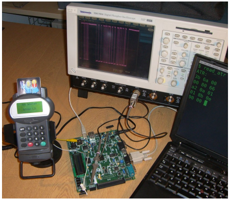
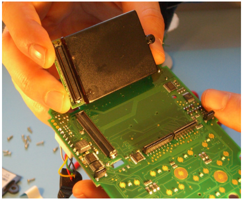
Chip & PIN – notes on a dysfunctional security system





Saar Drimer

http://www.cl.cam.ac.uk/~sd410/

UNIVERSITY OF CAMBRIDGE
Computer Laboratory

in collaboration with Steven J. Murdoch, Ross Anderson, Mike Bond

The Institution of Engineering and Technology (IET), Cambridge, UK, 4 March 2010

Presentation outline

- Introduction to EMV ("Chip and PIN") and background
- Yes-card attack
- Relay attack
- Terminal tampering attack
- "no-PIN" attack, and reactions
- The big picture

Chip & PIN has now been running in the UK for about 5 years

- Chip & PIN, based on the EMV (EuroPay, MasterCard, Visa) standard, is deployed throughout most of Europe
- In process of roll-out elsewhere
- Chip authenticates the card; PIN authenticates the cardholder
- UK was an early adopter: rollout in 2003–2005; mandatory in 2006
- Chip & PIN changed many things, although not quite what people expected

