Talk presented at IEEE Security and Privacy 2014

Chip and Skim: Cloning EMV cards with the pre-play attack

Mike Bond, **Omar Choudary**, Steven J. Murdoch, Sergei Skorobogatov, Ross Anderson

Computer Laboratory

UNIVERSITY OF CAMBRIDGE

EMV – leading system for payments across the world

Chip and Skim. Bond, Choudary, Murdoch, Skorobogatov, Anderson.

EMV – introduced to remove magstripe counterfeiting

- EMV uses CHIP & PIN
- Should protect against card cloning and abuse
- Should decrease fraud

Chip and PIN

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EMV is not totally secure in practice

- We discovered 2 important flaws in EMV
  - engineering flaw
  - protocol flaw
- In practice these allow same effect as card cloning
  - we can perform a “CHIP & PIN” transaction without the original EMV card

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EMV protocol for POS/ATM

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EMV protocol – online authorisation

K

K

D={Amount, Country, Date, **UN**, …}

REQ={UN,ATC,IAD,…}, AUTH REQ=MAC_K(D, **ATC**, IAD)

RESP={OK/BAD}, AUTH RESP=MAC_K(RESP, AUTH REQ,…)

UN = Unpredictable Number

ATC = Application Transaction Counter

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Evidence from real data: UN is a counter!

Time	UN
10:37:24	F1246E04
10:37:59	F1241354
10:38:34	F1244328
10:39:08	F1247348

- 17 bits fixed
- 15 bits seem to follow a linear counter

Chip and Skim. Bond, Choudary, Murdoch, Skorobogatov, Anderson.

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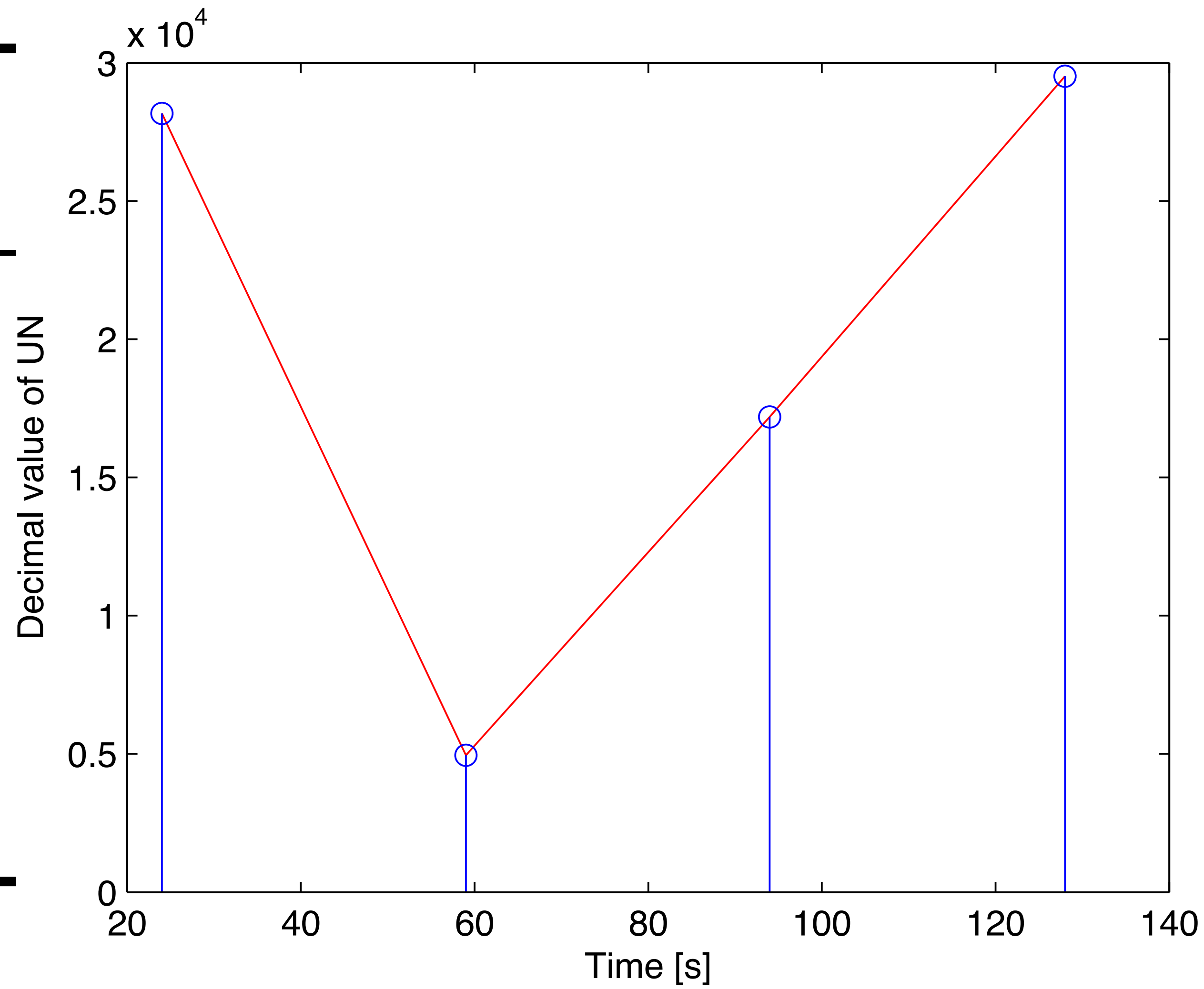

