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Unusual Car Navigation Tricks: Injecting RDS-TMC Traffic Information Signals

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Introduction

DISCLAIMER:

All the scripts and/or commands and/or configurations and/or schematics provided in the presentation must be treated as examples, use the presented information at your own risk.

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What's this all about ?

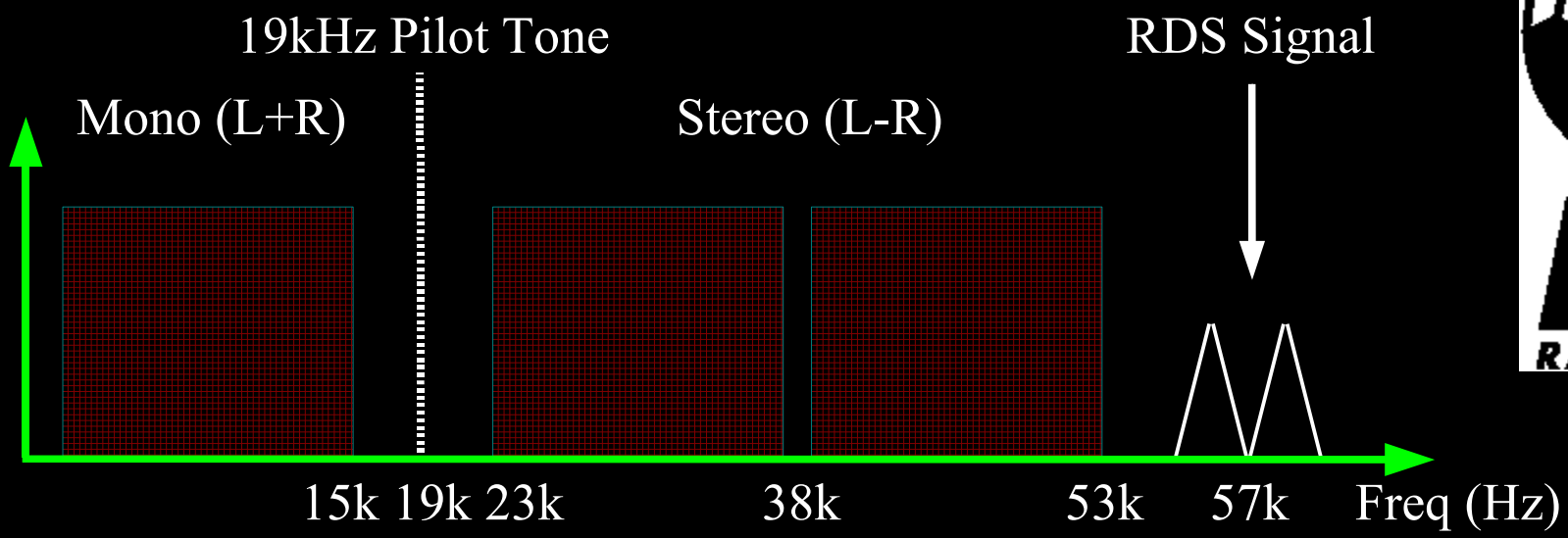
- Modern In-Car Satellite Navigation systems are capable of receiving dynamic traffic information
- One of the systems being used throughout Europe and North America is RDS-TMC (*Radio Data System – Traffic Message Channel*)
- One of the speakers bought a car featuring one of these SatNavs...he decided to play with it...just a little...
- We'll show how RDS-TMC information can be hijacked and falsified using homebrew hardware and software

Why bother ?

- First of all...hardware hacking is fun and 0wning a car is priceless ;-P
- ok seriously...Traffic Information displayed on SatNav is implicitly trusted by drivers, nasty things can be attempted
- more important: chicks will melt when you show this...

The Radio Data System

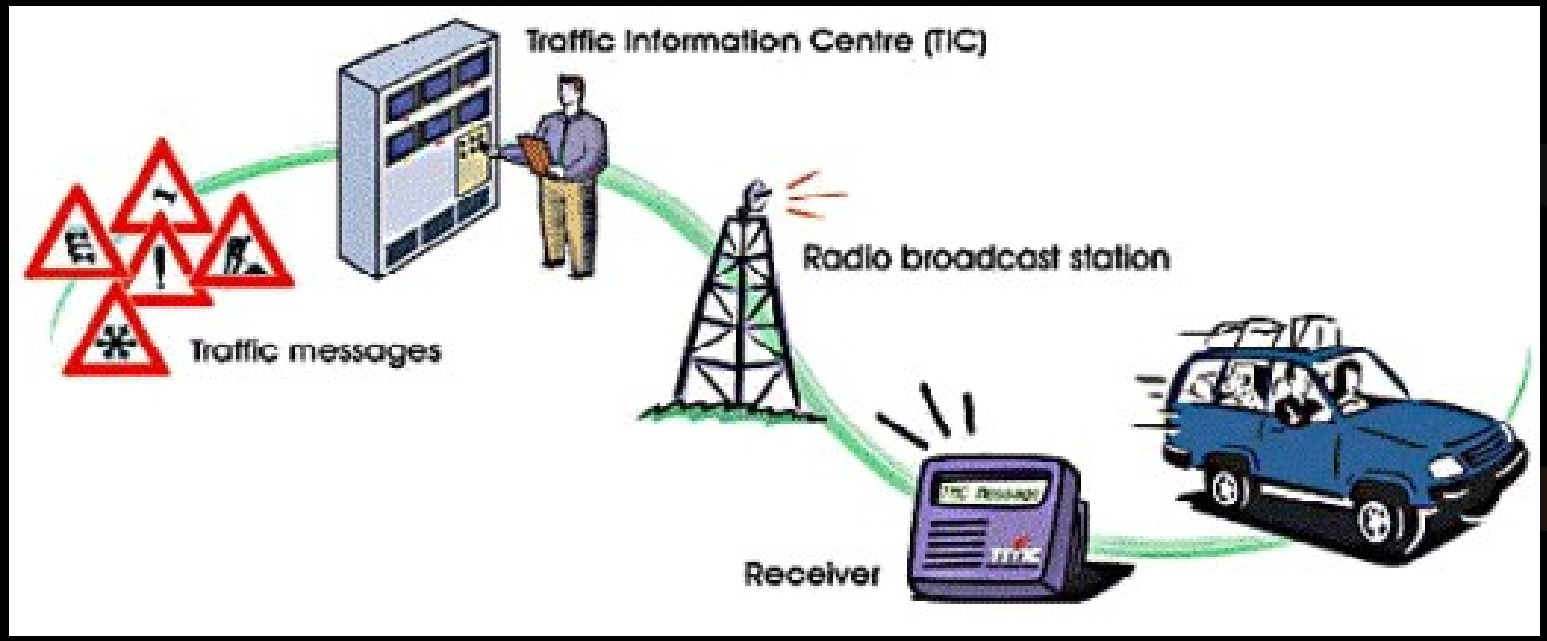
- RDS is used for transmitting data over FM (1187.5 bits/s)
- Described in European Standard EN50067 (April 1998)
- Its most prominent function is showing FM Channel Name on the radio display, also used for Alternate Frequencies, Programme Type, News override, etc.



