HPM Detector System with Frequency Identification

Ch. Adami, Ch. Braun, P. Clemens, M. Joester, S. Ruge, M. Suhrke, H.U. Schmidt, H.J. Taenzer
Fraunhofer INT, Appelsgarten 2, 53879 Euskirchen, Germany

Dr. Michael Suhrke

Electromagnetic Effects & Threats
Fraunhofer Institute for Technological Trend Analysis INT
Euskirchen, Germany

Fraunhofer INT

Outline

- Introduction
- HPM detector development at Fraunhofer INT
- Concept of frequency detection
- Single-channel HPM detector system with frequency identification
- Detector control panel
- Compact version
- Summary and outlook

Introduction

Motivation

- Critical infrastructure and modern equipment rely heavily on electronics.
- Crucial systems (IT network components, communication devices, supervisory control and data acquisition (SCADA) systems, …) equipped with (digital, program controlled) electronics and vulnerable to IEMI / High Power Electromagnetic (HPEM) attacks (both radiated and conducted).

  → Proven by HPM (High Power Microwave) tests of Fraunhofer INT.
- HPM sources can be built by a qualified engineer or assembled from components available on the market.
- General lack of awareness of the electromagnetic threat and usually no organisational instructions for IEMI / HPEM attacks.

In particular:

- Specific failure mechanisms of electronic systems due to an IEMI / HPEM attack mostly unknown → personnel cannot immediately trace back malfunctions to an attack.
- Covert operations and multiple attempts possible for the attacker without immediate countermeasures (recovery procedures, forensics, search for attacker).

  → ***These shortcomings can be eliminated by HPEM detection.***

Introduction

Requirements for HPEM Detection

- Detection of all ***signal types*** (continuous wave (CW), pulses: narrow band (some 100 ns … µs), damped sine (DS, some ns), ultra wideband (UWB, < 1 ns)) and signal parameters
- Broad ***frequency*** range (some 100 MHz ... 10 GHz)
- Sufficient detection ***dynamics*** (e. g. 10 V/m ... 10 kV/m)
- HPEM ***immunity*** (ideally some 10 kV/m)
- Detection of all ***directions*** and ***polarisations***
- Detection of ***radiated*** and ***conducted*** threats
- Analysis of ***signal form***
- ***Source localisation***
- Discrimination of ***false alarms***
- ***Integration*** into sensor networks and overall protection concept

HPM Detector Development at Fraunhofer INT

Objective

- Permanent surveillance of high-value or mission-critical stationary facilities
- Search and identification of HPEM sources
- Signal diagnostics and forensics as part of overall protection concept

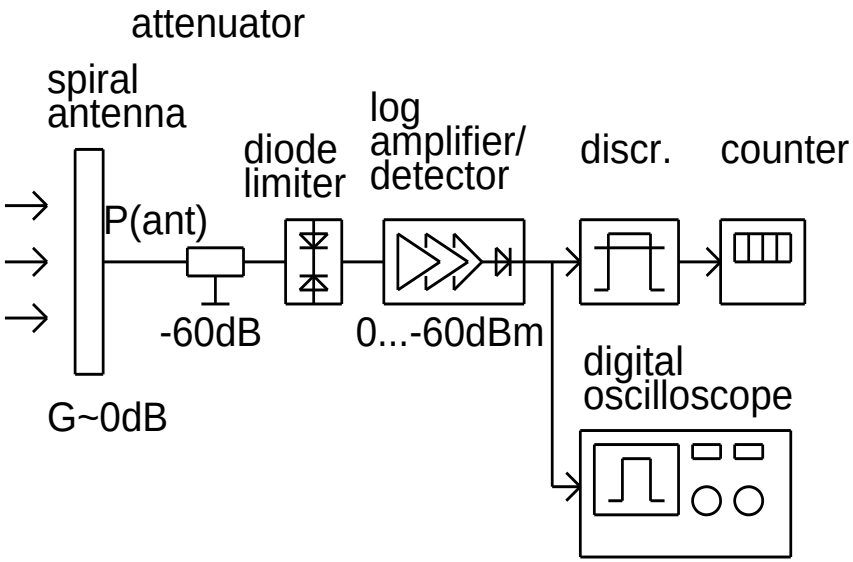
Extended detection features: **as *compared to simple warning devices***

- Detection of signals (pulse, UWB, CW) with field strength > 1 kV/m
- Damage immunity against field strengths of up to 10 kV/m
- Frequency independent detection (500 MHz – 8 GHz) of HPM sources in medium distances (at least detection of field strengths > 100 V/m) for warning and searching
  - ➞ Measuring dynamics preferably > 60 dB
- Polarization independence
- Detection in a defined sector in the horizontal plane (90°)
- Classification of the detected events by amplitude, pulse duration, pulse repetition frequency (PRF) or pulse number, pulse form, etc.
- Threat direction identification (four-channel system)

HPM Detector Development at Fraunhofer INT

Analog Detection Concept

- **Logarithmic amplifier-detector** IC for signal amplitude detection
  - Reduced sampling and data transfer rates as well as storage requirements by ***digitizing*** the ***signal envelope*** instead of the signal itself
- Allows:
  - High dynamic range: > 60 dB
  - Detection of signals in broad frequency range: 1 MHz – 8 GHz
  - Detection of both narrow band and pulsed signals down to some 10's of ns
  - Moderate circuit complexity (lower price, higher robustness)
  - Moderate power consumption (permanent battery operation)



