1. Introduction

In 2004 the Dutch press reported frequently about the euro counterfeit situation in the Netherlands. One of the criticized tools to check a banknote is the ‘UV-lamp’. It was written that the UV check had become useless. The UV lamp was qualified as old fashioned. Commercial purveyors advised their customers not to use UV lamps any longer. Infrared tools were recommended as being more reliable and future oriented.

Nowadays the UV feature is a so-called overt feature; the information is openly given to the general public. Images of all denominations under UV light are routinely provided to cashiers and also to the general public (Figure 1).

Figure 1.
Euro 20 note under UV light. Information openly available to the general public.

Originally, in the period between 1965 to 1980, the UV feature was introduced as a human invisible or covert feature. This feature was only used as a Machine Authentication Feature (MAF) in the sorting machines of many central banks, as was also the case at De Nederlandsche Bank.

It seems to be a common rule: over time MAFs shift from exclusive features for the use by central banks to a common feature used by cashiers and retailers. This process can be described in terms of the product life cycle. After a first life at the central bank level, features live a second life as a cashier feature, as is illustrated by Figure 2.

It is debatable whether there is another, third life when a feature becomes familiar among the general public. Small UV light emitting diodes are sold as a gadget for €2 in Dutch shops. Schoolchildren point this gadget to the EU-flag on euro notes and see the colours change!

After the UV-lamp the next MAFs that will be used more and more by cashiers are the infrared or IR-properties. Is there a way to predict which MAFs will be the next to move to the cashiers’ territory? And what will be the trend for new central bank features?

After a short description of the life cycles of four existing MAF features (UV, IR, magnetic and spectral properties) an analysis is presented. It would seem that all MAFs move eventually from a central bank environment to a
A central bank feature begins a second life as a cashier feature. Some features may even go through a third life. Usually the y-axis represents ‘numbers sold’. In this case the interest in the feature is indicated.

cashiers’ environment. We will show that it is also clear that the period during which central banks can use a particular MAF is becoming shorter and shorter. Since a central bank wants its MAFs to be different from those used by cashiers, a set of recommendations is given. It is made clear that the best MAFs are invisible to the general public or are difficult to visualize with a detector used by retailers.

Information on detectors for retailers on the DNB web site
Another trend is for central banks to inform retailers and other third parties about their security features. DNB is no exception. To help retailers choose an authentication device, DNB was the first central bank to organise a detector test and to publish in April 2004 the result on its web site www.dnb.nl. The report is based on tests performed on both genuine and counterfeit euro banknotes [11.1]. This publication was well received by the retail organisations in the Netherlands. DNB will update this report twice a year. The Annex presents a copy of the most recent results, published in January 2005.

2. Life cycle of UV

Hand sorting of banknotes stopped in the early 1970s when the first generation of banknote sorting machines came in operation, in many cases providing mechanisation of the hand sorting process. As far as our knowledge goes the dullness of a banknote under UV lighting was the first machine authentication feature used at a central bank level. The early UV detectors were based on the absence of UV reflection by the UV dull banknote paper. By that time however two more UV properties had become available into the banknote: fluorescent fibres inside the paper substrate - in those days only one colour was used - and later the fluorescent inks. During the 1990s, fluorescent threads were introduced, while the glue used to fix foil applications can also be made fluorescent.

Fifteen years after the first generation of sorting machines the second generation entered the central banks in the 1980s. These machines automated the counting, fitness sorting and authentication process almost entirely. And while these configurations at De Nederlandsche Bank incorporated several MAF detectors, UV detectors were no longer figured among them.
The UV detector migrated from a central bank level to a cashier level. UV lamps became increasingly used in Dutch shops to check the fluorescent fibres (against a dark, dull background). A real peak of interest occurred in 1987, when a major commercial bank, the Postbank, offered UV lamps, featuring their logo, to shopkeepers for a reasonable price (roughly equivalent to € 15).
Thus, UV features have protected banknotes for over 40 years! Figure 3 is a schematic representation of the life cycle of UV dullness in a banknote.