R·D·S
RADIO DATA SYSTEM

RDS-TMC Introduction

- First introduced around 1997 (Germany), implemented around Europe in the following years
  (Italy got it in 2004, Australia will get it in 2007)
- Described in ISO 14819-1
- TMC uses RDS for transmission over FM broadcasts



RDS-TMC Implementation

- Despite being a 10 year old protocol, implementation has been slow, SatNav systems have been fully supporting RDS-TMC only in the last few years
- implemented on most in-car SatNav shipped by the original manufacturer
- External and portable SatNav offer jacks for external FM receivers which add RDS-TMC capabilities
- RDS-TMC is available in both free and commercial services
- TMC can also be transmitted over DAB or satellite radio

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RDS-TMC Terminal

The Issue

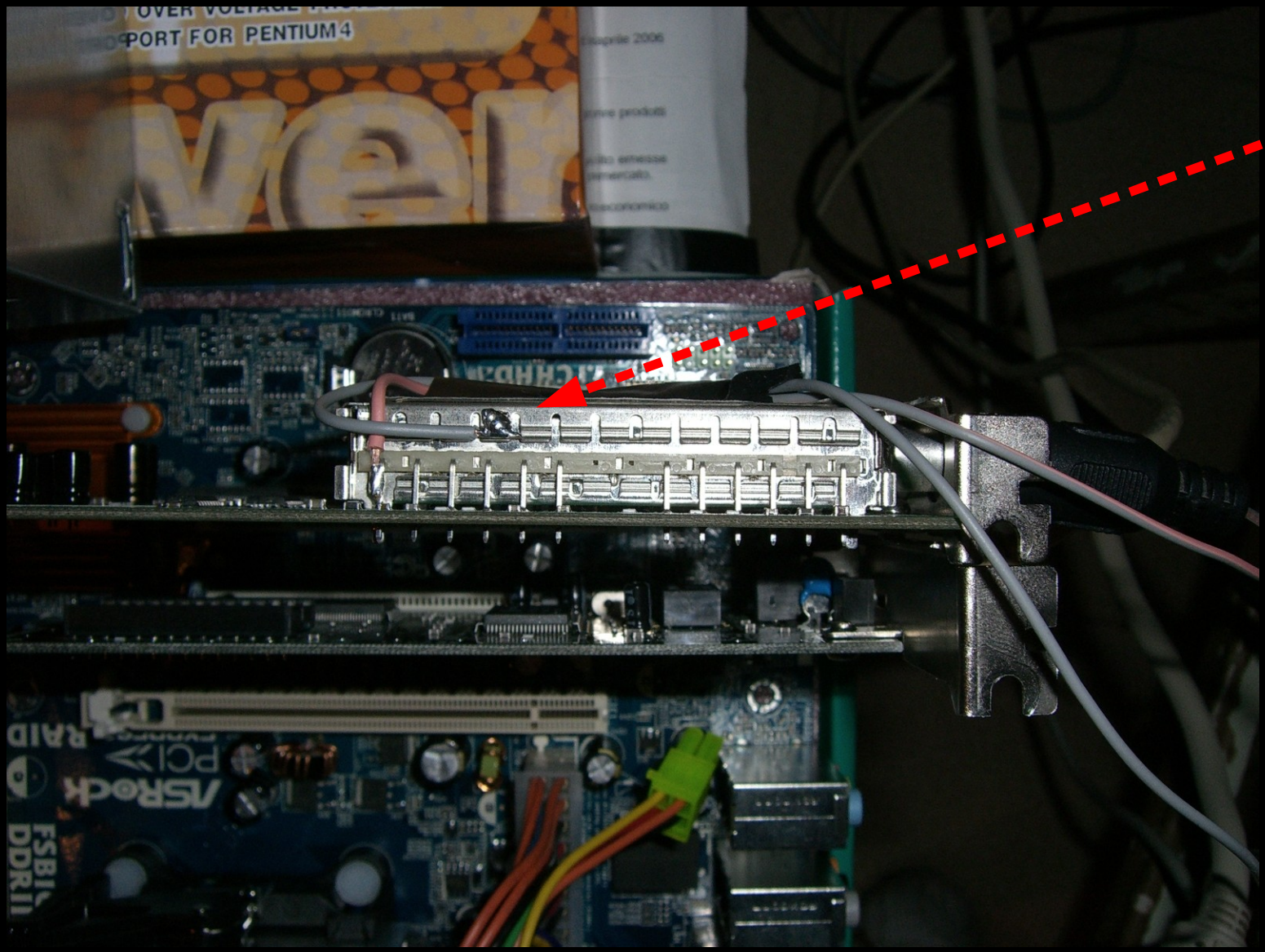
- there's no form of authentication of the data (encryption is supported for commercial services but irrelevant to our goals, more on that later)
- We tested the feasibility of decoding and injecting arbitrary TMC messages against our “victim”
- Off-the-shelf components and cheap electronics have been used
- ...you'll be the judge of our results...