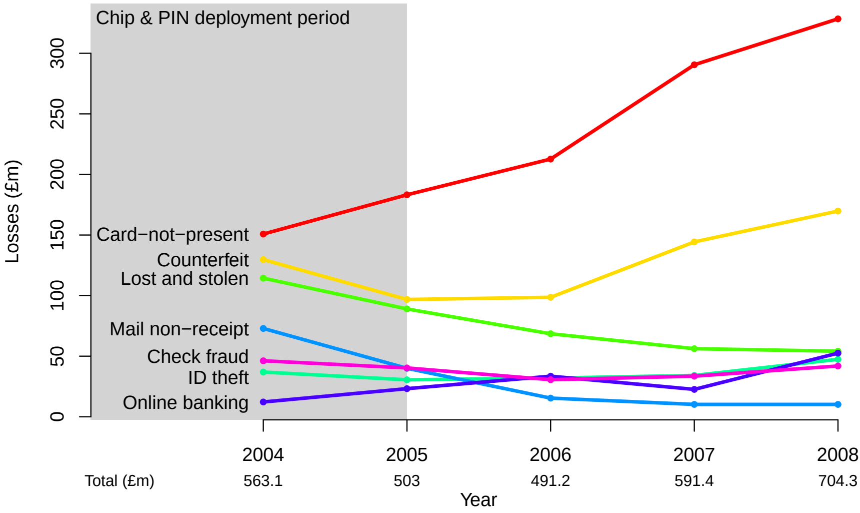
VISA

EXP: 30/11/09 ICC

SALE £50.00

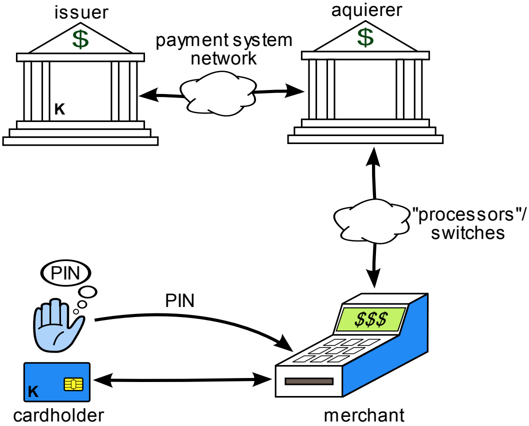
VERIFIED BY PIN

UK fraud figures 2004–2008



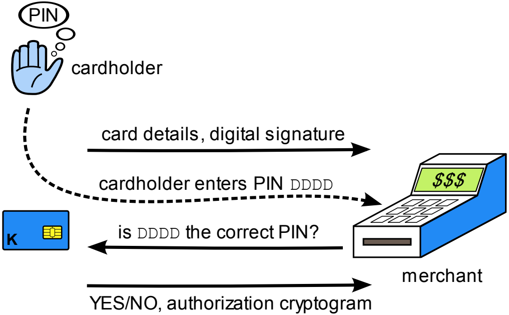
Source: APACS

EMV overview



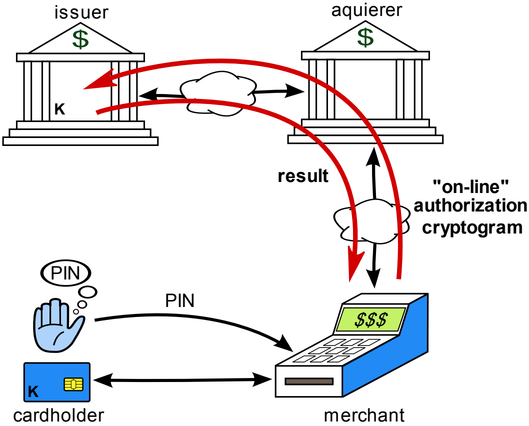
Authorisation of EMV transaction involves many parties

EMV overview – offline PIN


PIN
cardholder
card details, digital signature
cardholder enters PIN DDDD
K
$$$
is DDDD the correct PIN?
merchant
YES/NO, authorization cryptogram

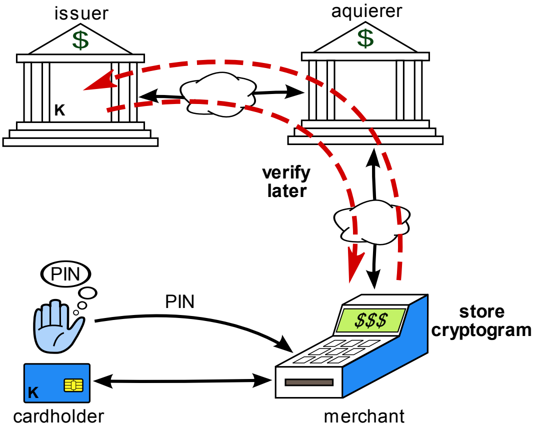
Card and cardholder authentication – PIN is sent to the card for checking if it is correct

EMV overview – online authorisation



The issuer approves the transaction before the exchange of goods takes place; merchant's receipt says “Verified by PIN”

EMV overview – offline authorisation



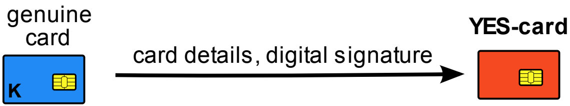
The issuer approves the transaction after the goods were exchanged

First EMV cards issued in the UK...

- Static Data Authentication (SDA)
  - No support for PIN encryption
  - card cannot sign fresh data
  - cheaper than Dynamic Data authentication (DDA) capable chips.
- Magstrip still on card
  - for backwards compatibility/backup
  - for use in non-EMV countries
  - still allows skimming
- Exact copy of magstrip tracks stored on chip
  - allows chip transactions to be processed as magstrip

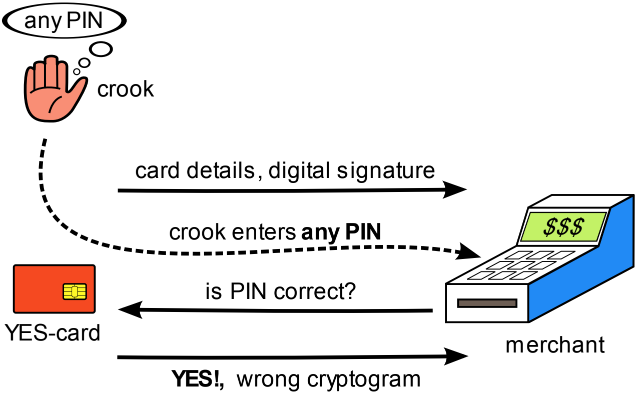
- The chip is hard to clone completely, so criminals rely on the mechanisms put in place for backwards-compatibility and cross-border interoperability

YES-card attack



Criminal copies all static data onto another card (certificate, application data, etc.) This chip on the YES-card is programmed to reply YES to any PIN entered