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No terminal ID

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REQ={UN,ATC,IAD,…}, AUTH REQ=MAC$_K$(D, **ATC**, IAD)

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Pre-play attack: exploit predictable UN

Step 1: Skim PIN & data for set of UNs

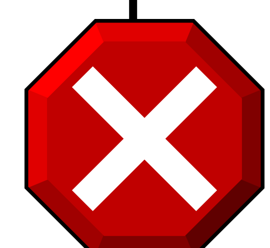
$D_1=\{\text{Amount, Country, Date, } \mathbf{UN_1}, \ldots\}$ →

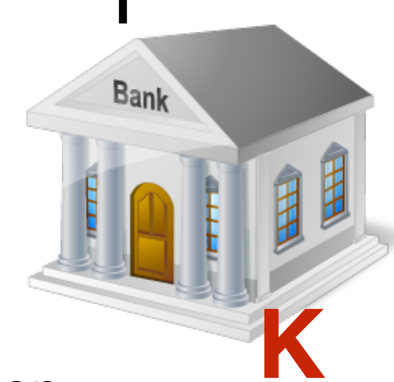
← AUTH REQ_1

$D_2=\{\text{Amount, Country, Date, } \mathbf{UN_2}, \ldots\}$ →

← AUTH REQ_2

⋮





ID	UN	AUTH REQ
1	xx	aa
2	yy	bb
…		

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Pre-play attack: exploit predictable UN

Step 2: replay data to get diamond

D={Amount, Country, Date, **UN**, …}

Replay from table of skimmed data

ID	UN	AUTH REQ
1	xx	aa
2	yy	bb
…		

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Can we find weak RNGs?

- Previous EMV specs only required 4 consecutive UNs to be different
    - a counter would work better than a secure TRNG
- We decided to find out …

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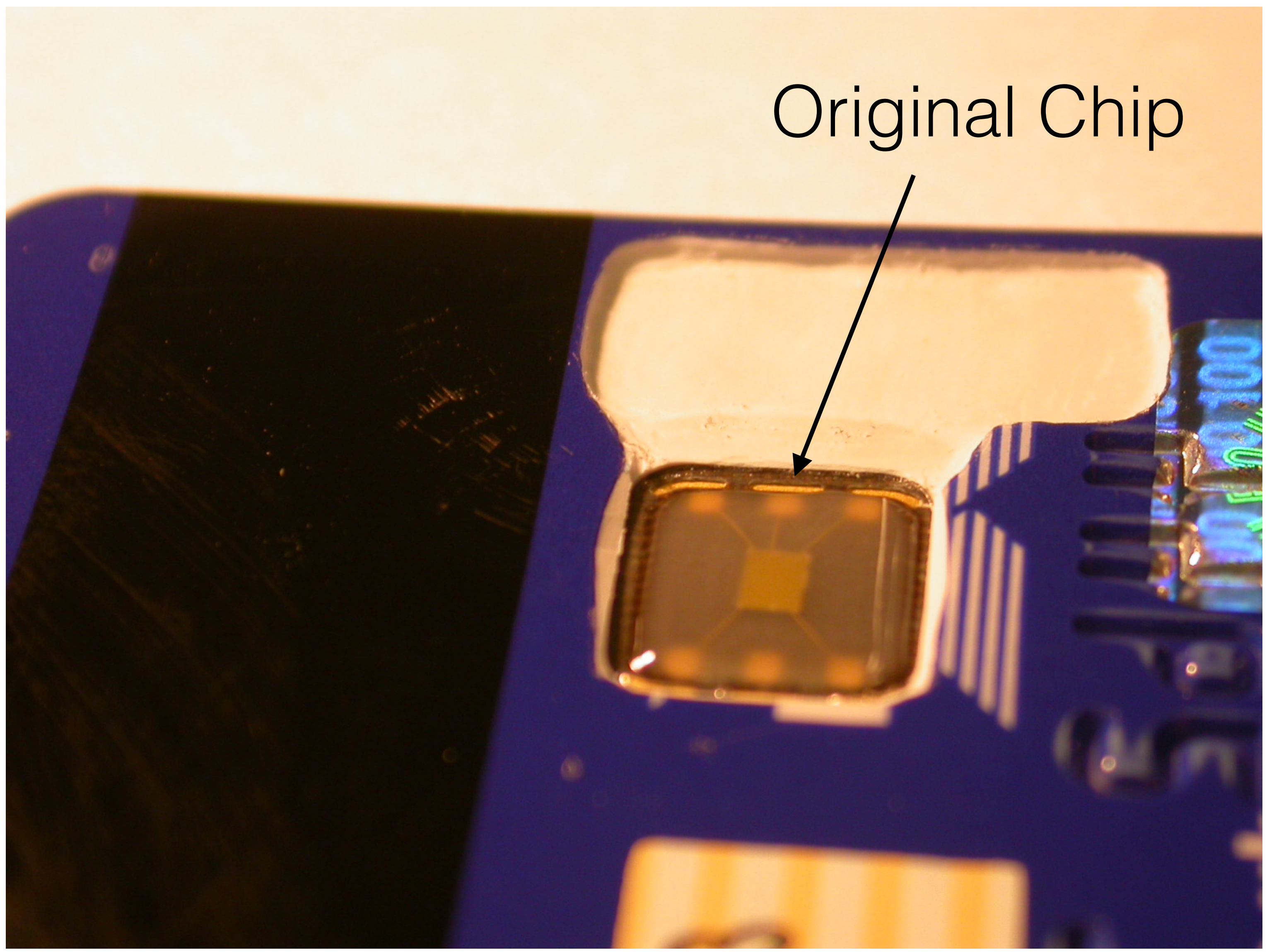
Searching for weak RNG: using ATM logger