The Victim

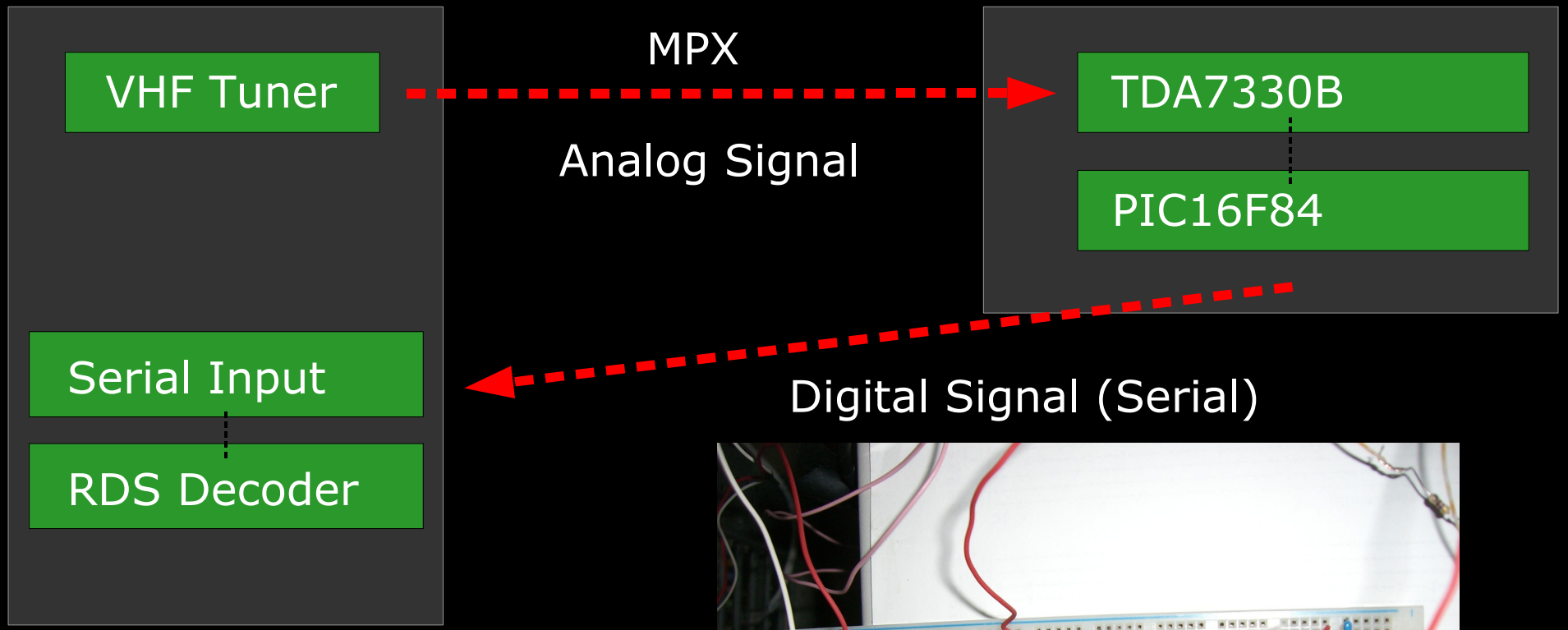
Sniffing RDS

- We need to get a "raw" FM signal (MPX), there's a number of tuners that provide an accessible pin for that
- We use the FM1216 module from Philips available on many PCI TV cards (*http://pvrhw.goldfish.org*)
- Once we have the signal we decode the RDS sub-carrier using a TDA7330B RDS Demodulator (which samples the 1.11875 kHz signal), a PIC for serial conversion and decoding software (sRDSd)
- Using custom hardware and software allowed us to fully understand the protocol and decode TMC (alternatively *http://rdsd.berlios.de* looks like the most promising project)

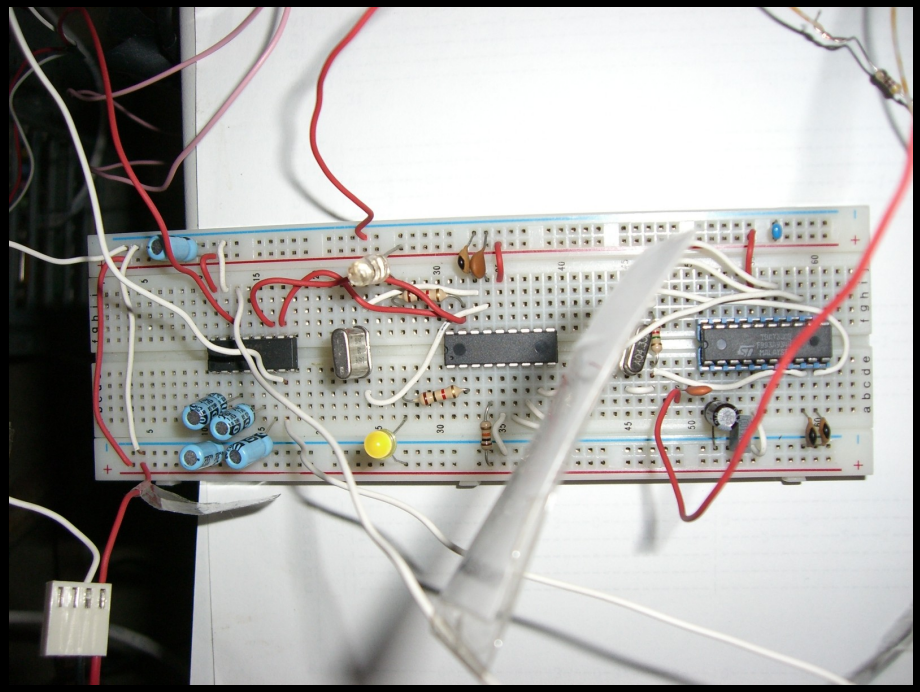
Sniffing RDS



Sniffing RDS



- Main components:
  - 1x TDA7330B
  - 1x PIC16F84
  - 1x MAX232



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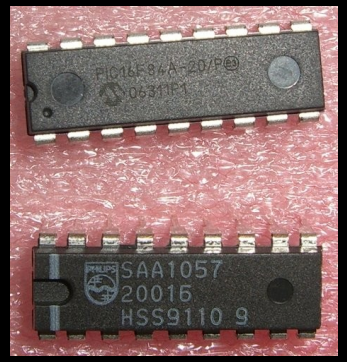
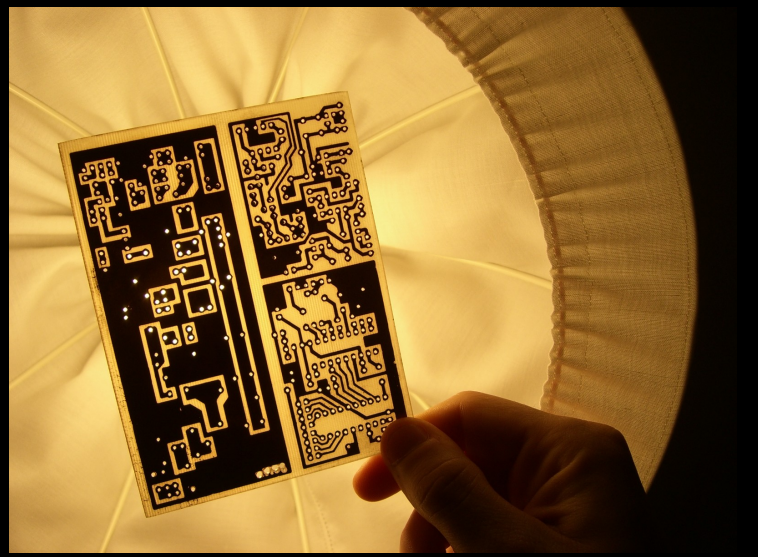
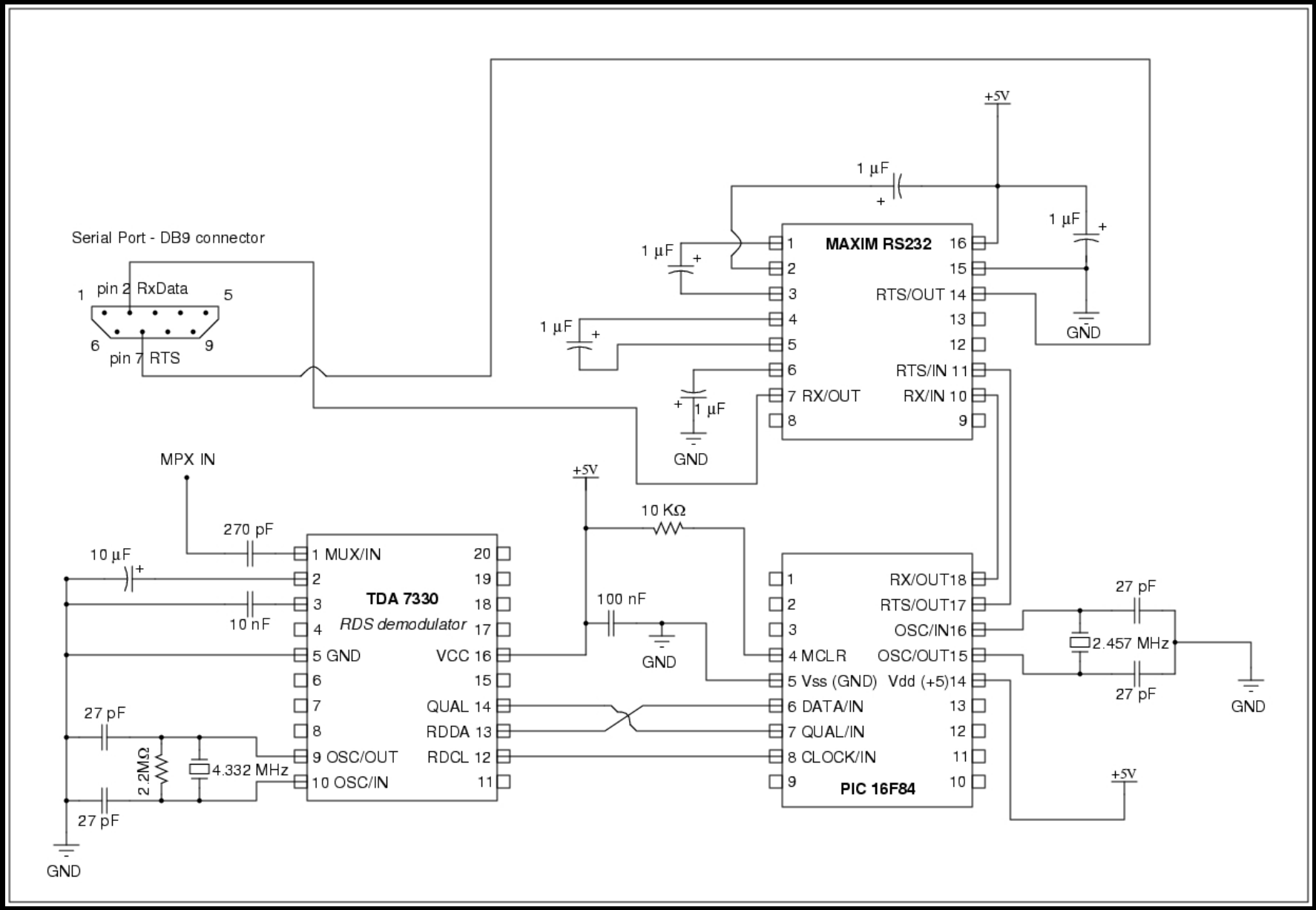
Assembly