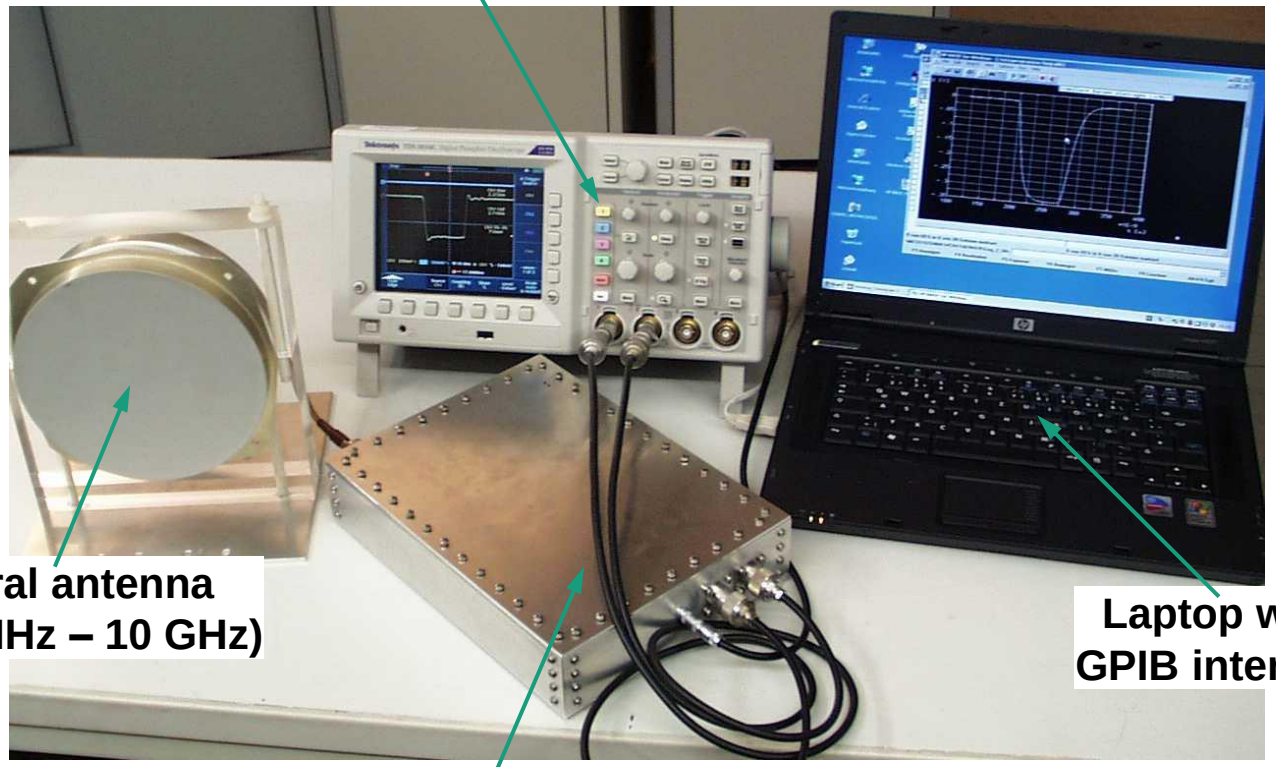
- **Disadvantage:**
  - ***Loss*** of information on ***signal frequency***

Fraunhofer INT

HPM Detector Development at Fraunhofer INT

Demonstrator of Single-Channel HPM Detection System

Battery-powered multi-channel oscilloscope



Spiral antenna
(500 MHz – 10 GHz)