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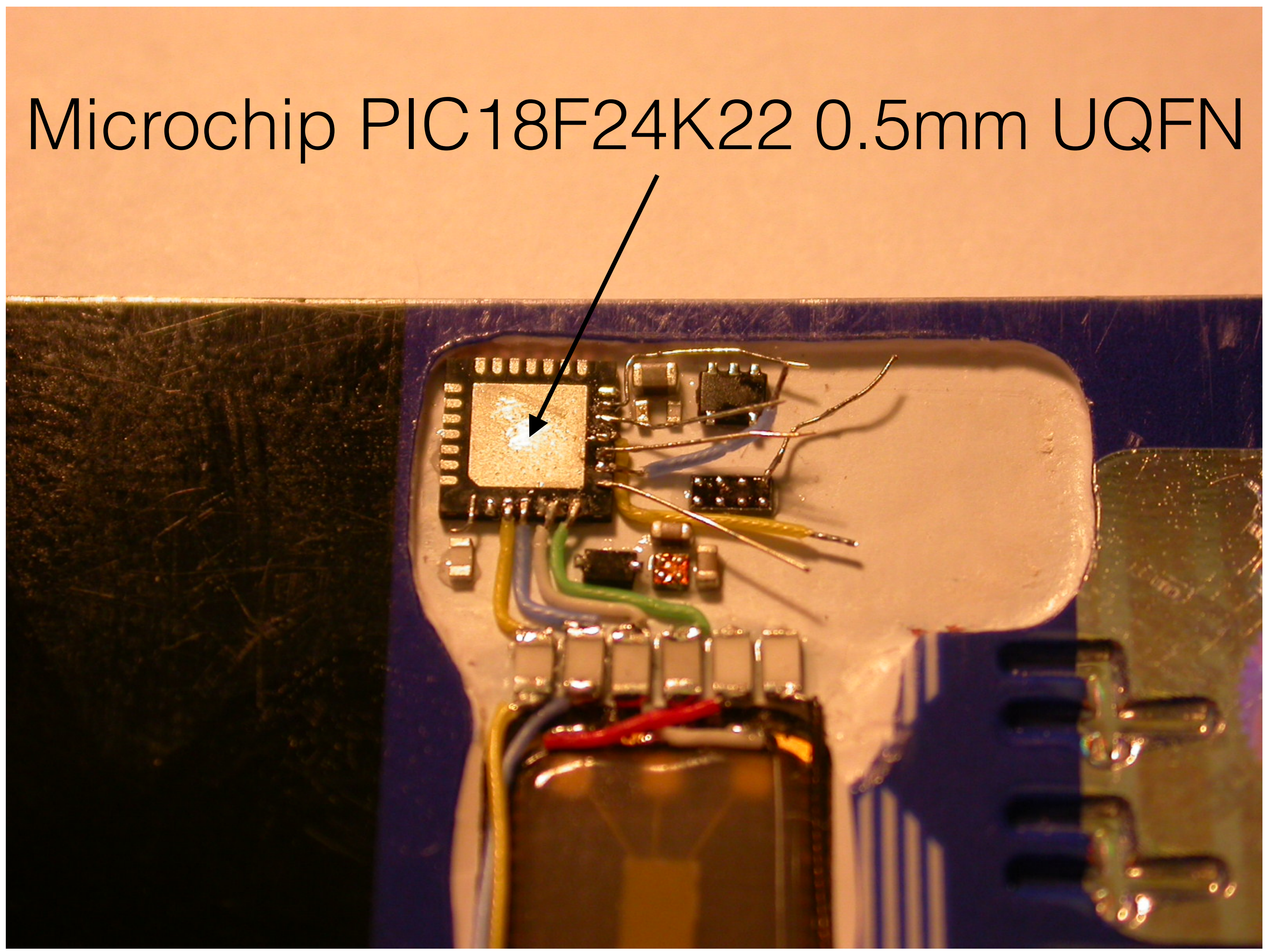