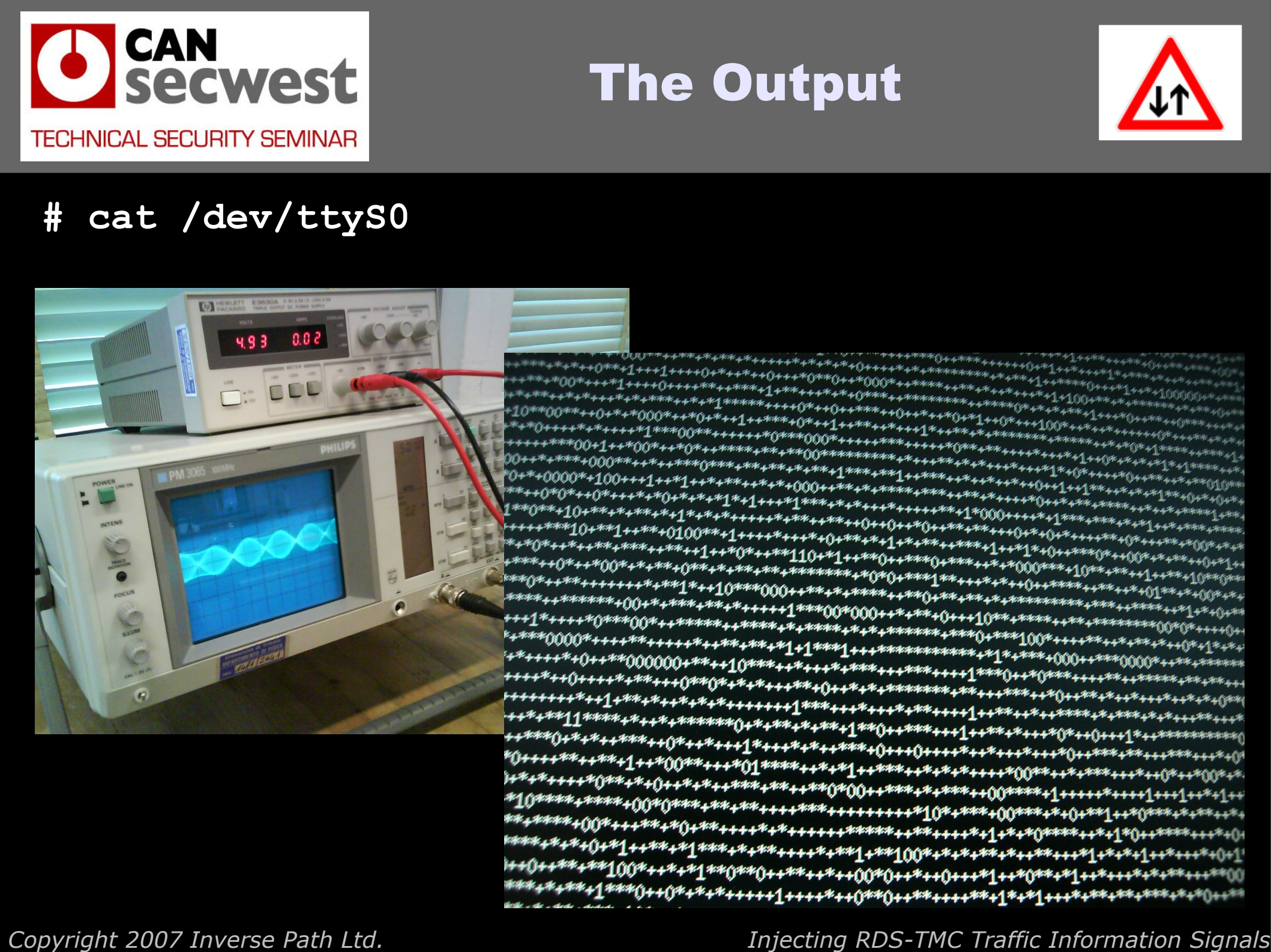
Sniffing Circuit



PIC Programming

- We program the PIC for converting RDS Demodulator data and send it to the serial port
- custom PIC programmer, a variation of the well known JDM one (*http://www.semis.demon.co.uk/uJDM/uJDMmain.htm*)
- output are 0 and 1, bad quality data is shown with * and + (either ignore sequences with bad data or replace them with 0 and 1 if you feel lucky)
- *http://dev.inversepath.com/rds/pic_code.asm*

The Output



```
# cat /dev/ttyS0
```

RDS Protocol

Group structure (104 bits):

Block 1	Block 2	Block 3	Block 4

Block structure (26 bits):

Data (16 bits)	Checkword (10 bits)

Block 1:

PI code	Checkword

Block 2:

Group code	B0	TP	PTY	<5 bits>	Checkword

PI code	= 16 bits
Group code	= 4 bits
B0	= 1 bit
TP	= 1 bit
PTY	= 5 bits
Checkword	= 10 bits

