Zentrale Stelle für Informationstechnik im Sicherheitsbereich

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A Forensic Analysis of GNSS Spoofing Attacks on Autonomous Vehicles

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Project DiForIT

- Development of a forensic process chain specifically for automated and connected road mobility.
- Evaluation of vehicle communication interfaces and network protocols to identify potential security risks.
- Assessment of the forensic relevance of collected vehicle data, considering technical, legal and regulatory factors.
- Implementation of robust data recording systems that ensure data security, integrity and privacy.

Gefördert durch:

Bundesministerium
für Wirtschaft
und Klimaschutz

aufgrund eines Beschlusses
des Deutschen Bundestages

The Role and Vulnerabilities of Location Tracking Systems

Ubiquity of location-based technology

- Location tracking is essential in navigation, logistics, emergency response and more.
- Autonomy: SAE Level 3 (and higher) vehicles rely on GNSS for partial autonomy.

GNSS Jamming

- High-power interference signals
- Disrupts signal reception

  -> Loss of positioning

GNSS Spoofing

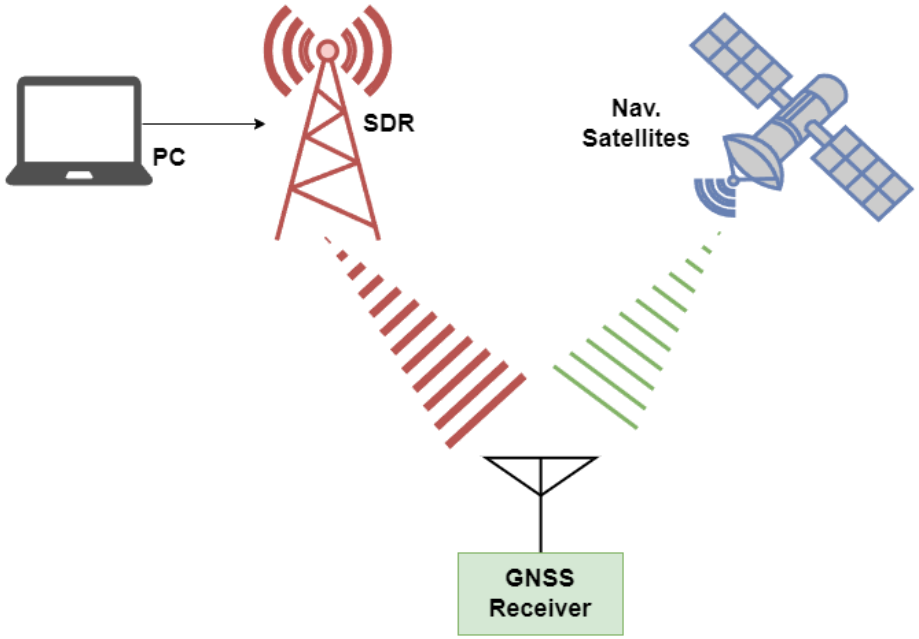
- Transmitting counterfeit signals
- Stronger signals overlay real ones