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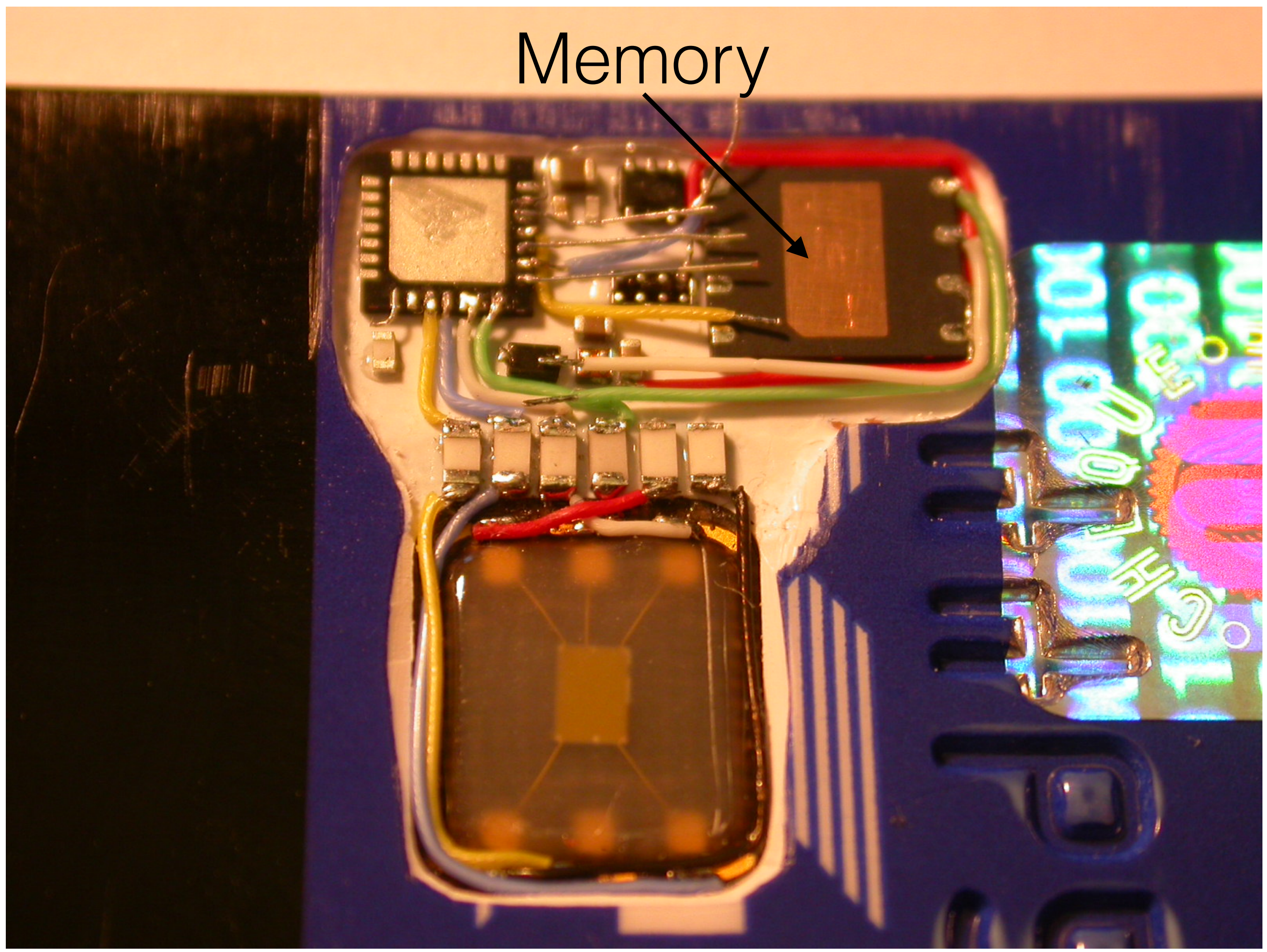

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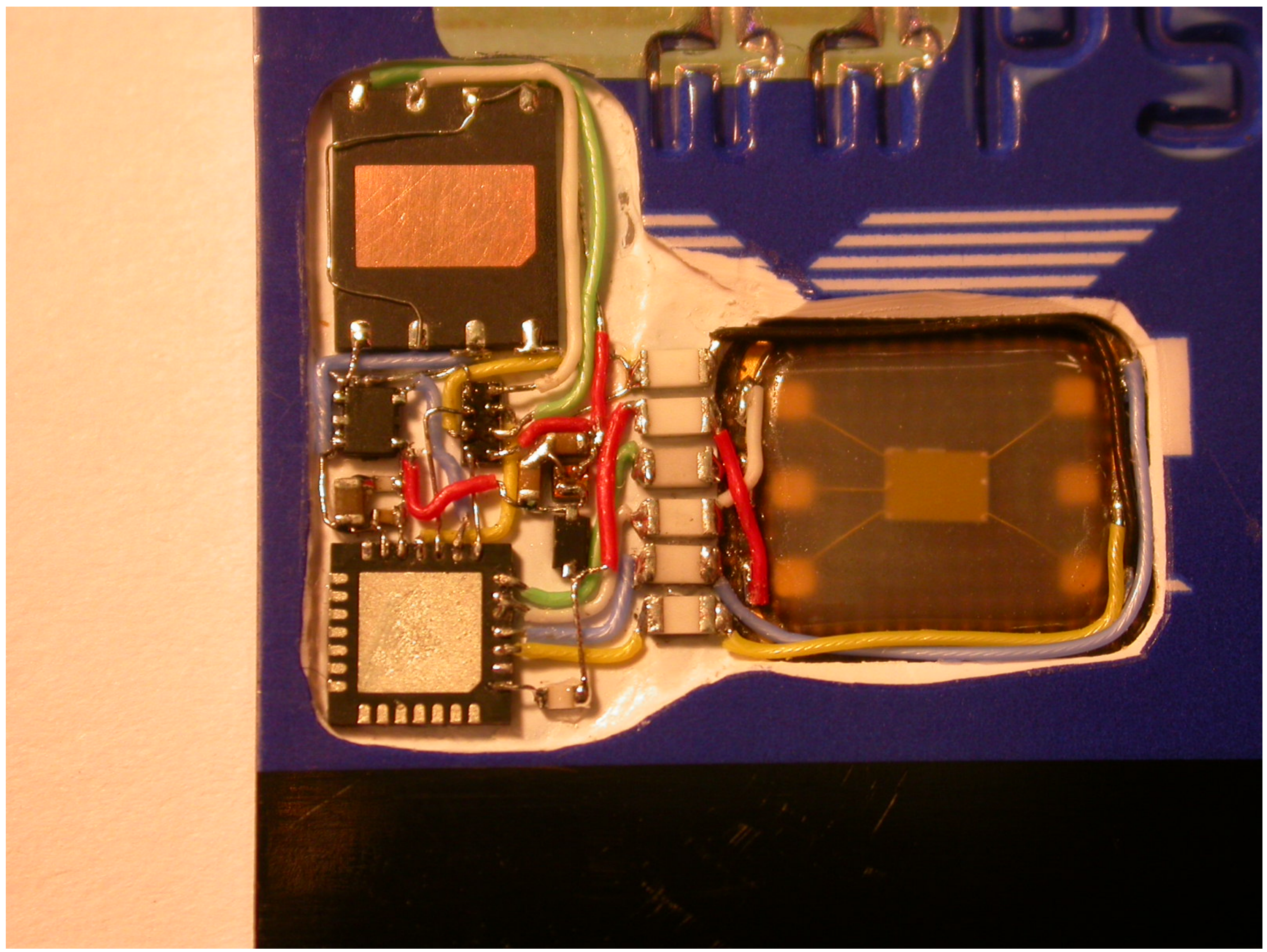