TMC / Alert-C Protocol

```
Block 1:
 ---------------------
| PI code | Checkword |
 ---------------------
Block 2:
 ------------------------------------------------------
| Group code | B0 | TP | PTY | T | F | DP | Checkword |
 ------------------------------------------------------
Block 3:
 ---------------------------------
| D | PN | Extent | Event | Checkword |
 ---------------------------------
Block 4:
 ----------------------
| Location | Checkword |
 ----------------------
```

T	= 1 bit
F	= 1 bit
DP	= 3 bits
D	= 1 bit
PN	= 1 bit
Extent	= 3 bits
Event	= 11 bits
Location	= 16 bits
Checkword	= 10 bits

TMC / Alert-C

PI code => Programme Identification

Group code => message type identification

B0 => version code

TP => Traffic Program

PTY => Programme Type

T, F, D => Multi Group messages

DP => Duration and Persistence

D => Diversion Advice

PN => +/- direction

Extent => event extension

Event => event code (see also TMDD – Traffic Management Data Dictionary)

Location => location code (DAT Location Table - TMCF-LT-EF-MFF-v06)

srdsd
Simple RDS Decoder

- Our custom tool for RDS decoding:
  - ISC-style licensed
  - performs nearly full RDS-TMC (and basic RDS) decoding
  - text and HTML output with Google Map links of GPS data
  - *http://dev.inversepath.com/rds/srdsd*

```
Simple RDS-TMC Decoder 0.1     || http://dev.inversepath.com/rds
Copyright 2007 Andrea Barisani || <andrea@inversepath.com>
Usage: ../srdsd/srdsd [-h|-H|-P|-t] [-d <location db path>] [-p
  <PI number>] <input file>
   -t display only tmc packets
   -H HTML output (outputs to /tmp/rds-<random>/rds-*.html)
   -p PI number
   -P PI search
   -d location db path
   -h this help

Note: -d option expects a DAT Location Table code according to
      TMCF-LT-EF-MFF-v06 standard (2005/05/11)
```

srdsd – PI Search

- We must "lock" parsing to the relevant PI
- Every FM Channel has its own code (google knows)
- You can guess the PI code by finding the most recurring 16-bit string:

```
# ./srdsd -P rds_dump.raw | tail

0010000110000000: 4140 (2180)
1000011000000001: 4146 (8601)
0001100000000101: 4158 (1805)
1001000011000000: 4160 (90c0)
0000110000000010: 4163 (0c02)
0110000000010100: 4163 (6014)
0011000000001010: 4164 (300a)
0100100001100000: 4167 (4860)
1010010000110000: 4172 (a430)
0101001000011000: 4185 (5218)

# ./srdsd -p 5218 -d ~/loc_db/ rds_dump.raw
```

srdsd output – 0A Group

```
Got RDS message (frame 75)
        Programme Identification: 0101001000011000 (5218)
        Group type code/version: 0000/0 (0A  - Tuning)
        Traffic Program: 1
        Programme Type: 01001 (9  - Varied Speech)
        Decoded 0A group:
                Traffic Announcement: 0
                Music Speech switch: 0
                Decoder Identification control: 100
                (Dynamic Switch / PS char 1,2)
                Alternative Frequencies: 10101010, 10101111
                (104.5, 105)
                Programme Service name: 0101001001010100 (RT)
                Collected PSN: RTL102.5

        Raw dump | Data              Checkword  Hex
        Block 1: | 0101001000011000 0000010100 5218
        Block 2: | 0000010100101100 0010101101 052c
        Block 3: | 1010101010101111 1010100110 aaaf
        Block 4: | 0101001001010100 0100110101 5254
```

srdsd output – 8A Group

```
Got RDS message (frame 76)
        Programme Identification: 0101001000011000 (5218)
        Group type code/version: 1000/0 (8A  - TMC)
        Traffic Program: 1
        Programme Type: 01001 (9  - Varied Speech)
        Decoded 8A group:
                Bit X4: 0 (User message)
                Bit X3: 1 (Single-group message)
                Duration and Persistence: 000 (no explicit duration given)
                Diversion advice: 0
                Direction: 1 (-)
                Extent: 011 (3)
                Event: 00001110011 (115 - slow traffic (with average speeds Q))
                Location: 0000110000001100 (3084)
                Decoded Location:
                        Location code type: POINT
                        Name ID: 11013 (Sv. Grande Raccordo Anulare)
                        Road code: 266 (Roma-Ss16)
                        GPS: 41.98449 N 12.49321 E
                        Link:
  http://maps.google.com/maps?ll=41.98449,12.49321&spn=0.3,0.3&q=41.98449,12.49321

        Raw dump | Data             Checkword  Hex
        Block 1: | 0101001000011000 0000010100 5218
        Block 2: | 1000010100101000 1110000111 8528
        Block 3: | 0101100001110011 0001011001 5873
        Block 4: | 0000110000001100 0111000011 0c0c
```

srdsd output – 3A Group

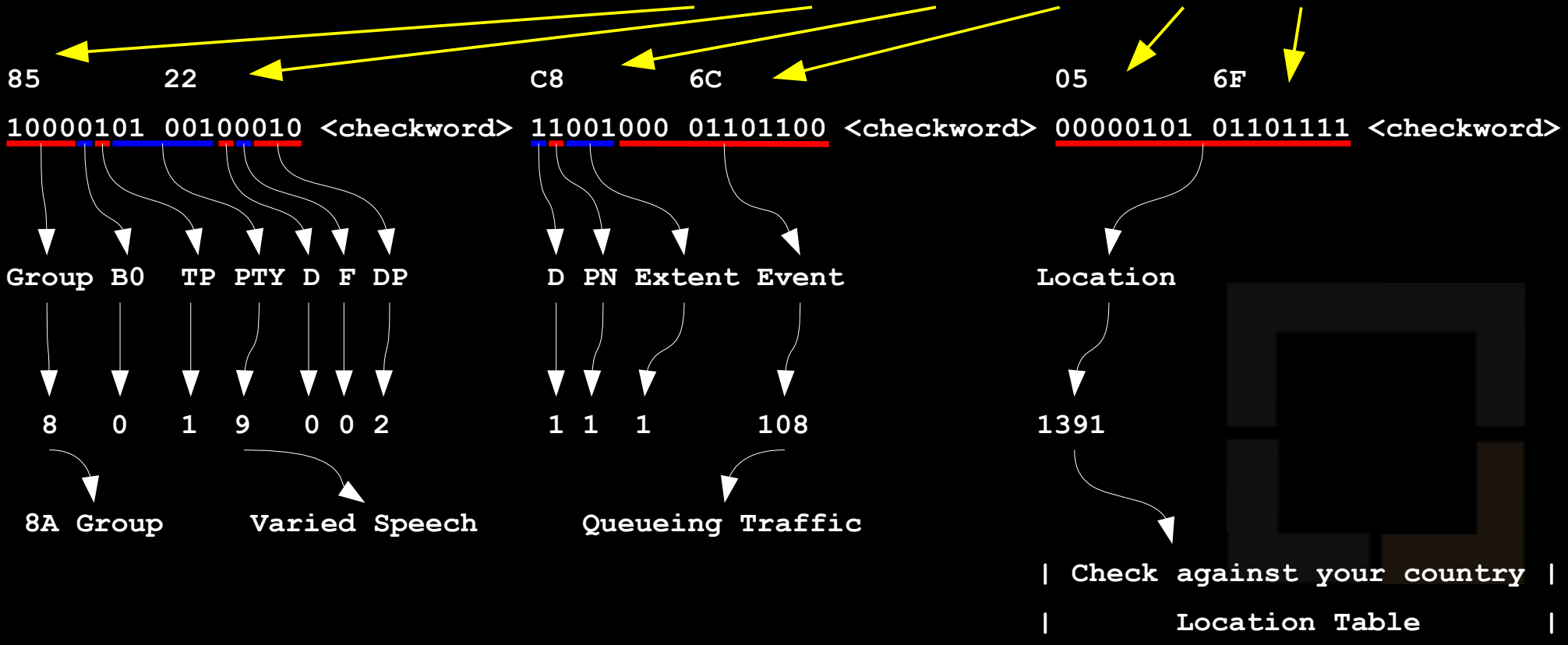
```
Got RDS message (frame 181)
        Programme Identification: 0101001000011000 (5218)
        Group type code/version: 0011/0 (3A  - ODA ID)
        Traffic Program: 1
        Programme Type: 01001 (9  - Varied Speech)
        Decoded TMC Sys Info group (3A - AID 52550):
                Location Table Number: 000001 (1)
                Alternative Frequency bit: 1
                Mode of Transmission: 0
                International Scope: 1
                National Scope: 0
                Regional Scope: 0
                Urban Scope: 0
                AID: 1100110101000110 (52550)

        Raw dump | Data              Checkword  Hex
        Block 1: | 0101001000011000 0000010100 5218
        Block 2: | 0011010100110000 1111101000 3530
        Block 3: | 0000000001101000 0010011011 0068
        Block 4: | 1100110101000110 1111001001 cd46
```