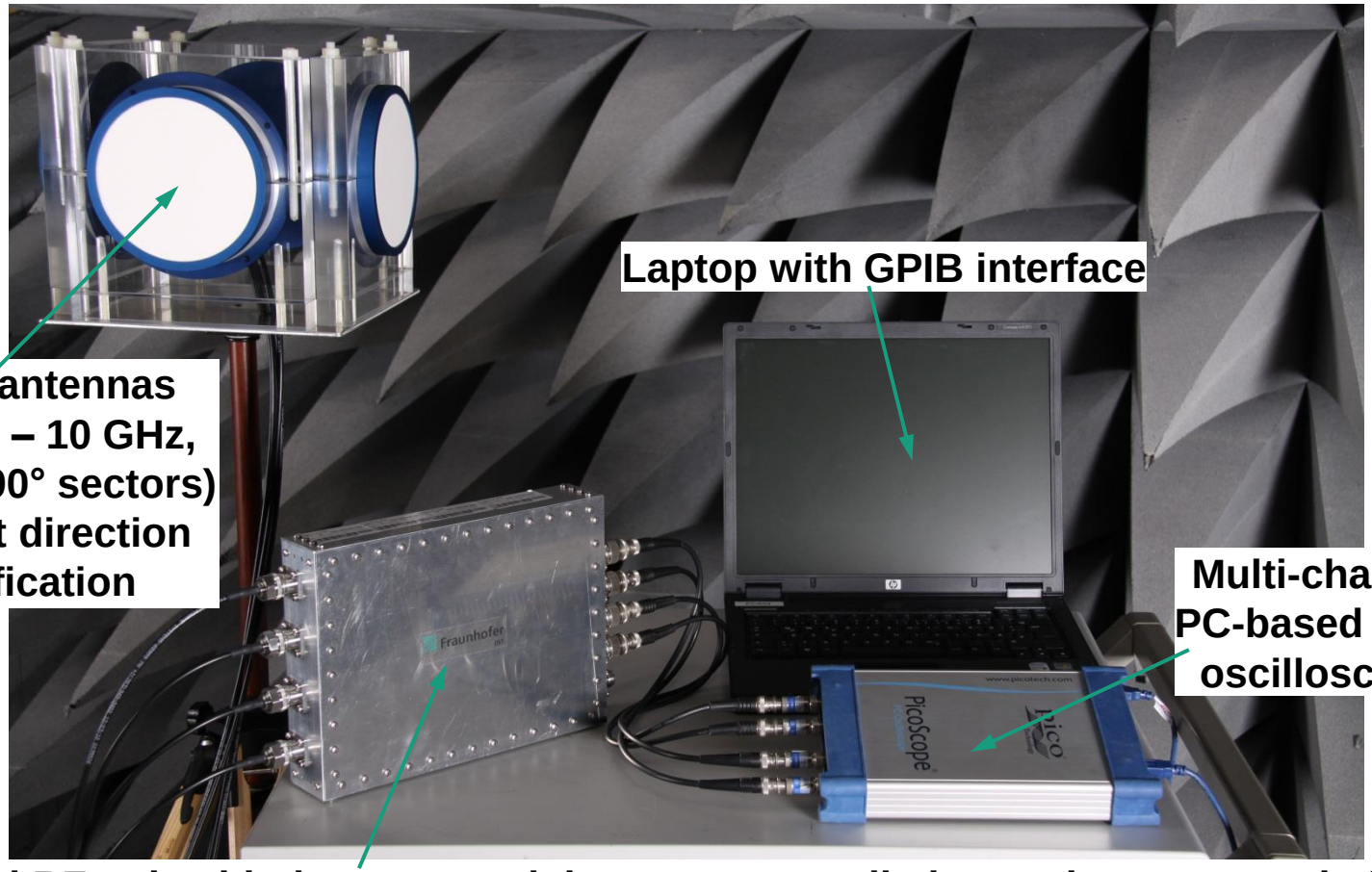
Laptop with
GPIB interface

Shielded RF unit with detector module, attenuators, limiter and power supply filter

Chr. Adami, Chr. Braun, P. Clemens, H.-U. Schmidt, M. Suhrke, H.-J. Taenzer “HPM detection system for mobile and stationary use“, EMC Europe 2011, York, UK.

HPM Detector Development at Fraunhofer INT

Demonstrator of Four-Channel HPM Detection System



Chr. Adami, Chr. Braun, P. Clemens, M. Jöster, H.-U. Schmidt, M. Suhrke, H.-J. Taenzer, *HPM Detector with Extended Detection Features*, EUROEM 2012, Toulouse, France, Sabath, Frank, Mokole, Eric L. (eds): Ultra-wideband, short-pulse electromagnetics 10. New York, Springer, 2014, pp. 345-353.

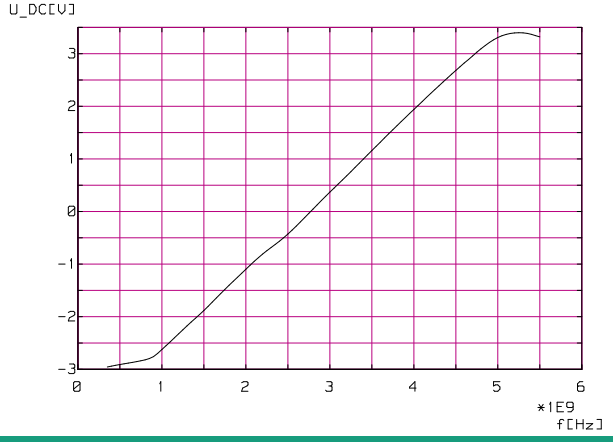
Fraunhofer INT

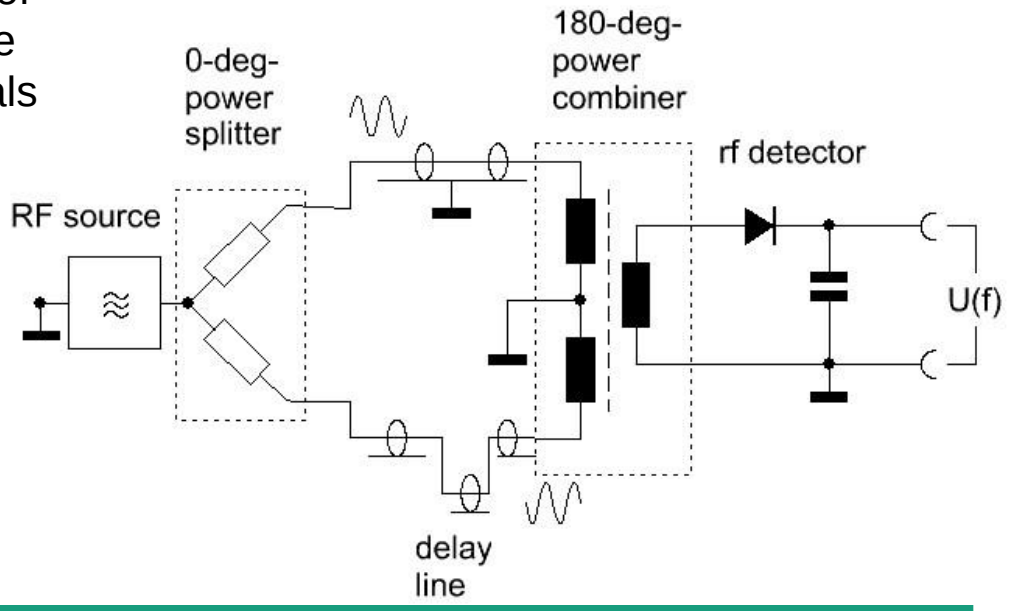
Concept of Frequency Detection

Basic Considerations

- **Aim:** Inclusion of missing ***frequency information*** for:
  - Improvement of HPEM source identification
  - Correction of frequency dependent characteristics of detector components
    - More accurate determination of field strength
    - Extension of usable frequency range