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Searching for weak RNG: using ATM logger

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Searching for weak RNG: using ATM logger

- Characteristic C (5 bits fixed):
  - Third nibble is 0
  - First bit is 0
- 11 ATMs had same output
- Possibly due to common lib

Weak RNGs	
ATM1	690d4df2
ATM1	69053549
ATM1	660341c7
ATM1	5e0fc8f2
ATM2	6f0c2d04
ATM2	580fc7d6
ATM2	4906e840
ATM2	46099187

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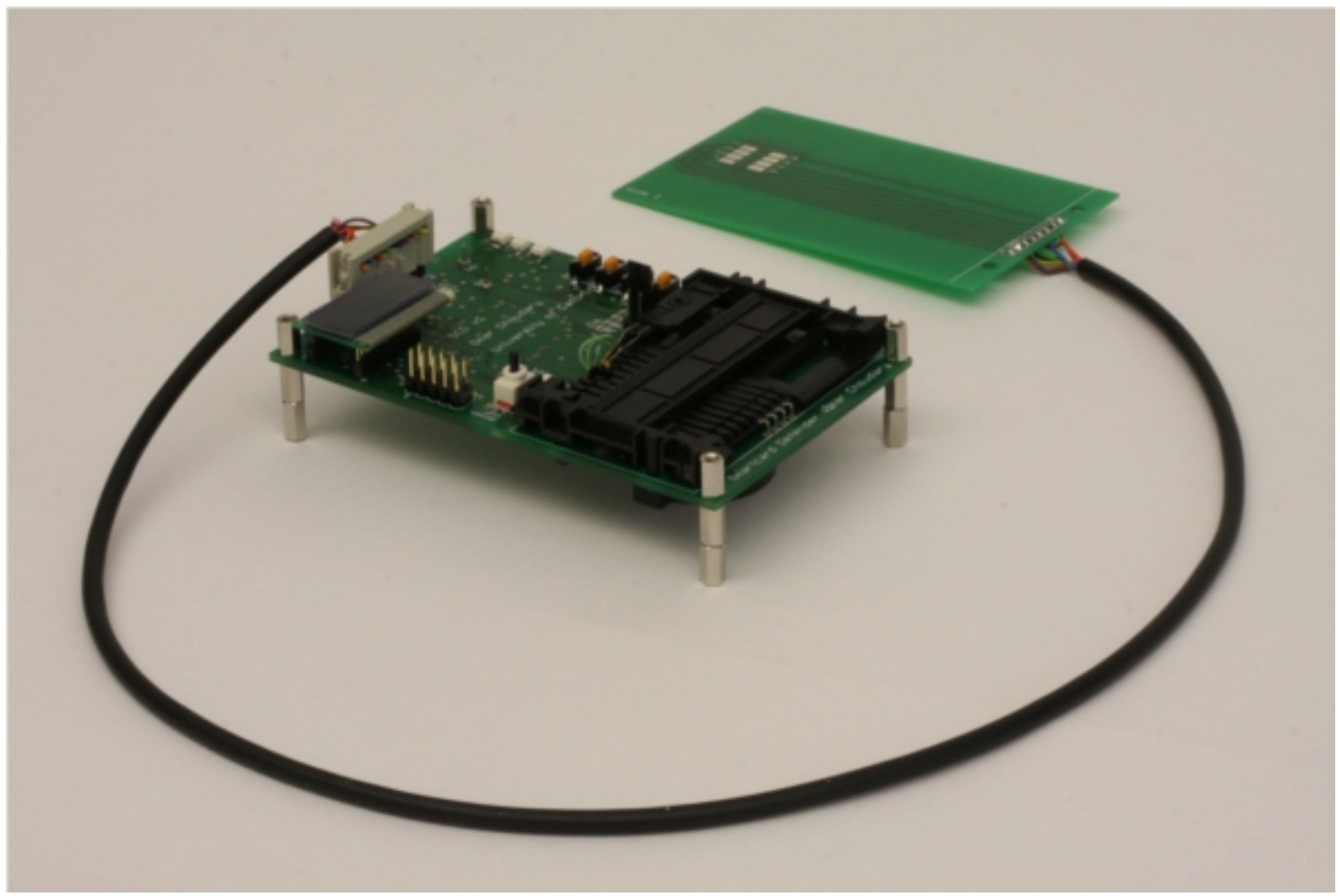
Searching for weak RNG: using SmartCard Detective



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Searching for weak RNG: using SmartCard Detective

- Results from local POS
- First bit still 0, but otherwise could not find clear pattern

Stronger RNGs	
POS1	013A8CE2
POS1	01FB2C16
POS1	2A26982F
POS1	39EB1E19
POS1	293FBA89
POS1	49868033

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The deeper problem:
We can use our own UN!