  -> Calculation of wrong position

GNSS Spoofing Explained

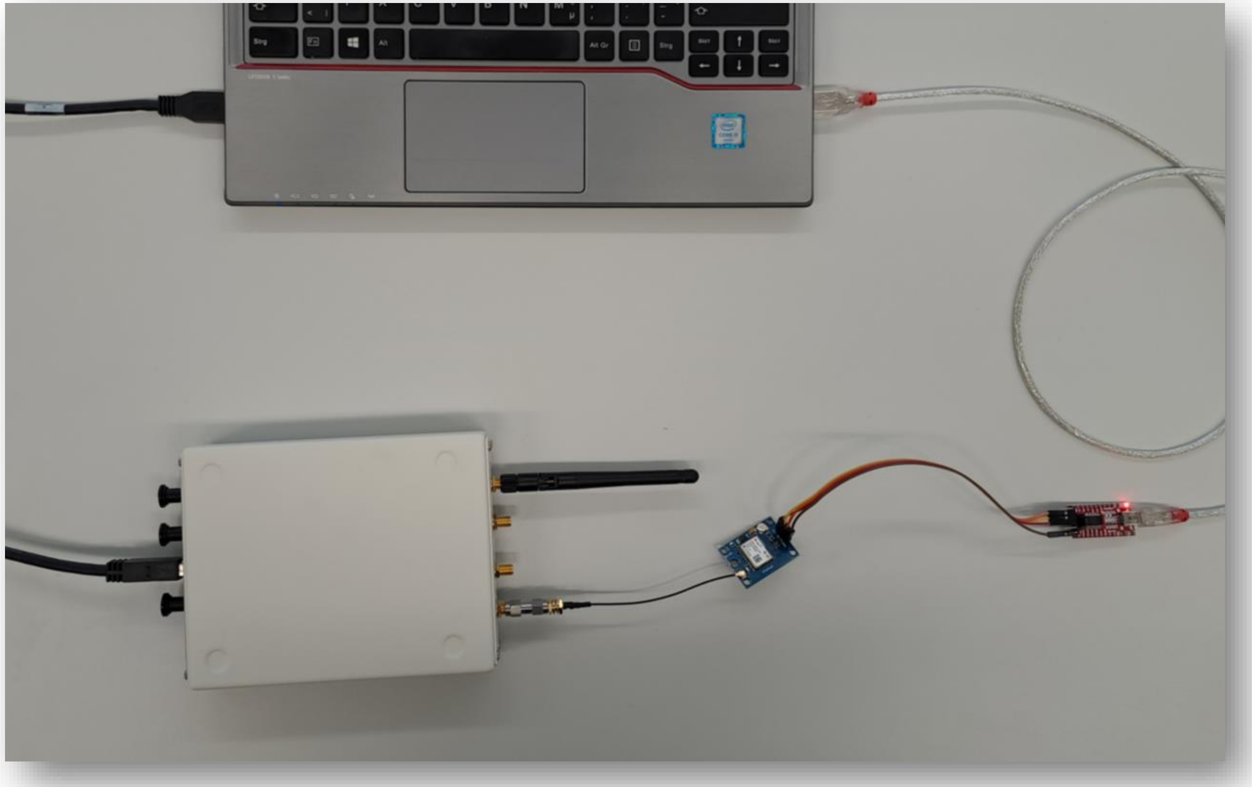
GNSS Spoofing Overview:

- Spoofing transmits fake signals stronger than the satellite signals.
- Goal: Trick the receiver into computing false position/time.
- Most common spoofing types:
  - Meaconing – replayed GNSS signals
  - Code Carrier Attack – fake replicated signals
  - Navigation Data Attack – forged navigation messages
  - App-Level Spoofing – Man-in-the-Middle
  - Multi-method – combinations for complex attacks



GNSS Spoofing – Practical Setup

- This is how the setup from the previous slide might look like in practice.
- Note the cable used to connect SDR and receiver to avoid broadcasting spoofed signals and possibly impacting other devices.



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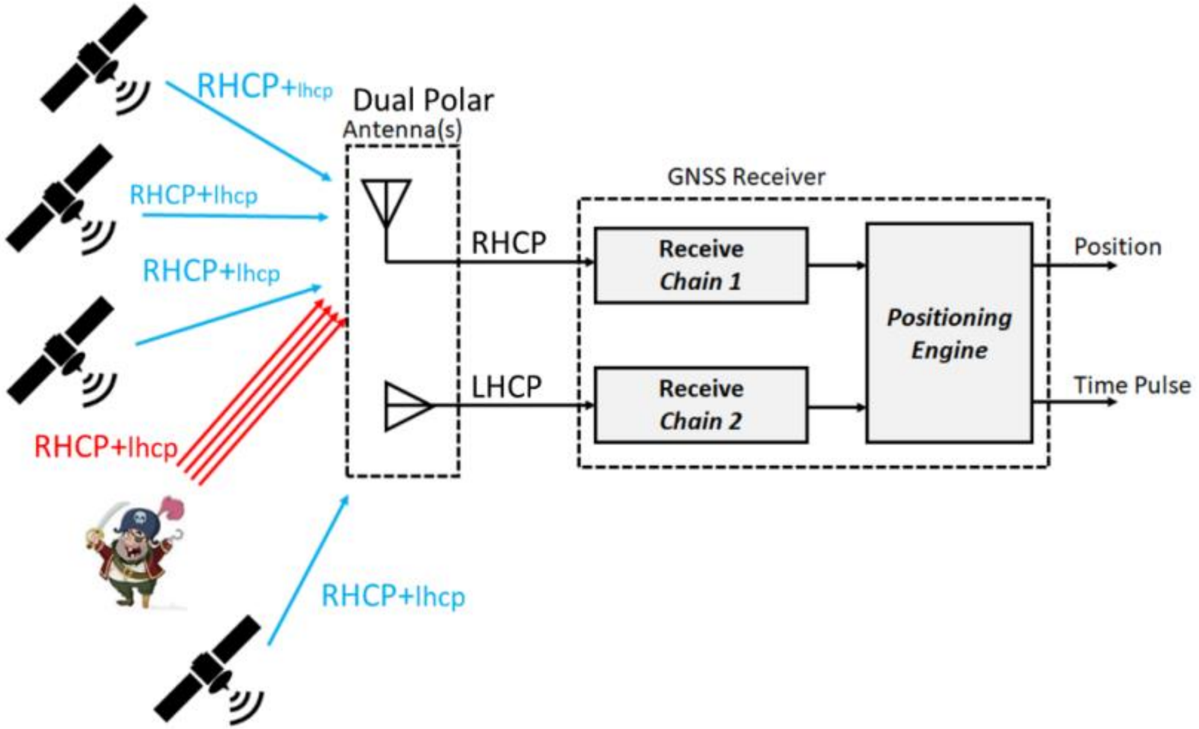
Countermeasures