- **Principle of frequency-to-voltage conversion – *delay-line frequency discriminator***
  - Linear increase with frequency of output amplitude from difference of delayed and undelayed signals due to phase shift



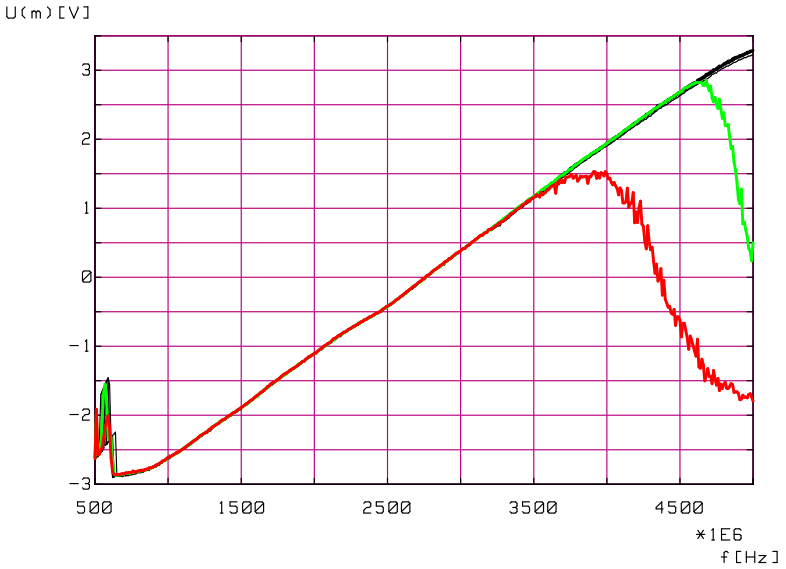


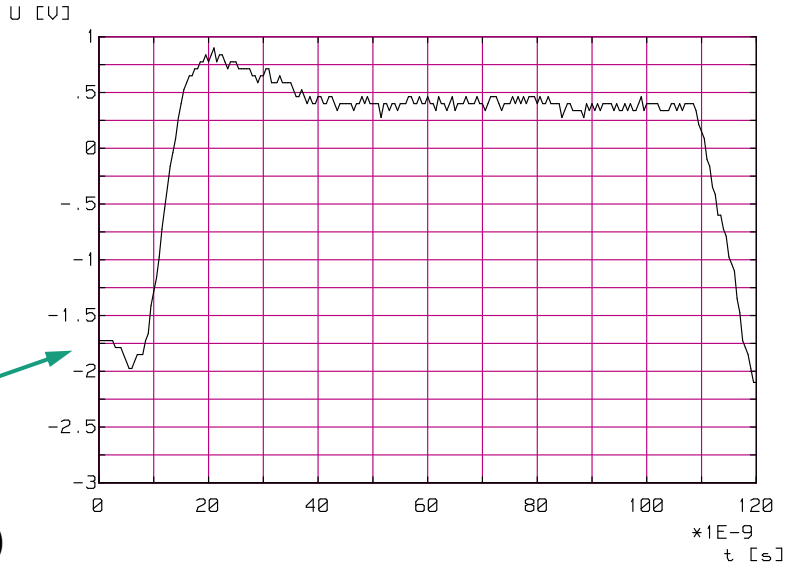
Fraunhofer INT

Concept of Frequency Detection

Realization for f > 600 MHz

- ***Integrated frequency discriminator***
  - Limitation of frequency range
    - Lower bound: f_{min} = 600 MHz
    - Upper bound: from dynamics of ***limiting amplifier*** (constant input amplitude for frequency discriminator)
      - f_{max} = 5.0 GHz for 0 … -40 dB
      - f_{max} = 4.6 GHz for 0 … -50 dB
      - f_{max} = 3.6 GHz for 0 … -60 dB
- **Detection of pulsed signals**
  - Frequency determination down to at least t_{min} = 100 ns for sufficiently accurate determination of pulse amplitude after overshooting (30 ns)
    (Input signal:
    - Width: 100 ns
    - Rise and fall times: 3 ns)