The decay phase of the UV life cycle is characterized by the increase of counterfeits with UV imitations as a share of total counterfeits. Although no graph based on real figures is provided, it is clear that more imitations of UV characteristics are found every year in the Netherlands (Figure 4). Two new products on the market have helped the counterfeiter: the introduction of re-cycled paper for copying machines in the 1990s provided easy access to UV-dull paper. And the arrival of the marker pens made it possible to imitate the fluorescent fibres by hand. As far as we remember these marker pens became wide spread around 1995.

The introduction in 2002 of the euro, with its many UV features, gave a further thrust to UV imitations in the Netherlands. In 2003 around 25% of the euro counterfeits bore imitated UV-features. A minority of these notes were of good quality, while the majority were poor or mediocre quality imitations.

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**Figure 3.**
Life cycle of the UV feature in banknotes. First used as MAF by the central banks, later used as cashier feature by retailers, bringing the total life of UV in banknotes to over 40 years.

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**Figure 4.**
Estimated curve of the proportion of counterfeits in the Netherlands that bear one or more imitation UV features such as UV dull paper, coloured fibres and fluorescent inks. The UV imitations are usually of poor quality.
**Improvements of the UV-features**

Will the increase of counterfeits with UV imitations end the life of UV features in banknotes? If nothing is done, yes. But if the UV features can be improved, no. Let’s have a quick look at some of the developments that have improved UV features.

The UV fibres in the banknote paper can be improved by application of e.g. dotted fluorescence, by two colours on one fibre and/or by micro-extrusion (see Figure 5). The ink offers also possibilities, such as UV pigments in a transparent ink. Although certainly not a new idea, UV properties could be made visible by using double UV excitation: under 254 nm and emission under 365 nm (365 nm is most common used). Also two, or even more, UV active inks printed in tight register, could help to increase security, as in the latest banknote issue of the Bank of Canada (e.g. CAD 100 [11.2]). These and similar techniques serve to make UV ink features more difficult to counterfeit. Of course, detection tools for retailers need to be adapted to show duplicity in UV excitation.

![Figure 5.](image)


### 3. Life cycle of infrared

One of the earliest IR detectors for the cashiers was the VOIR system, developed and sold by the Banque de France. At the time around 1995, the price of this IR camera system was over € 2,000. Nowadays IR viewers are available for 10 % of the old price!

Infrared features have entered the public domain, as can be concluded from the many current offers by different companies, not only for euro banknotes, but also for dollar notes (Figure 6 and 7). Recently the National Bank of Ukraine has issued a brochure with full information on both UV and IR. As far as we know this is the first brochure issued by a central bank with such full information on these two features (Figure 8).

The IR detection systems for cashiers can be distinguished into two groups:

a) camera systems or viewers, which need interpretation by the inspector; and

b) signal or auto recognition devices, where a green light or a beep sound tells the inspector that the note is genuine or counterfeited.

Prices of these detectors range from € 70 to € 400. Examples are the MCD-900 (Taiwan, € 198) and the Dors 1000 (Russia, € 239), both viewers, and the ‘signal’ detector Ėvision (Denmark, € 199).
Figure 6.
Right: Dors 1100 (Russia, 2004).

Figure 7.
Left: Information on IR features in the user manual for the ICT Money Counterfeit Detector (MCD-900), (Taiwan, 2003).
Right: Information on IR features in USD banknotes, brochure from Dors (Russia, 2004).
4. Life cycle of magnetic properties

Table top detectors that are able to detect magnetism in banknotes are – again as far as we know - on the market since the early 1980s (see Figure 9, magnetism in the serial number on Bank of England notes).

The use of magnetism in the euro banknotes was quickly discovered. Images made with a magnetic image scanner were made public directly after the launch of the euro notes, e.g. by San Diego Magnetics on the SPIE conference in January 2002 [11.3].

One of the first magnetic detectors for euro notes was the Arianne, introduced into the market in 2002 (by Perfomatic, Belgium, price € 200). Later others joined the market, such as Dors and PhotoEuro (see Figure 10).
Figure 9.
Published in The Observer, December 1985. Graphic by Jim Colthorpe.

Figure 10.
Magnetic marks on the 100 euro banknote:
Top left: MiroDAST- Scan Front Euro 100. Top right: MiroDAST- Scan Reverse Euro 100.
Bottom left: brochure from Dors with magnetic code on thread (Russia, 2004). Bottom right: brochure from PhotoEuro, price € 245 (Italy, 2003).
5. Life cycle of spectral properties.