- Discarding messages with an abnormally high signal strength.
- Ensuring signals from different satellites arrive from different directions, by utilizing signal polarization.
- Better Standards:
  - Galileo OS-NMA
  - Galileo CAS on E6 (for AD)



Simulation Setup

- Position comes from the simulation

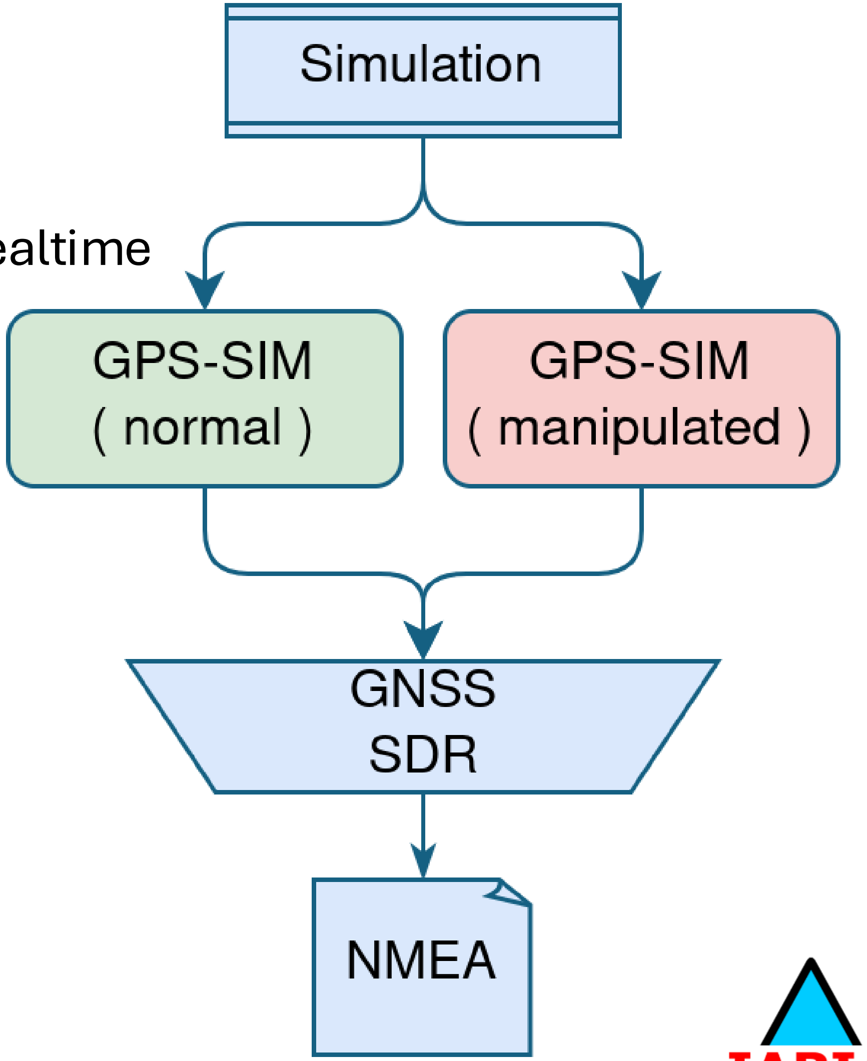
- Corresponding I/Q data is computed with gps-sdr-sim-realtime