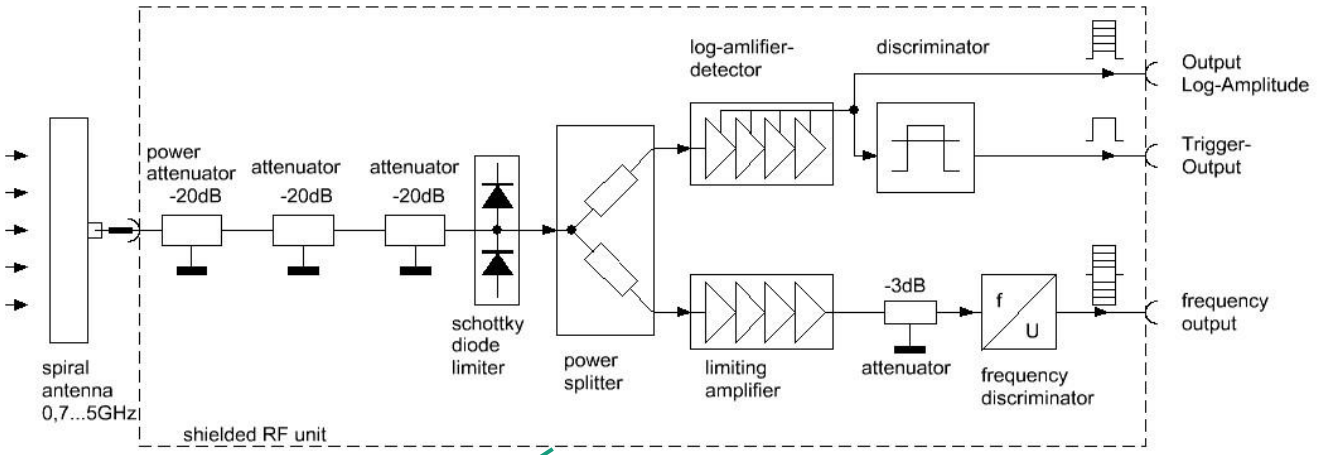
Fraunhofer INT

Single-Channel HPM Detector System with Frequency Identification

Overall System

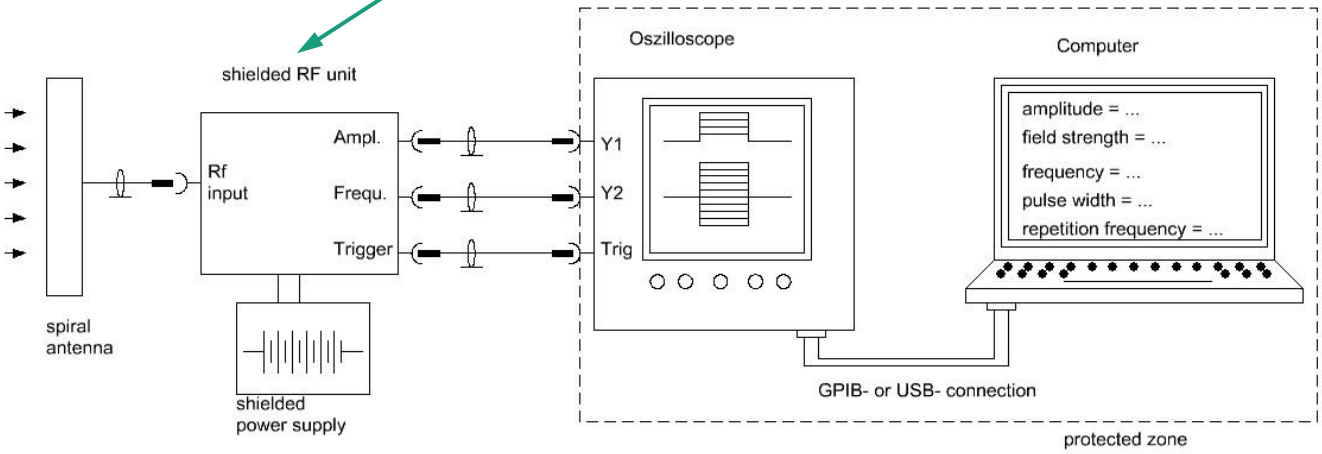
- **Block diagram of shielded RF unit**

  2 parallel channels for amplitude and frequency detection



- **Block diagram of entire detector**

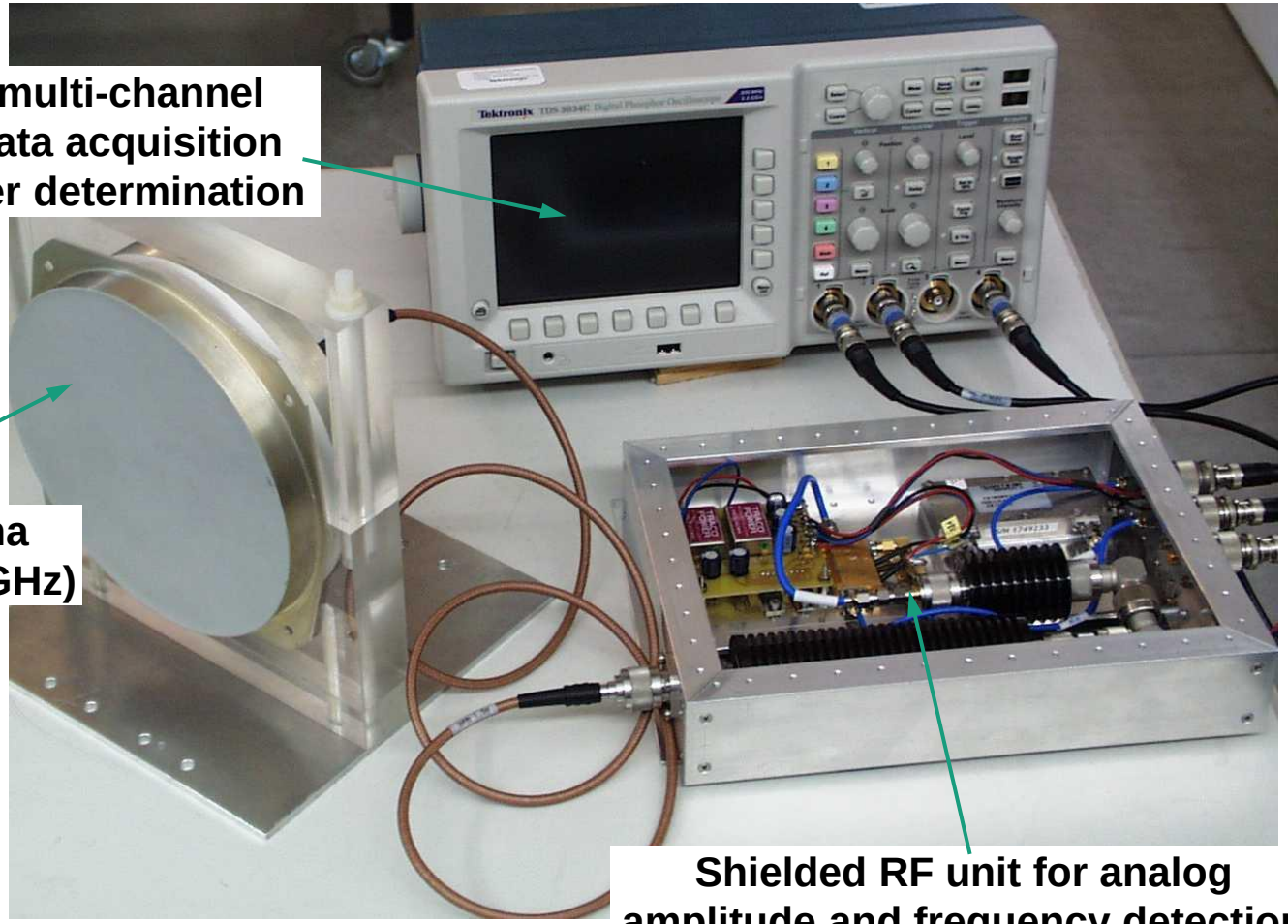
  Unshielded units (here: oscilloscope and control PC) in protected zone