K

K

D={Amount, Country, Date, **UN**, …} →

← REQ={UN,ATC,IAD,…}, AUTH REQ=$\text{MAC}_{\mathbf{K}}$(D, ATC, IAD)

RESP={OK/BAD}, AUTH RESP=$\text{MAC}_{\mathbf{K}}$(RESP, AUTH REQ,…) →

UN generated by Terminal (POS, ATM), not issuer!

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The pre-play attack by tampering UN

Step 1: get PIN & data for a **chosen** UN

D={Amount, Country, Date, **UN**, …}

AUTH REQ=MAC$_K$(D, ATC, IAD)

K

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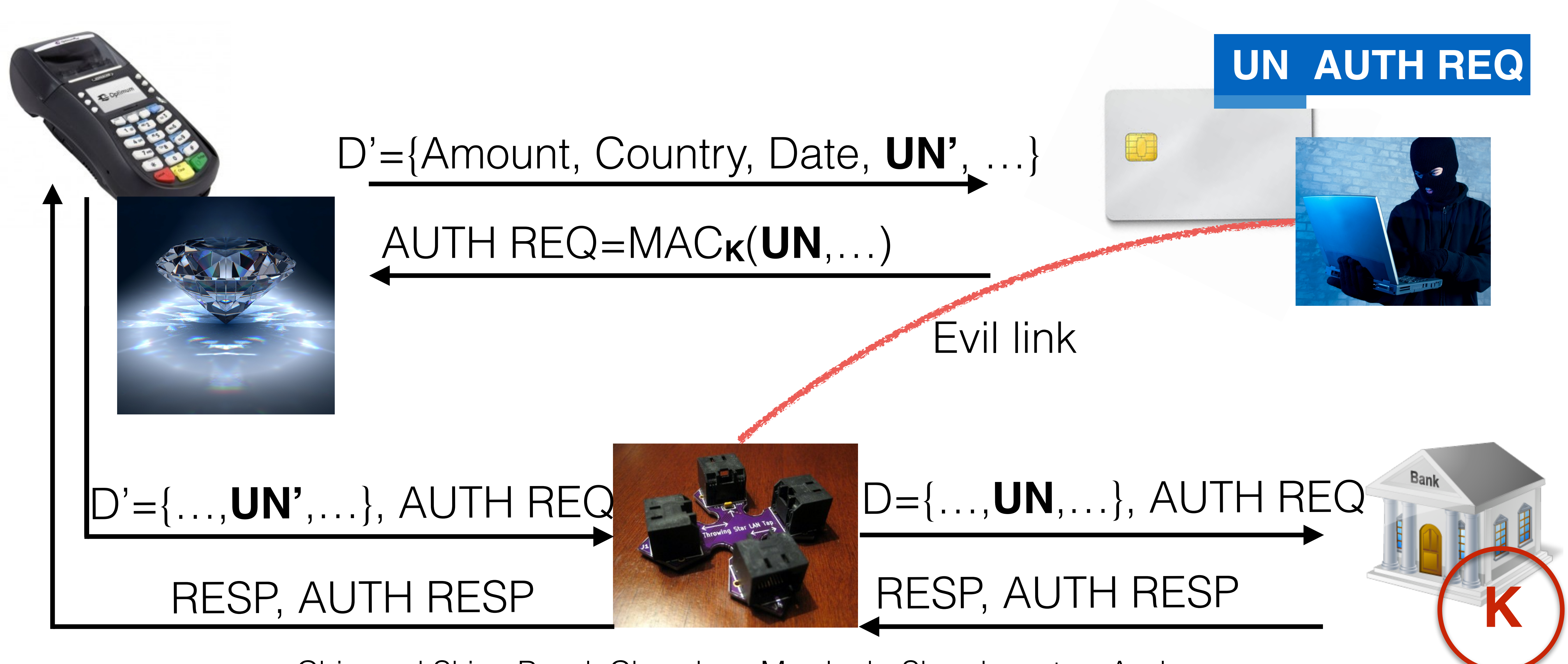
The pre-play attack by tampering UN

Step 2: replay data & tamper UN to get diamond



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Can we actually modify the UN sent by the terminal ?

Likely. It depends on bank, country, regulator, etc.