The follow up of the magnetic cycle are the features based on spectral properties (see Figure 11). Retail detectors for this type of feature are appearing on the market. The inventors are using typical spectral characteristics of the banknotes and developed dedicated small detectors. Different spectral properties can be detected, like luminescence or colour switches in foil or ink. An example of a feature based on a colour switch was given by Hueck Folien at the Banknote 2003 conference. The introduced an optical code on foil and Siemens provided a detector for this feature [11.4].

![Figure 11](image)

Figure 11.
Schematic overview of the ongoing life cycles of different MAF features.

6. New Developments

What kind of technology could be used for the follow up of the spectral properties, as indicated in Figure 11? There seem to be at least three areas which could provide new technologies for retail detectors:
- laser pen light,
- electronic chips,
- DNA-structure,
- ...

6.1 Exploitation of holographic features with a laser pen

Simple laser devices have been on the market for a few years. The average cost of such devices is in the same range as that of a UV viewer. Their typical wavelength is around 633 nm coloured. Also cheap blue laser light pen sources and strong green laser pen lights are appearing on the market. Such devices may be built into new detectors for retail use.
6.2 Electronic chips

Media reports and journals such as Currency News (e.g. June 2003 and February 2004) suggest that electronic chips inside banknotes may provide a new MAF feature. There are two main streams:

1) Contact-less reading: Radio Frequency Identification inlet (RFID), yes-or-no with a printed antenna,
2) Contact reading: chip comes in to direct contact with reader/detector.

The first group seems most promising for banknotes. According to the Banque de France the chip would have 128 - 256 bits with a read/write capability and about 10,000 write cycles. The chip’s thickness would preferably be about 30 microns. The target price would be 2 eurocent maximum [11.6].

The surface of the chip is very small and could be less than 0.5 mm$^2$. The surface of the antenna is larger: around 15 mm x 15 mm. The reading distance would be in the range of 1 – 10 mm.

6.3 DNA-based markers

Other developments that might lead to new MAF-features are the so called DNA based markers. Unique DNA strings are added to e.g. ink or paper and may be read by a detector. This technology is made available by Adnas (Applied DNA Sciences, Inc., [11.7]).

7. Analysis

Shorter life cycles: from 40 years to 7 years

Clearly central banks will move to much shorter life cycles for their Machine Authentication Features (MAFs). The life cycle of the UV features has spanned almost 40 years and IR may be calculated at around 30 years. The life cycle of the magnetic and spectral properties are approaching 20 years (see Figure 11).

Although the life span of an MAF is not identical to the life span of a banknote model, they are evidently connected. The reason behind new banknote designs is usually the introduction of new security features, for the public but also for detectors. The trend towards shorter life cycles for both the design of a banknote and the security features is a given fact. The ECB currently assumes that the life cycle of a new banknote model will be around 7 years and that a further decline in probable lifespan is likely [11.8, 11.9].

Life cycle analysis of security features
De Nederlandsche Bank NV
Presented at Banknote 2005 – February 2005
Feature in banknote has 2 cycles: first central bank than cashier
Historically central bank features have seemed to live second lives as cashier features. The pattern that seems to emerge is that security features originally used as central bank feature will double their lifespan as cashier/retail feature.

Increasing numbers of security features in banknotes
Once introduced it seems almost impossible for central banks to discontinue a security feature. Very few old features are scrapped when new features come in. As a consequence central banks are faced with increasing numbers of security features in their banknotes. The current euro banknotes boast no less than 37 security features.

MAFs that are visible are reproduced
It is clear that MAFs that are visible for the general public will be reproduced by the counterfeiter; counterfeiters are forced, so to speak, to reproduce any visible MAFs.
Another aspect is the communication on MAFs by central banks. Central banks are usually very quiet about their MAFs; open communication would push counterfeiters to imitate them.