Fraunhofer INT

Single-Channel HPM Detector System with Frequency Identification

Demonstrator of Single-Channel Amplitude and Frequency Detector



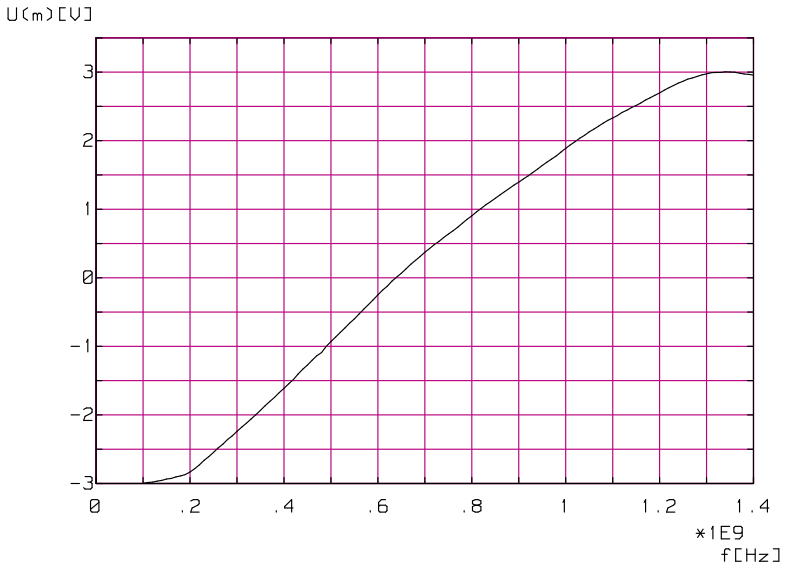
Concept of Frequency Detection

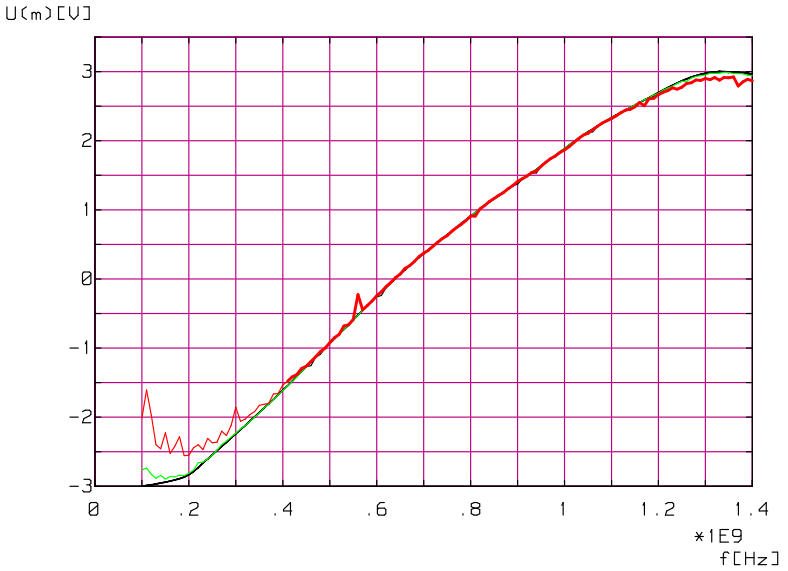
Extension to lower frequencies

2nd frequency detection channel:

- ***Integrated frequency discriminator***
  - Frequency range for linear frequency-voltage characteristics
    - Lower bound: f_{min} = 200 MHz
    - Upper bound: f_{max} = 1.3 GHz

- ***Limiting amplifier***
  Frequency range from amplifier dynamics
  - Lower bound
    - f_{min} = 100 MHz for 0 … -60 dB
    - f_{min} = 200 MHz for 0 … -65 dB
    - f_{min} = 350 MHz for 0 … -70 dB
  - Upper bound:
    - f_{max} = 1.3 GHz for 0 … -65 dB
    - f_{max} = 1.2 GHz for 0 … -70 dB