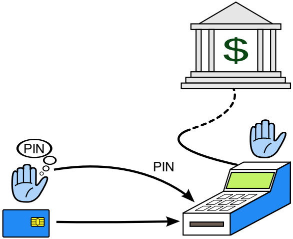
YES-card attack



The YES-card attack only works in off-line transactions because the wrong cryptogram would be detected in an on-line authorisation

solution: DDA, online authorisation

Relay attack: Alice thinks she's paying $20, but is charged $2,000 elsewhere



We take a normal Chip and PIN transaction,

separate the card and the terminal,

and connect them with a long wire (of course this is not very practical)

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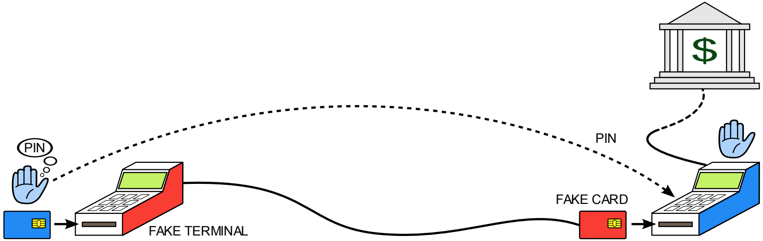

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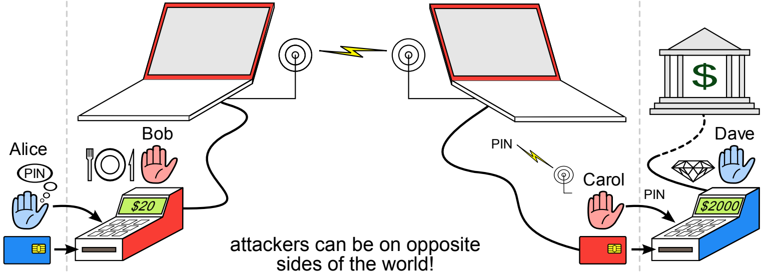
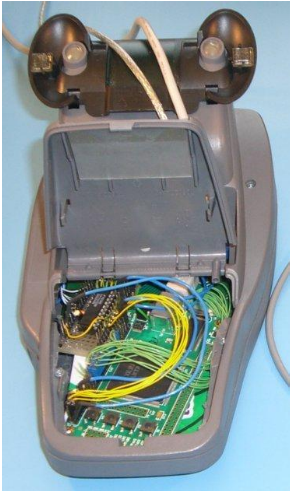
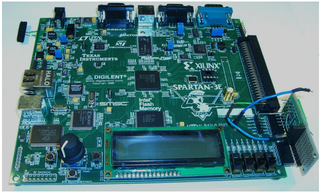


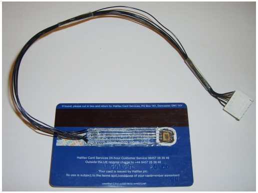
Alice inserts her card into Bob's *fake* terminal, while Carol inserts a fake card into Dave's *real* terminal. Using wireless communication the $2,000 purchase is debited from Alice's account.

solution: distance bounding

The relay kit:





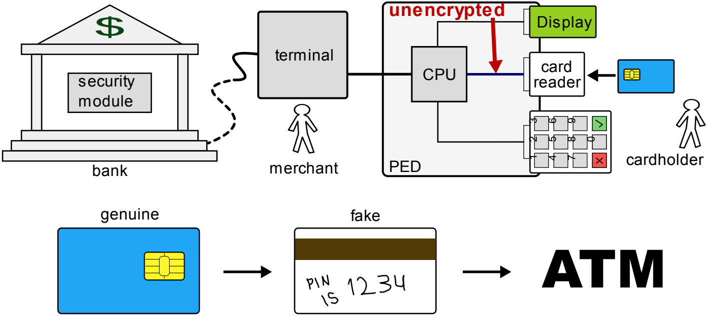


$500 worth of off-the-shelf hardware, two laptops and moderate engineering skill is all it takes.