8. Intrinsic versus extrinsic features
An important parameter for selecting MAFs and other security features is the origin of the feature: is the production inside a secure manufacturer - or intrinsic - or is it provided from outside, extrinsic, as a semi-finished product?
Typical examples from intrinsic security features are the watermark, meaning that it can only be associated to the production inside a security paper mill. Other examples of intrinsic features are intaglio print and the MicroPerf. Such features can only be produced inside a security printing works in the course of the genuine production process.
Semi-finished products are in principle less suitable to be used as bearers of MAFs since they will be delivered from outside to the security paper mill or printer. However, the last two decades the development is clearly in favour of extrinsic security features. These extrinsic features are added to the paper or printing process, like e.g. threads, foils and special fibres. Recent examples are the electronic chips. A disadvantage of such features is that they add a link to the production chain. And an additional link will add transportation movements, security requirements and confidentiality clauses.
Also from other point of views it is advisable to consider the pro-and-cons of intrinsic versus extrinsic features. The physical and chemical resistance of add on features like foil are usually less performing than the intrinsic features. A security thread or a chip could be removed from a banknote. And also: extrinsic features might be recovered more easily from the banknote residue after destruction, while this seems not possible for intrinsic features.
High investments seem to be necessary for new intrinsic and extrinsic MAFs that will keep the counterfeiter at distance.
An overview of several intrinsic and extrinsic security features is given in Table 1.
Machine Authentication Feature (MAF)

<table>
<thead>
<tr>
<th>Production process</th>
<th>Intrinsic</th>
<th>Extrinsic</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Paper</td>
<td>Mass variations within the paper (watermark, barcode watermark, …)</td>
<td>Security thread, UV-fibres, other types of fibres, luminescent pigments, other pigments, taggents, markers, chips, …</td>
</tr>
<tr>
<td>2. Foil</td>
<td>…</td>
<td>Glue, special unique colours, additional layers, nanotechnology, …</td>
</tr>
<tr>
<td>3. Silk screen/roto gravure</td>
<td>…</td>
<td>OVI pigments</td>
</tr>
<tr>
<td>4. Offset</td>
<td>Spectral values (layers of ink), …</td>
<td>UV-fluorescence, IR, …</td>
</tr>
<tr>
<td>5. Intaglio</td>
<td>Ink mass variations (intaglio relief, …)</td>
<td>Magnetic pigments, OVI pigments, …</td>
</tr>
<tr>
<td>6. Numbering</td>
<td>Number + database</td>
<td>Magnetic pigments, OVI pigments, …</td>
</tr>
<tr>
<td>7. Perforations</td>
<td>(micro)perforation patterns through finished banknote, …</td>
<td>…</td>
</tr>
<tr>
<td>8. Cutting</td>
<td>Shape of edges, …</td>
<td>…</td>
</tr>
</tbody>
</table>

Table 1.
Overview of intrinsic and extrinsic features in a banknote.

9. Recommendations for the development of MAF features

Since several ‘old’ MAFs seem to have reached the end of their lifespan, it is clear that the central banks need to develop new MAFs. Although the development of these features is strictly confidential, there is no reason to be silent about recommendations for the development of such features.

9.1 Limit the number of MAFs in a banknote, remove obsolete features

When a new feature enters a note, another feature should disappear, due to the limited space available in a banknote and also because of the cost. Limiting the total number of security features in their banknotes would help central banks to evaluate their security feature portfolio. This evaluation could be improved if security features are divided across different user groups, such as the general public, cashiers (including retailers), central banks and other third parties. With 3 to 5 features for every user group, the total number of features in a banknote could be limited to e.g. 20.

9.2 Make MAFs invisible to the human eye

MAFs should not be visible to the human eye, they should be covered or ‘covert’. The best MAFs are those that are physically invisible to the public. This may be achieved in either of two ways:
- by stealth techniques (camouflage, hiding),
- being invisible, using invisible ‘ingredients’ like e.g. taggents.

9.3 Make MAFs difficult to visualize

It should not be possible to make a MAF visible to the human eye with a (simple) detector.

9.4 Give priority to intrinsic over extrinsic ones

While the market is offering more and more extrinsic MAFs, the choice of intrinsic MAFs is very limited. Yet, if a choice can be made, intrinsic MAFs are to be preferred over semi-finished features, because they can only be created inside a paper mill or banknote security printing works. In principle intrinsic features are more secure.
10. Conclusions

10.1 After a life as central bank feature, it is almost certain that the feature will live a second life as a cashier feature. As a general rule, the lifespan of such features in banknotes will be doubled.