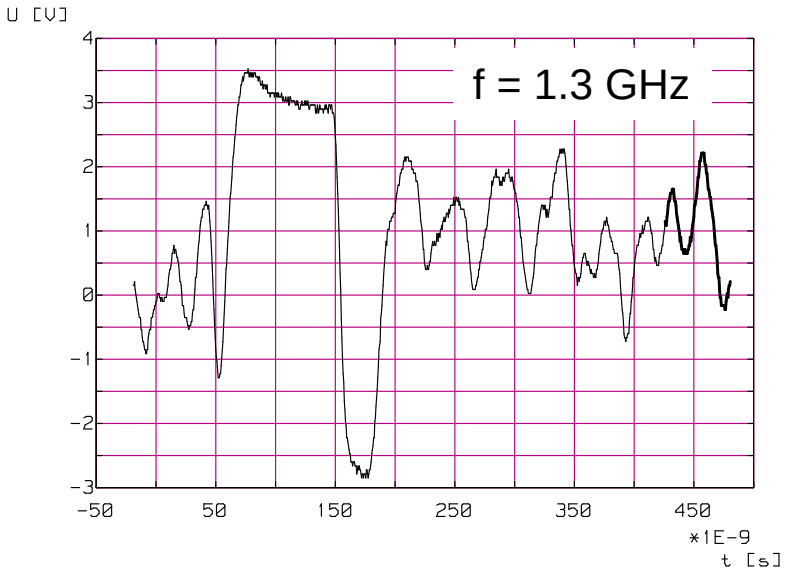
Fraunhofer INT

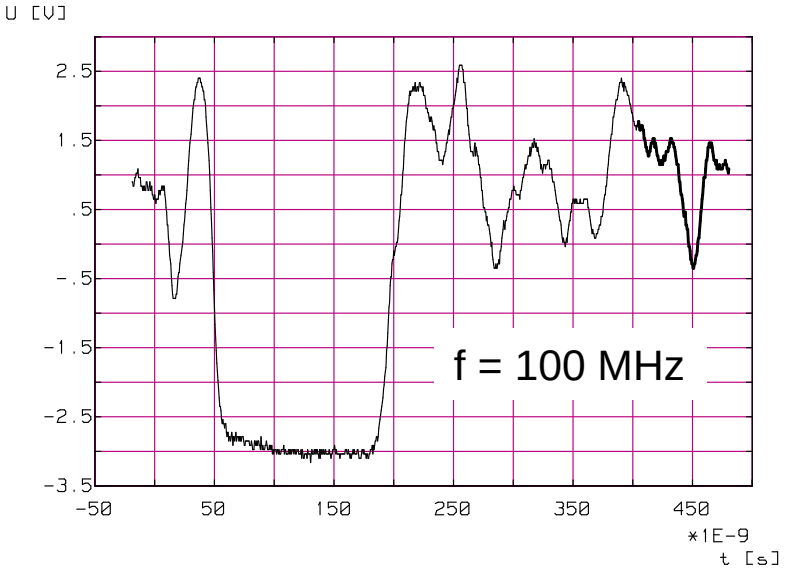
Concept of Frequency Detection

Extension to lower frequencies

- **Detection of pulsed signals by frequency discriminator**
  - Overshooting (30 ns) for upper frequency range
  - Pulse prolongation (50 ns) for lower frequency range
    - → Start of amplitude measurement after 50 ns
  - Minimum detectable pulse width:

    t_{min} = 100 ns





Fraunhofer INT

Detector Control Panel

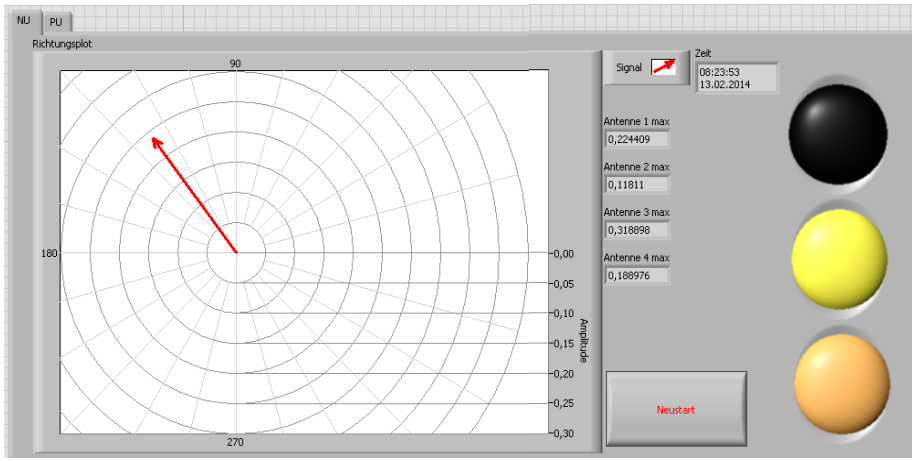
Two-Stage User Interface

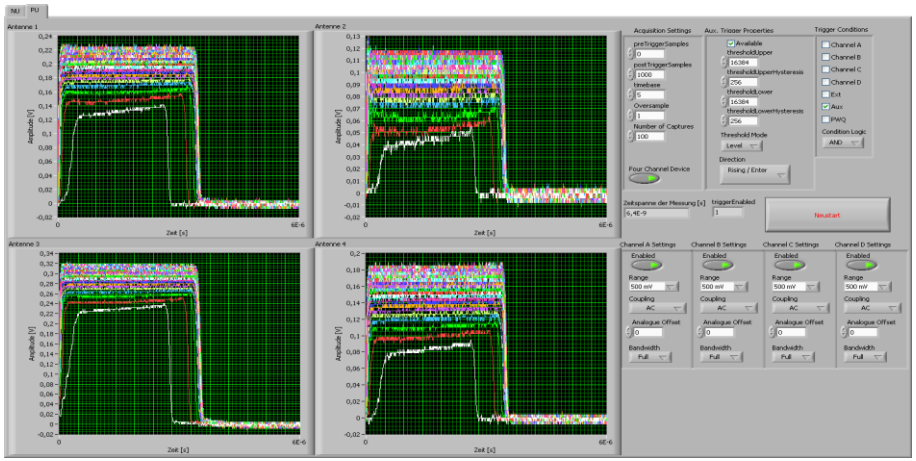
“Overview”:

- *For non-experts*
- Direction detection
- Rough amplitude display (3 levels)

“Raw data”:

- *For experts*
- Oscillograms of all four antennas
  - Possibility of diagnostics and forensics
  - Discrimination of false alarms

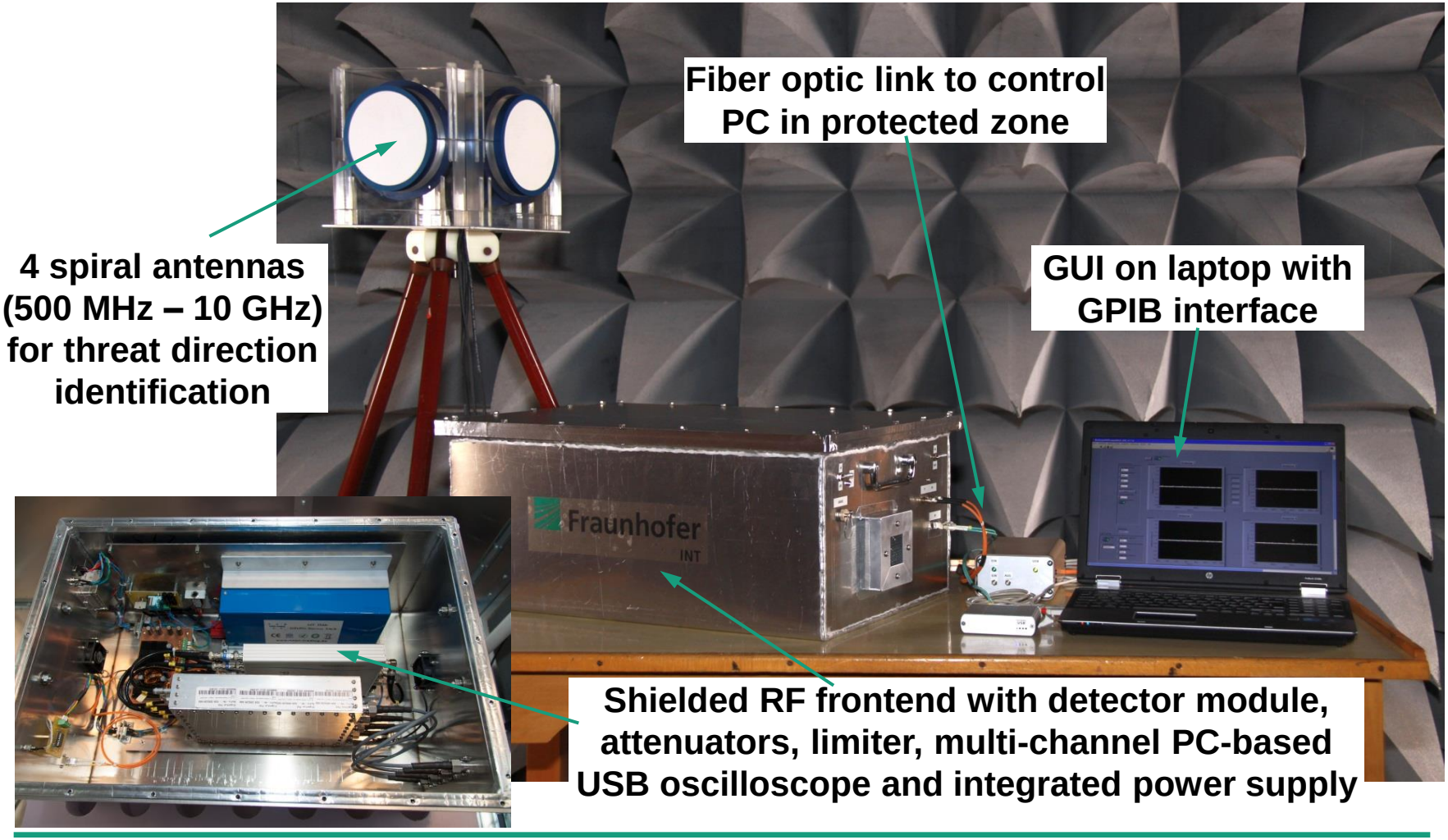




Fraunhofer INT

Compact Version

Demonstrator of Compact Four-Channel HPM Detection System



Fraunhofer INT

Summary and Outlook

- IEMI / HEPM attack detection is necessary and its importance is underestimated
- Additional processing of ***threat frequency information*** allows
  - Improvement of HPEM source identification
  - Improved accuracy of signal characterization
  - Extension of frequency range
- Realization for narrow band and pulsed threat signals with ***delay-line frequency discriminator***
- Development of two-stage ***user interface***
- Development of ***compact detector version*** for field tests
- **Future development:**
  - Extension of parameter range for entire system (low frequencies, short pulses)
  - Merging of frequency and direction detection (multi-channel system)
  - Further reduction of weight and size of the compact version
  - Integration into overall detection concept