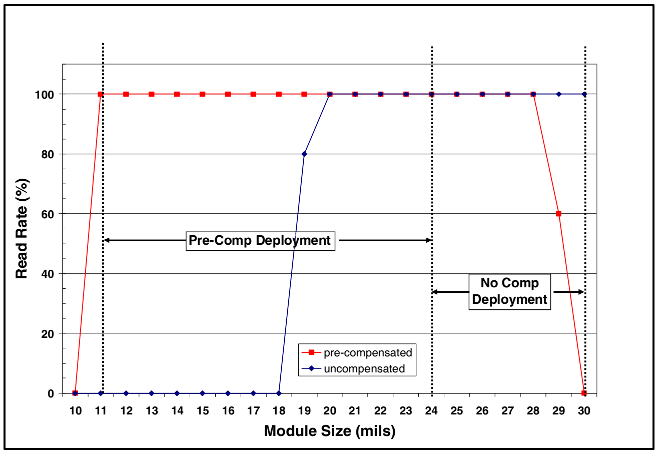

Figure 3: Read Rate of Methode Nano-Ag ink on HP office paper printed with normal ink volume. The black dotted vertical lines demark the preferred deployment ranges for pre-compensated and uncompensated module sizes.

Similarly, in Figure 3 the authentication results of the Methode Nano-Ag ink on HP office paper printed with normal ink volume are plotted. In this scenario, pre-compensation is recommended for module sizes 11 through 24, and no compensation is recommended for module sizes 25 through 30.

Table 3: Authentication Results for 2D DataMatrix symbols using Methode Nano-Ag ink on Teslin. (UC = Uncompensated, PC = Precompensated)

Mode	Ink Volume	Size (mils)	Read Rate(%)
UC	Normal	10-16	0
		17	80
		18	0
		19-30	100
PC	Normal	10	0
		11	80
		12-17	100
		18	60
		19	100
		20	60
		21-23	100
		24	60
		25	100
		26-28	40
		29-30	0

Figure 4 shows the effects of pre-compensation using Methode's Nano-Ag ink as well as the differences in ink-substrate interaction which occur in the printing process. The ink absorbs into the HP office paper while it settles on top of the Teslin substrate. Note the significant difference in the surface topology as well as the reflectivity of the ink between the two substrates.

Differences in interaction with the substrate also affect the conductivity of the ink. Table 4 lists the resistivity measurements of the Methode Nano-Ag ink on the two substrates printed in both normal and heavy ink volumes. Curing was performed by allowing the prints to air dry for a week at room temperature (approximately 21ºC) and humidity (approximately 35% relative humidity). Because the ink is absorbed into the substrate as seen in Figure 4, the HP office paper/conductive ink combination is expected to function more as a "mesh" and the Teslin substrate/conductive ink combination more as a "wire". Consequently, there is a significant increase in the resistivity measurements for HP office paper compared to the Teslin substrate.

Table 4: Resistivity Measurements of air cured Methode Nano-Ag ink.

	Normal Ink Vol.	Heavy Ink Vol.
HP office paper	16.1 ohm/sq.	16.4 ohm/sq.
Teslin	0.7 ohm/sq.	0.9 ohm/sq.

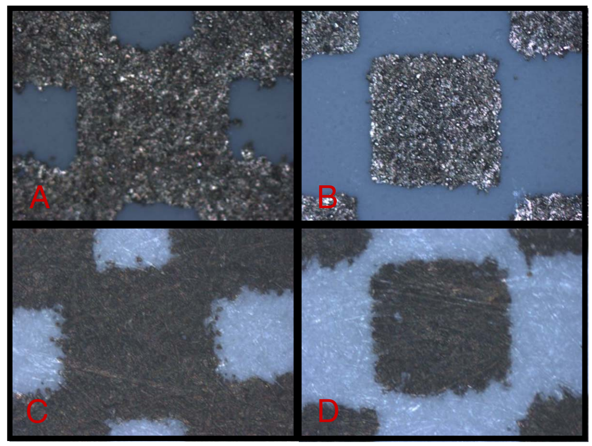

Figure 4: Micrographs of the nano-Ag Methode ink from 2D DataMatrix bar codes with module sizes of 30 mils printed with normal ink volume. (A) Uncompensated on Teslin (B) Pre-compensated on Teslin (C) Uncompensated on HP office paper (D) Pre-compensated on HP office paper. Images captured on an Olympus BX51M microscope and taken from the same location in the DataMatrix.

Replication of a Personal Check

For replication of a personal check we took a more qualitative approach to the problem. Since our objective was a pass/fail scenario, we approached the problem through several rounds of trial and error. Performing trials in this way we were successfully able to replicate and authenticate a personal check in less than 30 minutes. Since the checks were scanned, we simply needed to remove any noise artifacts induced from the scanning process. We omit any figures displaying numbers from the checks since the numbers correspond to the authors' bank accounts.

Discussion and Conclusions

Comparison of the results of VersaInk to the Methode Nano-Ag ink indicates that the conductive ink formulation is a viable ink for use in printing where print quality is critical to the application. Using structural pre-compensation, we were able to further extend the range of module sizes which could be used in deployment of a security-related print campaign. In addition, since the resistivity of the silver based ink is very good, the ink can be introduced for use in a multi-modal authentication (e.g. conductive reader + optical reader) approach.

It is important to note that just because there are multiple approaches to authentication it does not necessarily increase the difficulty of spoofing the security deterrent. This is shown by the fact that we were able to easily replicate an existing personal check with minimal time and effort. There was no need to even obtain the E13B font family to print the MICR numbers at the bottom of the check. Materials to print and authenticate checks can easily be obtained on the internet and one need only run a quick search to find any number of merchants to purchase supplies from. Because both aspects of the MICR ink (optical appearance and magnetic reading) are overt, the two "modes" of the MICR numerals collapse to, effectively, a single security mode, affording no "true" multi-modal protection.

The ramifications of a fraudulent check can include financial loss and/or identity theft. While a post-mortem analysis of a fraudulent check can be performed, the time and effort required to repair damaged credit from identity theft can be substantial. It is therefore critically important to assess any security deterrents used and approach the problem from the perspective of a would-be-counterfeiter. Our finding suggests using an independent security approach for the MICR reading and the optical (visible) appearance of the MICR ink itself—for example, by overprinting the MICR ink with a separate visual pattern based on non-magnetic black ink.

References

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[7] The GNU Image Manipulation Software (GIMP), www.gimp.org.

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Author Biography

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