10.2 Shorter life cycles for both banknote design and security features are the trend. The life cycle for a central bank feature (MAF) - followed by a second life as a cashier feature - will move from a total of approximately 30 years in the past to probably a total of about 15 years in the future.

10.3 With the introduction of new security features, old features that have became obsolete for the market and which are at the end of their lifespan, should be discontinued. Central banks should limit the number of security features in their banknotes to a maximum of 20.

10.4 MAFs should not be visible to the public and should resist visualisation with detectors like UV, IR or magnetic image scanners, so that counterfeiters will not be encouraged to reproduce it.

11. References

11.1 Quarterly Bulletin De Nederlandsche Bank NV, December 2004
11.2 Church, Sara; ‘CAD banknote boasts new security features’ Keesing Journal of Documents & Identity, Issue 9, Amsterdam, 2004
11.5 Leaflet: ’JRRus News, Holographic Machinery & Originators’ Moscow 10 November 2004
11.7 ‘New program for embedding DNA marker into currency and other monetary instruments’ Product & Image Security & Data Authentication’ May/June 2004.
11.8 ‘Next generation of euro banknotes will be different’ interview with Antti Heinonen, Keesing’s Journal of Documents, Issue 3, Amsterdam 2003
11.9 ‘R&D Plans for new Euro Unveiled’ interview with Brian Dennis, Currency News, Volume 1, No 5, May 2003

An earlier version of this paper was presented within the Paper Committee of the Banknote Printers’ Conference, Oslo, Norway 25-26 May 2004.
APPENDIX

Counterfeit Detection Equipment Survey
January 2005

As published on the website of De Nederlandsche Bank
www.dnb.nl

Version
2 February 2005
Counterfeit Detection Equipment Survey
January 2005, De Nederlandsche Bank

1 Devices that require recognition of security features by the user

These devices help the user in checking one or more of the euro banknotes' features. With this help, but relying ultimately on their own knowledge, the user of such a device may reach an independent decision on whether a note is genuine or counterfeit.

Suppliers of detection equipment not included in the present survey are invited to apply for future inclusion by downloading and completing an application form from our 'Detection Equipment' webpage.

<table>
<thead>
<tr>
<th>Device name</th>
<th>Testing technique</th>
<th>&gt; 1 feature tested?</th>
<th>Price (EUR) excl. VAT</th>
<th>Importer and/ or distributor</th>
<th>Original supplier manufacturer</th>
<th>Note insertion</th>
<th>Can the device be upgraded by user?</th>
<th>Is device suitable for cordless operation?</th>
<th>Date of inclusion in this survey</th>
</tr>
</thead>
<tbody>
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<td>D-200 Tower</td>
<td>IR-camera, magnifying glass UV-lamp, magnetism</td>
<td>yes</td>
<td>299</td>
<td><a href="http://www.gerong.nl">www.gerong.nl</a></td>
<td>AccuBANKER Miami, USA</td>
<td>manual</td>
<td>unnecessary</td>
<td>no</td>
<td>week 17 2004</td>
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<tr>
<td>D-200 Tower</td>
<td>IR-camera, magnifying glass UV-lamp, magnetism</td>
<td>yes</td>
<td>249</td>
<td><a href="http://www.moneytronic.nl">www.moneytronic.nl</a></td>
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<td>manual</td>
<td>unnecessary</td>
<td>no</td>
<td>week 18 2004</td>
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<tr>
<td>Euro-OK</td>
<td>Mirror, lamp, magnifying glass, note dimensions</td>
<td>yes</td>
<td>99</td>
<td><a href="http://www.euro-ok.nl">www.euro-ok.nl</a></td>
<td>Destic Veendam, Nederland</td>
<td>manual</td>
<td>unnecessary</td>
<td>no</td>
<td>week 17 2004</td>
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<tr>
<td>IR-07€</td>
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<td>nee</td>
<td>239</td>
<td><a href="http://www.coin-masters.com">www.coin-masters.com</a></td>
<td>Beijing Royal Aviation</td>
<td>manual</td>
<td>unnecessary</td>
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<td>197,5</td>
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<td>unnecessary</td>
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<td>MD 30</td>
<td>Infrared camera UV-lamp</td>
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<td>199</td>
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<td>MoneyChecker</td>
<td>Infrared camera UV-lamp several lenses, other</td>
<td>yes</td>
<td>895</td>
<td><a href="http://www.scbs.nl">www.scbs.nl</a></td>
<td>OeBS tech GmbH Wenzen, Oosternijk</td>
<td>manual</td>
<td>unnecessary</td>
<td>no</td>
<td>week 17 2004</td>
</tr>
</tbody>
</table>
2  Autorecognition devices

These devices indicate, by means of a visible or audible signal or on a text display, whether a banknote is found to be genuine. The user just inserts a note and the device decides.