Injecting RDS-TMC

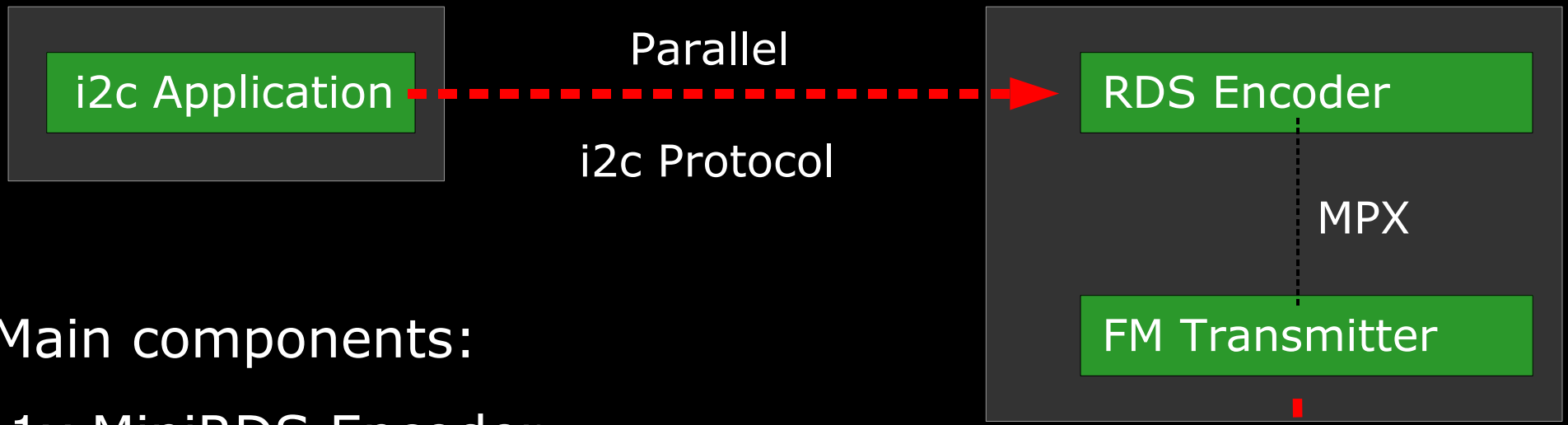
- We use a commercialy available RDS encoder (40$ USD), but it's reasonable to build your own (we are working on it)
- i2c is being used for communicating with its chipset, we use our custom C application over the supplied client for being able to send different Group Types
- We set all parameters (PI, PTY, etc) + the remaining data (last 3 RDS Blocks in Hexadecimal)
- The checkword is automatically computed by the chipset
- *http://dev.inversepath.com/rds/i2c_minirds.tar.gz*

Injecting RDS-TMC

```
unsigned char PI_buf[PI_BUF]     = { '\x52', '\x18' };                          /* PI */
unsigned char PS_buf[PS_BUF]     = { 'R', 'A', 'D', 'I', '0', '1', '0', '5' };  /* PS */
...
unsigned char UDG2_buf[UDG2_BUF] = {'\x35','\x30','\x00','\x66','\xCD','\x46'}; /* 3A */
unsigned char UDG1_buf[UDG1_BUF] = {'\x85','\x22','\xC8','\x6C','\x05','\x6F'}; /* 8A */
```



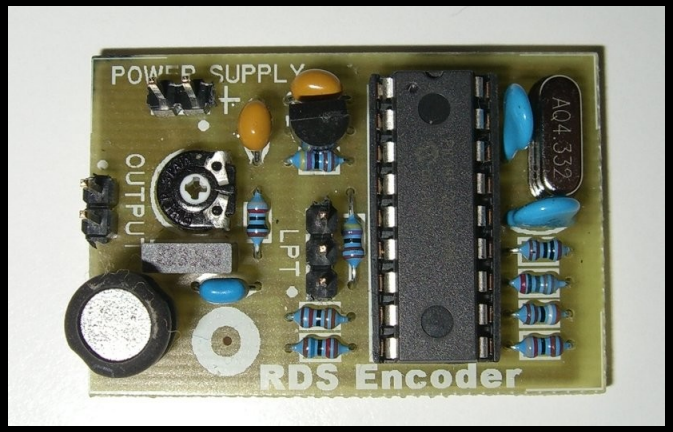
Injecting RDS-TMC



Main components:

- 1x MiniRDS Encoder
  (*http://www.pira.cz*)
- 1x FM transmitter
- 1x PIC16F84
- 1x SAA1057 (digital PLL tuning)
- 1x closed dipole antenna

Injection Circuitry



Transmitting FM

- The FM transmitter can be tuned to arbitrary frequencies
- It's important to have a stable transmitter for data injection
- Long distances can be easily covered (but it might be desirable to keep it short enough to reach only the victim)

Transmitting FM

TX "*The Sterilizer*" Antenna

(Resistance is Futile)