Issuer

syntax, semantic: ISO 8583, ISO 20022, …

transport: AS2, AS3, SWIFT, FTP, IFX, …

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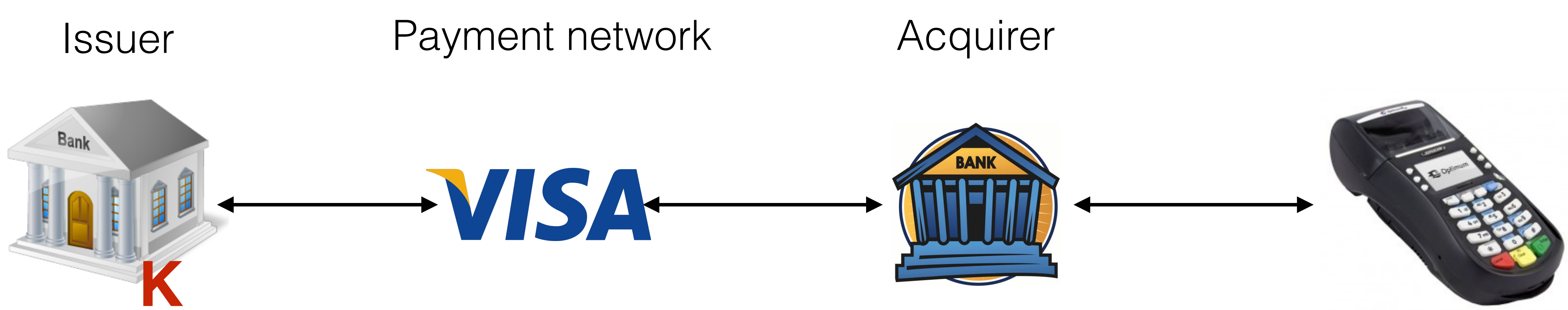

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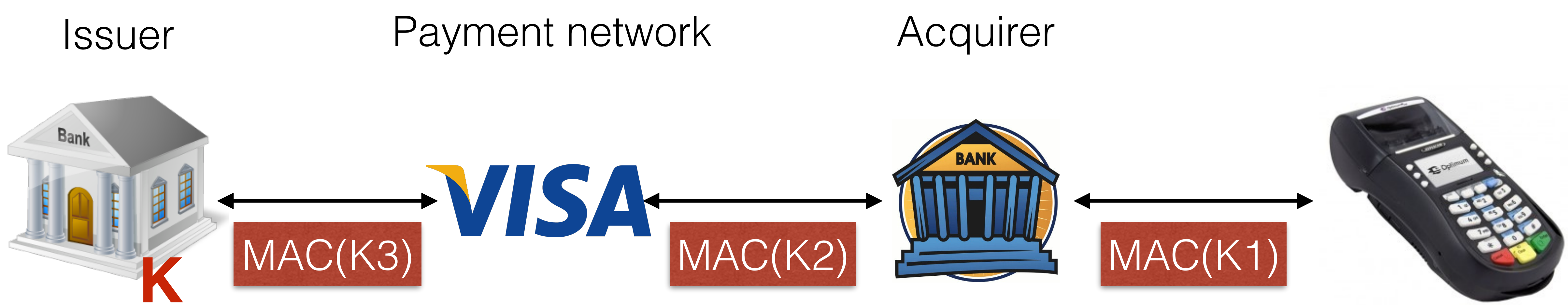

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Can we actually modify the UN sent by the terminal ?

… ***emergence of new functionality such as authentication methods*** …
[VISA "Transactions Acceptance Device Guide" 2013]

Practical example: Maxwell Parsons in UK

- injected data into the bank system (reverse transactions), steeling £2,560,000 in 7 months

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Can we actually modify the UN sent by the terminal ?

- Even if authentication is enabled, there are options:
  - Malware infection of POS/ATM
  - Supply chain attacks (react on covert signal)
  - Collusive or dishonest merchant

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It is a protocol problem

- Issuer relies on fresh UN for transaction
- But UN generated by terminal
- Terminal might not have incentive to cooperate

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Card authentication via DDA does not help

Start transaction

Card data records

Signature over data records

PKI

Same UN for both DDA and ARQC => skim signature as well

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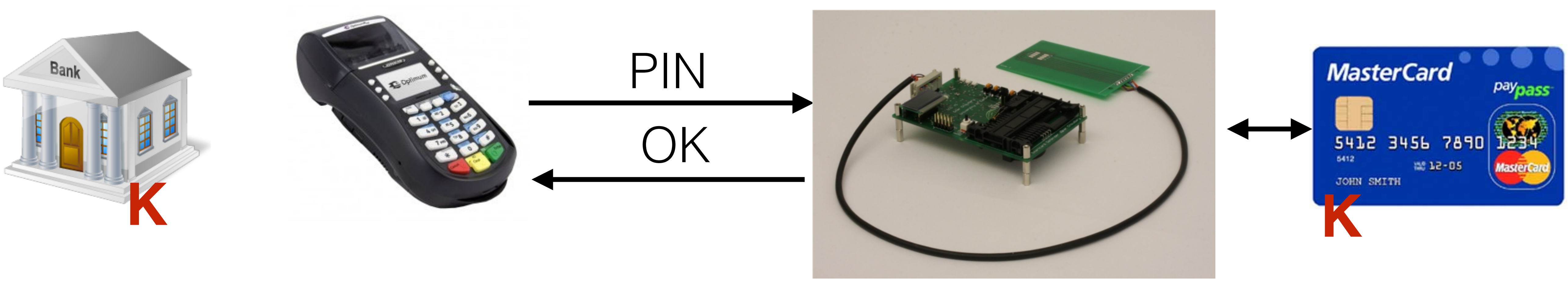
PIN verification does not help either

Simply skim PIN during step (1) of attack, or lie [Oakland '10]



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Blocking a pre-play attack using the Transaction Certificate (TC)

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D={Amount, Country, Date, **UN**, …}

REQ={UN,ATC,IAD,…}, AUTH REQ=MAC_K(D, ATC, IAD)

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RESP={OK/BAD}, AUTH RESP=$\text{MAC}_{\mathbf{K}}$(RESP, AUTH REQ,…) →

External Authenticate

RESP, AUTH RESP →

D’ →

Final exchange

← TC=$\text{MAC}_{\mathbf{K}}$(D’, ATC, **IAD**)

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Importance of TC not taken into consideration

- Problem 1: TC not routinely kept
  - not needed for clearance, may be discarded
  - only needed to ensure that card does not need to go online (issuer) at next transaction and to provide liability protection to acquirer
- Problem 2: TC may be sent within 24 hours
  - good: send daily TC batches to reduce #messages
  - bad: this leaves system open to pre-play attack

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What could EMV do

- Fix RNG everywhere
- Mandatory authentication between all parties
- Request terminal to keep log of UNs for disputes
- Mandatory check or at least storage of TC for every transaction
  - **TC should be the only probative evidence** in case of disputes
- For high-value transactions, check TC before customer leaves the shop!