We demonstrated the relay attack on BBC1's "Watchdog", February 2007

Watch video: `http://www.youtube.com/watch?v=X7pjUIxKoEc`
Academic paper and more info: `http://www.cl.cam.ac.uk/research/security/banking/relay/`

Terminal tampering attack



By "tapping" the communication line between the card and the terminal's processor, criminals can create a magnetic strip version of the card and use at ATMs that do not read smartcards (like in the U.S.)

Tamper proofing is supposed to protect the PIN and card data in transit

- Various standard bodies require that terminals be tamper proofed: Visa, EMV, PCI (Payment Card Industry), APACS (UK bank industry body)
- Evaluations are performed to well-established standards (Common Criteria)
- Visa requirement states that defeating tamper-detection would take more than 10 hours or cost over **USD $25,000 per terminal**

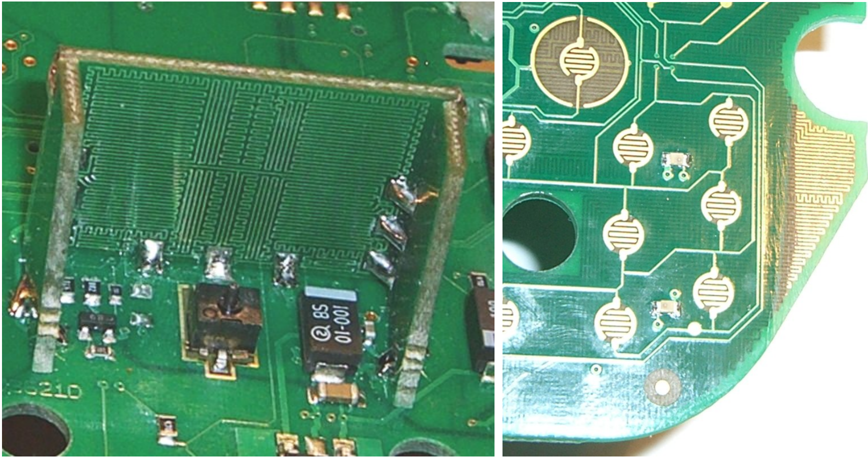
VISA

APACS

PCI Security Standards Council

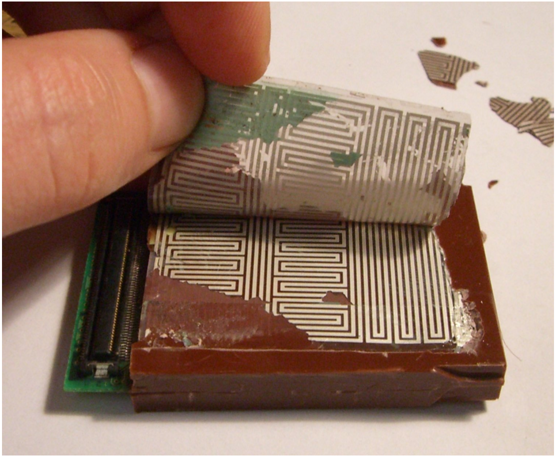
Common Criteria

Protection measures: tamper meshes



Ingenico i3300

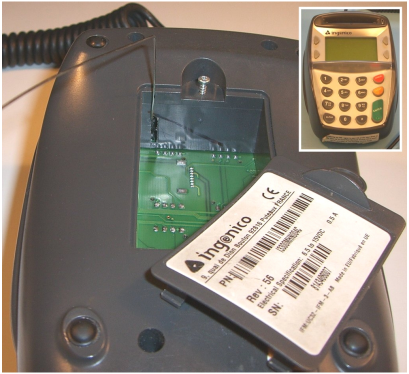
Protection measures: tamper meshes



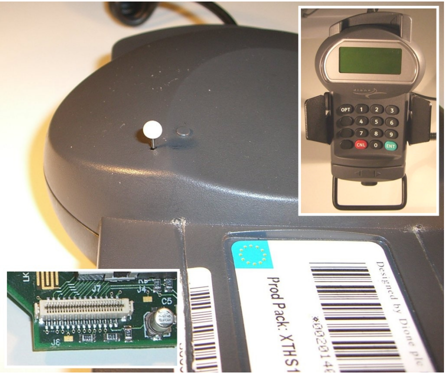
Ingenico i3300

We found how to attack these terminals using paperclips

Ingenico i3300


ingenico
9, quai de Dion Bouton 92816 Puteaux FRANCE
PN
Rev : 56
SN:
Electrical Specification: 6.5 to 15VDC 0.5 A
Made in EU/Fabriqué en UE

Dione Xtreme



It's just a matter of knowing where to drill!