  - Once for the true position

  - Once for the wrong position –> Spoofing

- Outputs are merged, with the "normal" signal dampened

- GNSS-SDR is used to reinterpreted the data to NMEA



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GNSS Spoofing Detection in Autonomous Vehicles

Detection Techniques:

- LSTM models for anomaly detection (Dasgupta et al.)
- Error covariance analysis in Kalman filters (Liu et al.)
- Hybrid sensor fusion: GNSS + IMUs + odometry
- Slow-drift attacks in urban settings highlight stealth
- Physics-based IDS monitor vehicle behavior in real time
- Machine learning enhances early spoofing detection

Forensic Recorders

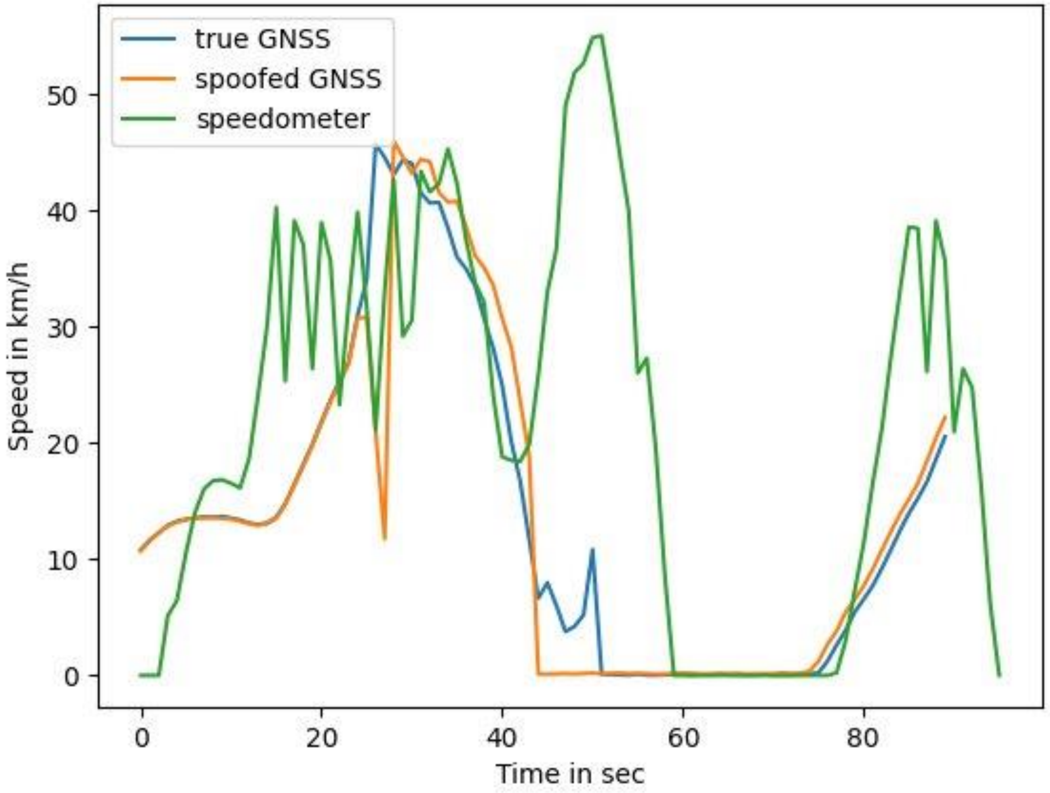
- Multiple forensic frameworks could be investigated
- Standard forensic investigation:
  - Strategic preparation
  - Operational preparation
  - Data collection
  - Investigation
  - Data analysis
  - Documentation

EDR	DSSAD	AV-Guard
- Mandatory	- (soon) mandatory	- Not mandatory
- Last 5 seconds	- Last few minutes	- Days to years
- Crash related data	- ADAS related data	- Processed sensor data

Forensic Analysis

- EDR:
  - Speed data of GNSS and speedometer
- DSSAD:
  - Check if and how much control the vehicle systems had
- AV Guard:
  - Route data as GPS points

Result: Difficulties in detecting GNSS Spoofing with such a limited amount of data.



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Forensic Advice

- Consider use cases for attacks
  - Geofencing
  - Kidnapping executed by triggering the vehicles safe mode
- Consider interesting data points
- Validate it with the simulation setup

Expected interesting data points:

- Route data and camera pictures, i.e. dashcams
- Raw sensor data, e.g. NMEA

Thank you for your attention

Do you have any questions?

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