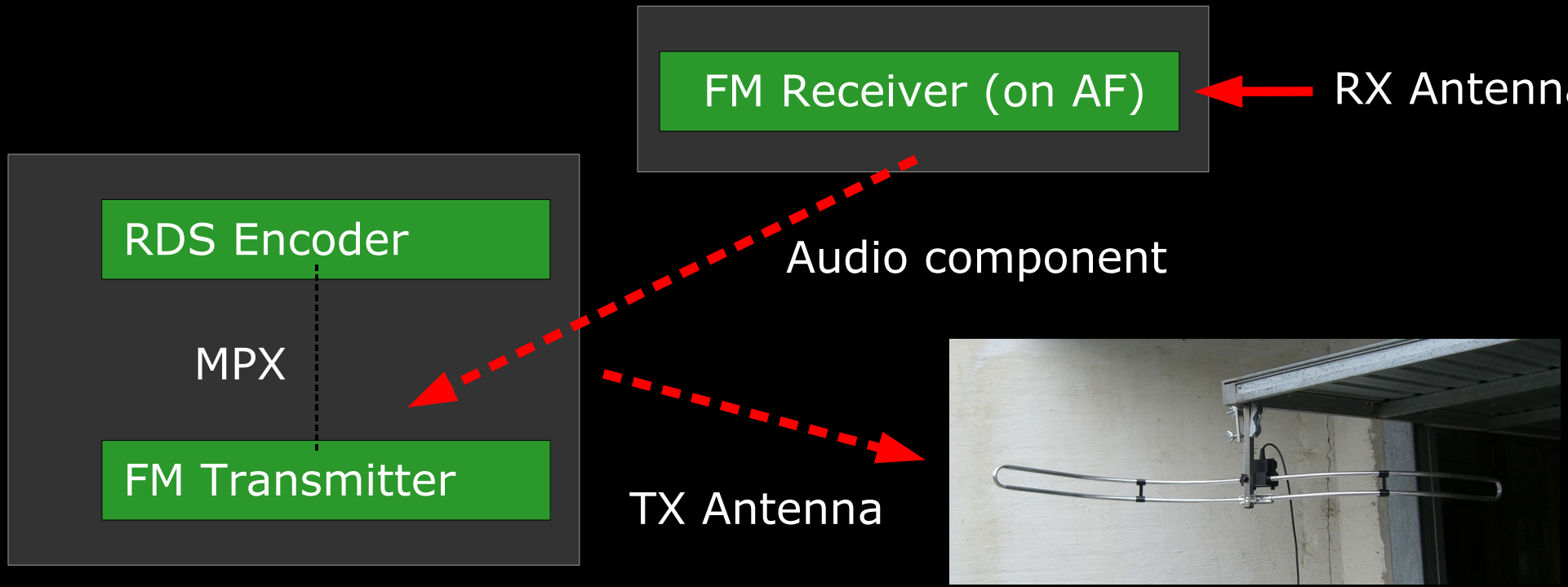
Locking the SatNav Tuner

- RDS-TMC is detected using 3A Sys Info groups which specify the Location Table, the Scope of the service and timing settings
- Hijack existing channels:
  1. Find the frequency of a channel that provides RDS-TMC
  2. Obscure the channel and send 8A packets (3A not necessary) when SatNav locks on it (careful timing)
- Fake a FM broadcast using 3A groups:
  1. Find an unused frequency
  2. Transmit 3A groups continuosly + 8A packets

Being Stealthy

Option 1: Mix the audio component taken on the Alternate Frequency (AF) for the hijacked channel

Option 2: Fake a new channel on an unused frequency



Attack 1: Standard Traffic Msgs

- We can create:
  1. Queues
  2. Bad Weather (Rain, Smog, Fog, Fresh Snow,...)
  3. Full Car Parks
  4. Overcrowded Service Areas (OMG!)
  5. Accidents
  6. Roadworks

  ...and so on...

- Not particularly exciting but still nice...it gets better though...

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Attack 1: Standard Traffic Msgs

Code 108

-

Queueing Traffic

Attack 2: Closing Roads

- We can close arbitrary roads, bridges and tunnels with a number of Events: Closed, No through traffic, Accidents
- The SatNav will pop-up the event (even if no diversion is specified on our model) and ask the user for a detour
- If the closed road is encountered during re-calculation of the route (which is a very common thing) it will be *silently* avoided

- this attack is also known as “keep your parents from reaching home”...

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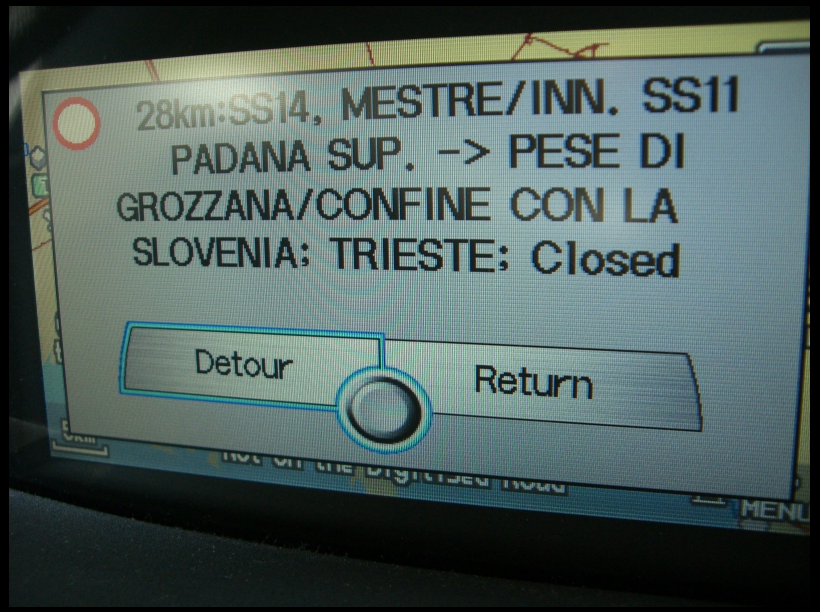
Attack 2: Closing Roads



Code 401 - Closed

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Attack 2: Closing Roads

Normal route to home

Route avoiding the "Closed" Event

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Attack 3: Security Messages

- The Event table supports a number of security related messages
- We doubt anyone ever used them so far
- They pose a very interesting target for social engineering purposes (Homeland Security would freak out)

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Attack 3: Security Messages

Code 1518 – Terrorist Incident

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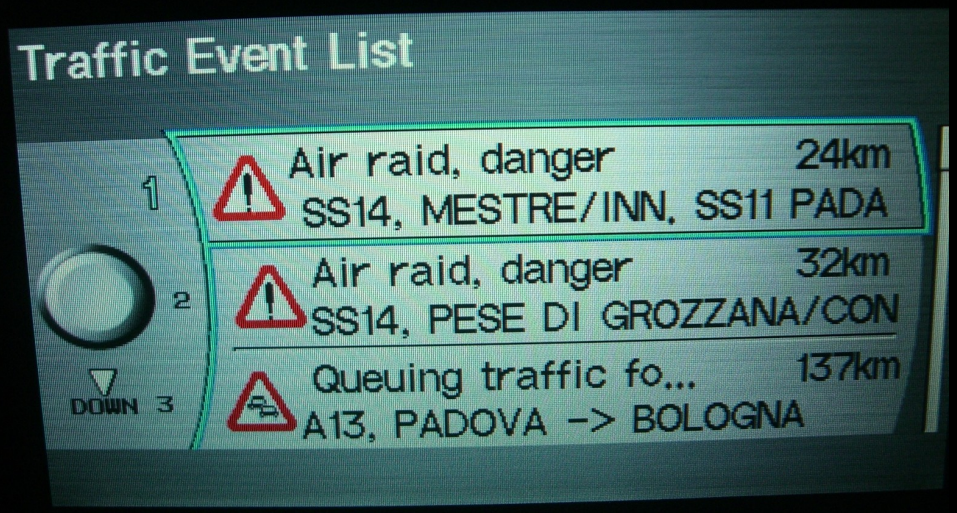
Attack 3: Security Messages