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Conclusions

- We discovered a deep and important flaw in the EMV implementation, indistinguishable from card cloning
- Issuer relies on freshness, but this is generated by another party
  - Changing the protocol is unlikely to happen
  - Practical solution is mandatory use or retention of TC
- Lack of understanding and deliberate overstatement of security may lead to customers being defrauded
- Bank regulators should prohibit EMV liability shift

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Questions?

Speaker: Omar Choudary

Co-authors: Mike Bond, Steven Murdoch, Sergei Skorobogatov, Ross Anderson

E-mail: firstname.lastname@cl.cam.ac.uk

Security Group, Computer Laboratory

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Industry response

- RNG attack disclosed in early 2012
- Banks and payment switches acknowledge receipt
- April 2012 EMVCo publishes update on RNG
- However, ATMs and terminals still vulnerable to malware
  - industry insider mentioned Malta's case may involve ATM malware

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ATM reverse engineering

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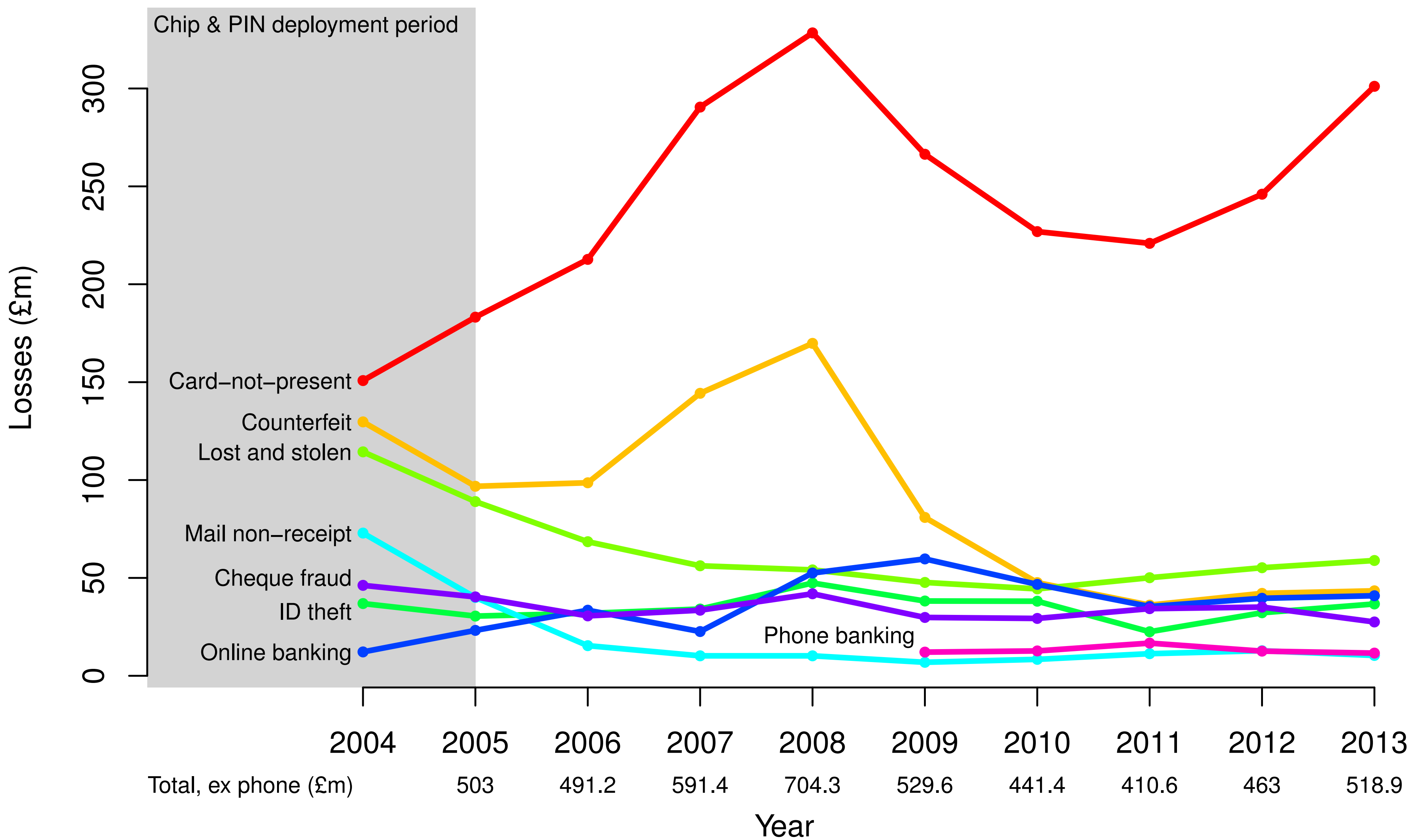
Bank losses by kind



Fraud levels on UK-issued payments cards

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