Each type of device is tested only once, unless several suppliers each offered the same device but with different software versions. When this is the case, the detection performance of two seemingly identical devices may differ considerably. If devices were tested for the current survey with a software version that differs from the version that was previously tested (period April 2004 - September 2004) this is indicated in red italics. For each device included in this survey, the test results below are applicable with the reported software versions only. Contact your supplier if you are uncertain whether the test results apply to your configuration or in case you need assistance to upgrade your device.

All devices were tested with the same representative trial sets of counterfeits and genuine euro banknotes. The trial set with genuine euro notes contains a broad range of banknotes which cashiers might be presented with in real-life situations. The note quality varies from new to limp and soiled notes with tears and adhesive tape repairs. The used notes were taken from actual circulation, but the trial set contains a higher than average share of soiled and damaged notes. The survey shows per device which percentage of counterfeit notes was correctly identified as counterfeit and which percentage of genuine notes was recognized as genuine. The test results reported here represent a snapshot and do not provide guarantees as to, for instance, the correct identification of novel types of counterfeit. Regularly performed follow-up tests will include, to the extent possible, newly identified counterfeits.

Suppliers of detection equipment not included in the present survey are invited to apply for future inclusion by downloading and completing an application form from our 'Detection Equipment' webpage.

<table>
<thead>
<tr>
<th>Device name</th>
<th>Type/plus software version</th>
<th>Price [EUR] excl. VAT</th>
<th>% counterfeit correctly identified</th>
<th>% genuine notes correctly recognised</th>
<th>Importer and/or distributor</th>
<th>Original supplier/manufacturer</th>
<th># 1 feature tested?</th>
<th>Note insertion</th>
<th>Upgrading possible by user?</th>
<th>Suitable for cordless operation?</th>
<th>Date of test</th>
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<td>96,8</td>
<td>100</td>
<td><a href="http://www.veka-systems.nl">www.veka-systems.nl</a></td>
<td>Nanjing NewTech</td>
<td>China</td>
<td>no</td>
<td>manual</td>
<td>no</td>
<td>week 52 2004</td>
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<td>original version</td>
<td>79,95</td>
<td>100</td>
<td>98</td>
<td><a href="http://www.veka-systems.nl">www.veka-systems.nl</a></td>
<td>Shenzhen Double Power</td>
<td>China</td>
<td>yes</td>
<td>manual</td>
<td>no</td>
<td>week 52 2004</td>
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<td>CashTester CT 5000</td>
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<td>100</td>
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<td>Germany</td>
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<td>manual</td>
<td>yes</td>
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<td>98,4</td>
<td>98</td>
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<td>Germany</td>
<td>yes</td>
<td>manual</td>
<td>yes</td>
<td>week 50 2004</td>
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<td>98,4</td>
<td>98</td>
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<td>Device name</td>
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<td>Price (EUR) excl VAT</td>
<td>% counterfeits correctly identified</td>
<td>% genuine notes correctly recognized</td>
<td>Importer and/or distributor</td>
<td>Original supplier/manufacturer</td>
<td>&gt; feature tested?</td>
<td>Note insertion</td>
<td>Upgrading possible by user?</td>
<td>Suitable for cordless operation?</td>
<td>Date of test</td>
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## Counterfeit Detection Equipment Survey (continued)

January 2005, De Nederlandsche Bank

<table>
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<tr>
<th>Device name</th>
<th>Type and/or software version</th>
<th>Price EUR excl VAT</th>
<th>% counterfeit notes identified</th>
<th>% genuine notes correctly recognised</th>
<th>Importer and/or distributor</th>
<th>Original supplier/manufacturer</th>
<th>Multiple feature tests</th>
<th>Note insertion</th>
<th>Upgrading possible by user?</th>
<th>Suitable for cordless operation?</th>
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