Code 1481 – Air raid, danger

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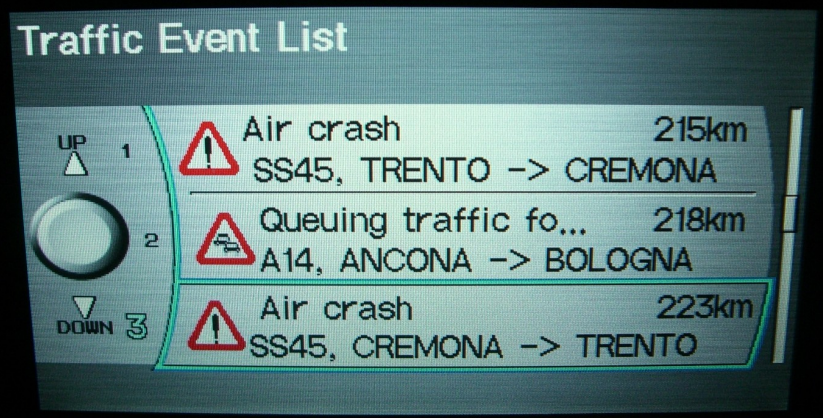
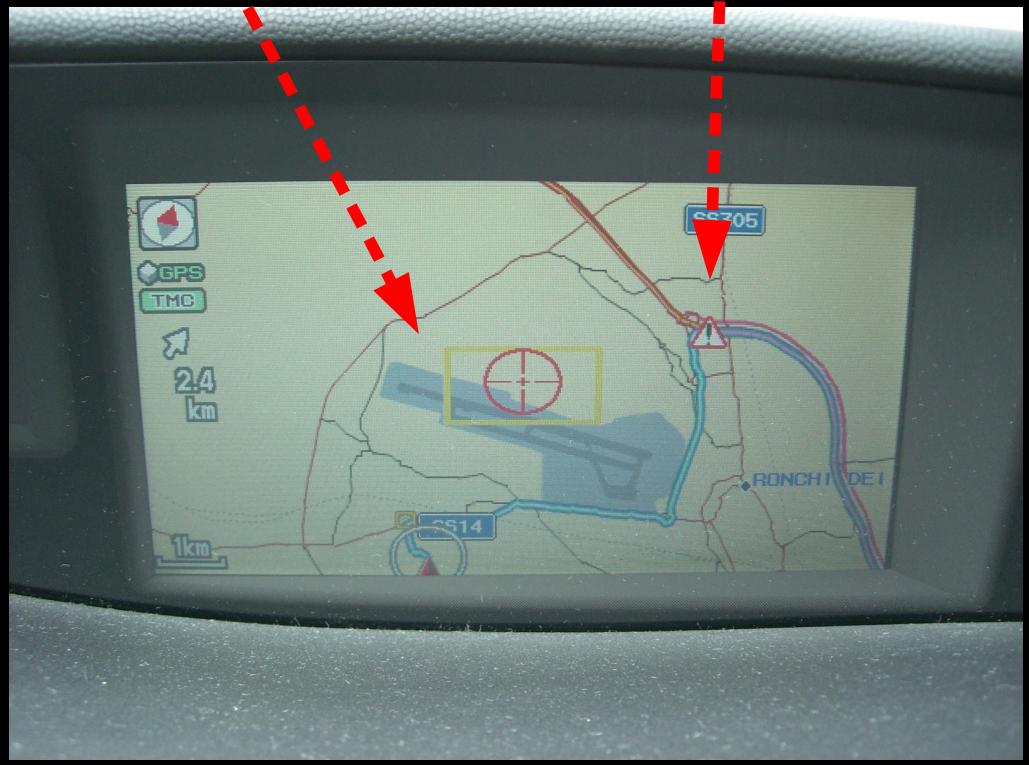
Attack 3: Security Messages



Code 978 – Air crash

Airport

Event



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Attack 3: Security Messages

Code 1516 – Bomb alert

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Attack 3: Security Messages

- Security messages can be pop-up, if they affect current route
- Video Clip time!

Code 1571

Security alert. Stationary traffic

Other funny messages

Code 1456 – Bull Fight (you never know...)

Code 1560 – Delays due to parade

...and many more...(no you can't have a pony)

Implementation Issues

- On our Honda integrated SatNav we've seen that:
  - The PI is not associated to the frequency, any PI can be used on any frequency for hijacking
  - Total cancellation (Event: 2047, Location: 65535) is not honoured
  - Broadcast message (Location: 65535) is not honoured
  - Diversion bit is ignored for some categories and always assumed = 1
- We expect other SatNav systems to have similar or even more interesting issues

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RDS-TMC Encryption

- TMC supports a very lightweight encryption for commercial services
- Described in ISO 14819-6
- It's used for signal discrimination rather than authentication
- Only the Location Code is encrypted
- It involves bitwise operations against a key
- The key can be trivially broken by sampling some data
- Terminals that support encryption are also expected to accept un-encrypted data, so injection is still possible

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Security Considerations

- RDS-TMC can be trivially injected
- Drivers don't tend to have any security awareness towards their SatNav, social engineering, forced detours and panic attacks are possible
- We don't think it's "*The End Of The World As We Know It*" but these systems should be authenticated considering their increased usage and expansion
- These technologies have a very long life span and "patching" is not easy
- We hope to increase awareness about these kind of problems

The Future

- TMC is also supported over DAB and satellite radio, it's harder to inject compared to FM but still possible
- TPEG (Transport Protocol Experts Group) is the new standard designed for replacing TMC. It supports encryption but it's still optional. (*http://tpeg.org*)
- GST (Global System for Telematics) is an impressive new architecture for delivering a number of services. It's backed up by many manufacturers and it will support PKI for billing and transport purposes. Adoption is many years away from now. (*http://gstforum.org*)

Similar Systems

- Microsoft DirectBand (*http://www.directband.com*), used for MSN Direct, is another FM subcarrier channel for data transmission
- It has a larger bandwidth (15 times that of RDS) and full encryption
- Other than special wristwatches it's also been used on SatNav systems for traffic information (*http://garmin.msndirect.com*)
- Closed standard, not available in Europe, looks very promising...we'd love to play with that too ;)

The End

Thanks for listening!
Questions?


(shameless plug)
http://www.inversepath.com

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http://gettingaroundgermany.home.att.net
Thanks to Brian Purcell