... tamper resistance protects the banks' keys, not the cardholders' PINs

solution: PIN encryption, iCVV, better certification of terminals

We demonstrated the attack on BBC Newsnight in February 2008

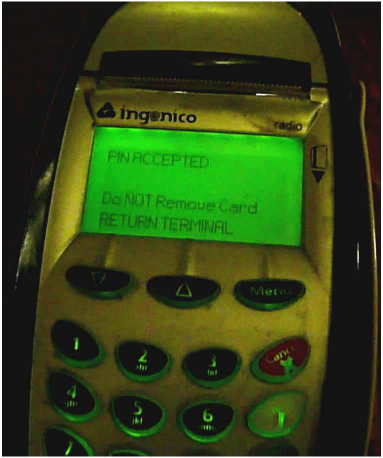
```
$ read_atr
ATR:
3b 6a 00
00 80 66
a2 0a 01
01 8b 0e
90 00
```

Criminals have been tampering with terminals since at least 2006...

Watch video: `http://video.google.com/videoplay?docid=7109740591622124830`
Academic paper and more info: `http://www.cl.cam.ac.uk/research/security/banking/ped/`

no-PIN attack

- The no-PIN attack allows criminals to use a stolen card without knowing its PIN
- It requires inserting a device between the genuine card and payment terminal
- This attack works even for online transactions, and DDA cards

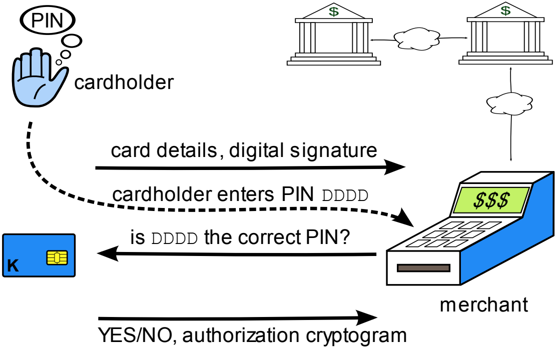


BBC Newsnight filmed our demonstration for national TV

BBC Newsnight, BBC2, 11 February 2010

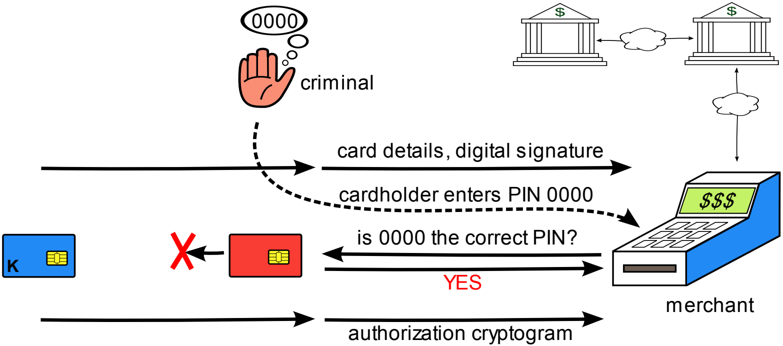
Watch video: `http://www.youtube.com/watch?v=JPAX32lgkrw`
Academic paper and more info: `http://www.cl.cam.ac.uk/research/security/banking/nopin/`

no-PIN attack


PIN
cardholder
$
$
card details, digital signature
cardholder enters PIN DDDD
$$$
K
is DDDD the correct PIN?
merchant
YES/NO, authorization cryptogram

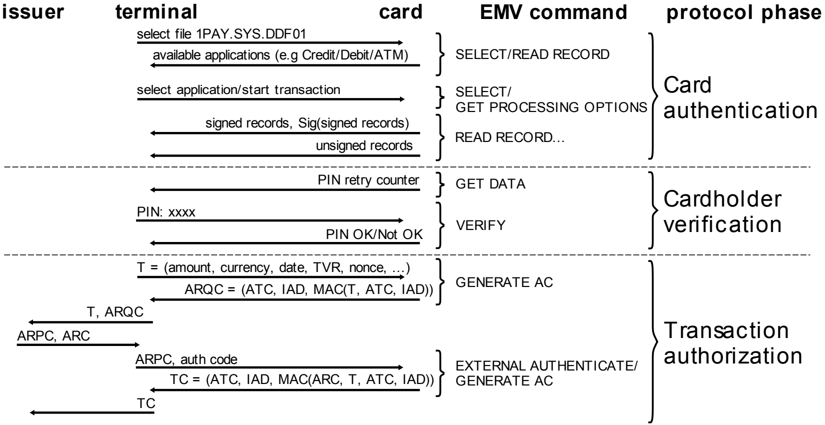
This is a normal transaction

no-PIN attack



The “wedge” (MITM) suppresses the “check PIN” command and replies “YES” to any PIN entered by the crook

no-PIN attack



issuer terminal card EMV command protocol phase

select file 1PAY.SYS.DDF01

available applications (e.g Credit/Debit/ATM)

SELECT/READ RECORD

select application/start transaction

SELECT/
GET PROCESSING OPTIONS

signed records, Sig(signed records)

unsigned records

READ RECORD...

Card authentication

PIN retry counter

GET DATA

PIN: xxxx

PIN OK/Not OK

VERIFY

Cardholder verification

T = (amount, currency, date, TVR, nonce, ...)

ARQC = (ATC, IAD, MAC(T, ATC, IAD))

GENERATE AC

T, ARQC

ARPC, ARC

ARPC, auth code

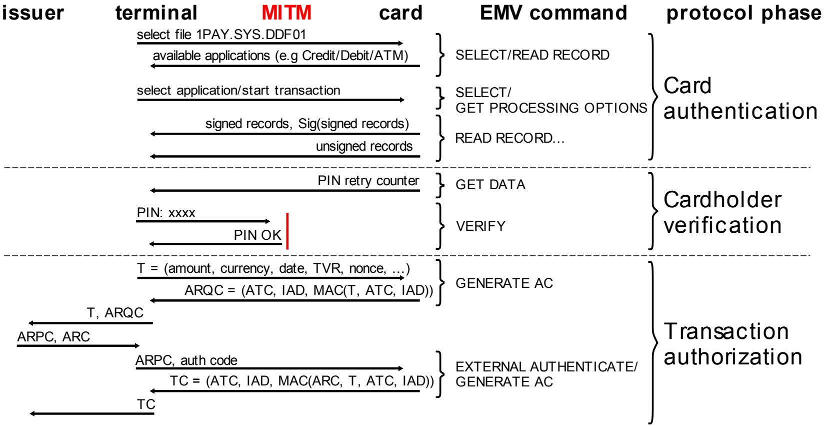
TC = (ATC, IAD, MAC(ARC, T, ATC, IAD))

EXTERNAL AUTHENTICATE/
GENERATE AC

TC

Transaction authorization

no-PIN attack



issuer **terminal** **MITM** **card** **EMV command** **protocol phase**

select file 1PAY.SYS.DDF01

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ARPC, auth code

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EXTERNAL AUTHENTICATE/
GENERATE AC

TC

Transaction authorization

solution: ?

Reaction

> *It requires possession of a customer's card [which is valid until it is reported stolen]*

Stolen cards are precisely the reason why Chip and PIN was introduced – to authenticate the cardholder.

> *there are much simpler ways to commit fraud under these circumstances at much less risk to the criminal.*

I call this the "we suck anyway defence", and it is unacceptable.

> *Cambridge claims that their latest attack is both a new discovery and undetectable; this is not true.*

This is worrying... if the attack was known, why wasn't if fixed?

Source: UK Cards Association (formerly APACS)
`http://www.theukcardsassociation.org.uk/view_point_and_publications/what_we_think/-/page/906/`

Reaction

> *The industry is confident that the forensic signature of such an attack is easily detectable... at the time of the transaction.*

The confidence isn't reassuring. We tried it. Many times. It works.

> *Neither the banking industry nor the police have any evidence of criminals having the capability to deploy such sophisticated attacks.*

- Absence of evidence is not evidence of absence
- Our many successful no-PIN transactions went undetected
- Criminals are very sophisticated – ATM skimmers, for example
- Break once, use anywhere

Source: UK Cards Association (formerly APACS)
`http://www.theukcardsassociation.org.uk/view_point_and_publications/what_we_think/-/page/906/`

Reaction

> *…card company… will always rely on primary evidence to review the facts of the case and would never use a paper receipt for evidence as suggested.*

Untrue. In at least one case, a bank used a receipt as primary evidence to refuse a refund

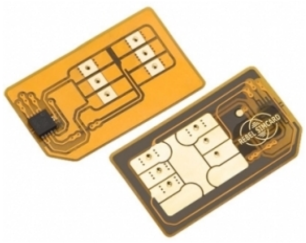
http://www.lightbluetouchpaper.org/2010/02/26/reliability-of-chip-pin-evidence-in-banking-disputes/

> *We believe that this complicated method will never present a real threat to our customers' cards*

Believe? Never?

Source: UK Cards Association (formerly APACS)
http://www.theukcardsassociation.org.uk/view_point_and_publications/what_we_think/-/page/906/

Reaction... “kit is too big”



Miniature SIM card “shims” exist for breaking phones from network lock-in

terminal → MITM:
`0020008008240000ffffffff`

MITM → terminal:
`9000`

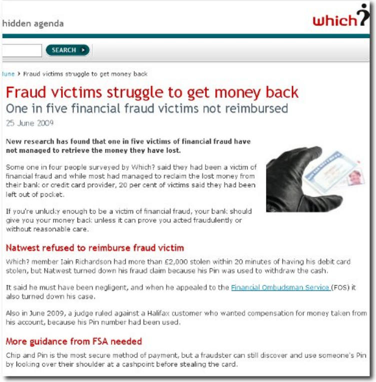
The no-PIN attack requires three lines of Python code

```
if DEBUG_VERIFY_PRE and command_ascii[0:4] == "0020":
  debug("Spoofing response to VERIFY command")
  return binascii.a2b_hex("9000")
```

Why is this a significant failure

- Both terminal and card completed a successful transaction from their perspective
    - flags indicate that something failed, but not what actually took place
- First attack on back-end transaction authorisation
    - up to now, our attacks were on how card were used
- Evidence is crucial
    - banks need to keep evidence and prove the *correct* PIN was used (TVR, ARQC, CVMR, IAD)
- Chip and PIN security is further undermined
    - this is a protocol failure, and it is unclear whether it can be easily fixed
    - when challenged, banks may no longer rely on unsubstantiated security claims

Weak customer protection leaves many victims "out of pocket"



Fraud victims struggle to get money back

One in five financial fraud victims not reimbursed

25 June 2009

New research has found that one in five victims of financial fraud have not managed to retrieve the money they have lost.

Some one in four people surveyed by Which? said they had been a victim of financial fraud and while most had managed to reclaim the lost money from their bank or credit card provider, 20 per cent of victims said they had been left out of pocket.

If you're unlucky enough to be a victim of financial fraud, your bank should give you your money back unless it can prove you acted fraudulently or without reasonable care.

Natwest refused to reimburse fraud victim

Which? member Iain Richardson had more than £2,000 stolen within 20 minutes of having his debit card stolen, but Natwest turned down his fraud claim because his Pin was used to withdraw the cash.

It said he must have been negligent, and when he appealed to the Financial Ombudsman Service (FOS) it also turned down his case.

Also in June 2009, a judge ruled against a Halifax customer who wanted compensation for money taken from his account, because his Pin number had been used.

More guidance from FSA needed

Chip and Pin is the most secure method of payment, but a fraudster can still discover and use someone's Pin by looking over their shoulder at a cashpoint before stealing the card.

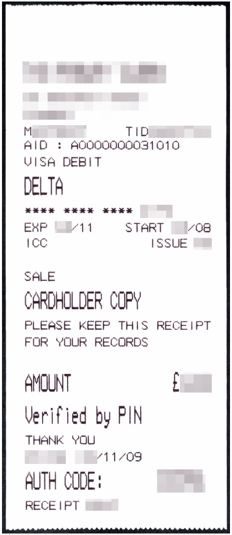
One in five cardholders do not get their money back

banking code/payment services directive are elusive

banks reluctant to provide victims the evidence they use to determine that they are negligent

Source: `http://www.which.co.uk/news/2009/06/fraud-victims-struggle-to-get-money-back-179150.jsp`

Banks are not usually required to provide verifiable evidence when disputes occur

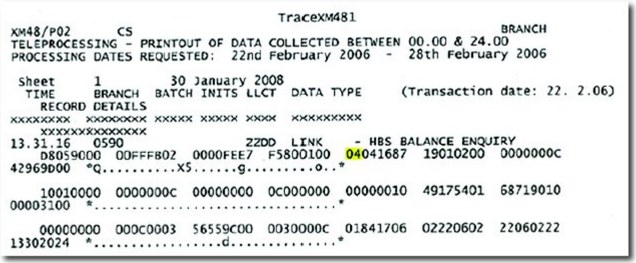


[redacted]

M[redacted] TID[redacted]
AID : A0000000031010
VISA DEBIT
DELTA
**** **** **** [redacted]
EXP [redacted]/11 START [redacted]/08
ICC ISSUE [redacted]

SALE
CARDHOLDER COPY
PLEASE KEEP THIS RECEIPT
FOR YOUR RECORDS

AMOUNT £[redacted]
Verified by PIN
THANK YOU
[redacted] [redacted]/11/09
AUTH CODE: [redacted]
RECEIPT [redacted]



```
                                       TraceXM481
XM48/P02       CS                                                  BRANCH
TELEPROCESSING - PRINTOUT OF DATA COLLECTED BETWEEN 00.00 & 24.00
PROCESSING DATES REQUESTED:  22nd February 2006  -  28th February 2006

 Sheet      1         30 January 2008
  TIME      BRANCH  BATCH INITS LLCT  DATA TYPE     (Transaction date: 22. 2.06)
    RECORD DETAILS
xxxxxxxx  xxxxxxxx xxxxx xxxxx xxxx  xxxxxxxxx
    xxxxxxxxxxxxxx
13.31.16    0590                ZZDD  LINK     - HBS BALANCE ENQUIRY
    D8059000  00FFFB02  0000FEE7  F5800100  04041687  19010200  0000000C
42969D00  *Q..........X5......g.........o..*

    10010000  0000000C  00000000  0C000000  00000010  49175401  68719010
00003100  *................................*

    00000000  000C0003  56559C00  0030000C  01841706  02220602  22060222
13302024  *..................d.............*
```

- Evidence in a recent court case – highlighted digits are supposed to indicate a chip transaction, but in proprietary format
- “Verified by PIN” on receipts is meaningless without the ability to verify it
- Banks sometimes destroy primary evidence

Source: `http://www.cl.cam.ac.uk/~rja14/Papers/halifax-log.pdf`

What has failed?

- Liability engineering – banks care less about the security systems they maintain
- Over-specification – thousands of pages of specification inevitably lead to insecure implementations
- Poor design choices – fallback enable security holes to remain, and protocols to be broken by design
- Tick-box mentality – certification doesn't work when certification labs carry no penalty for certifying broken equipment
- Not understanding the enemy – assumption that the enemy is incompetent, and that merchants are always honest
- Closed system forced on public – no external review

For all these reasons, the "Chip and PIN" system is fundamentally broken.

The end – thanks!

© Cartoonbank.com

"You know, you can do this just as easily online."

Our group's blog:

`http://www.lightbluetouchpaper.org/`

Further information:

`http://www.cl.cam.ac.uk/research/security/banking/`

P.C Vey, Published in The New Yorker January 16, 2006
`http://www.thenewyorkerstore.com/product_details.asp?mscssid=4p9f5xl1p94g8h&sitetype=1&sid=121796`