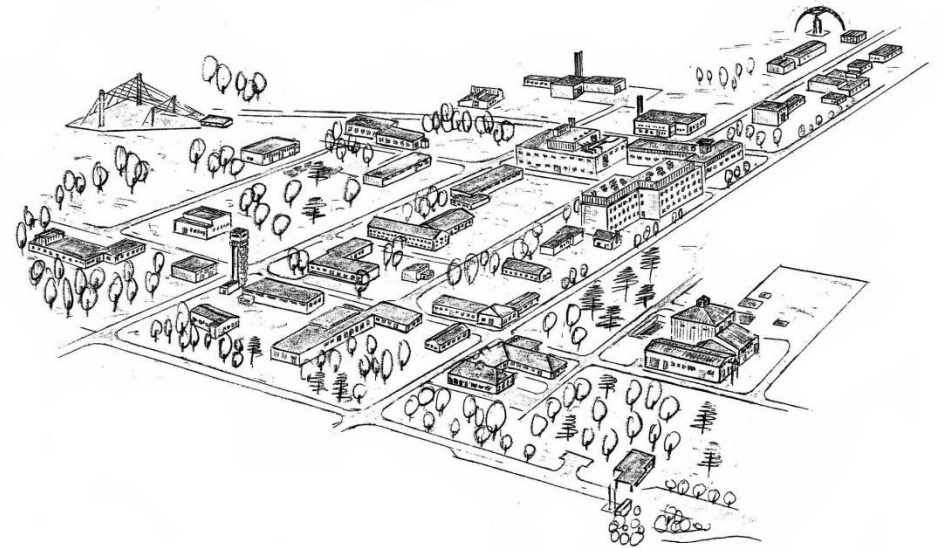


Bundeswehr Research Institute for Protective Technologies and NBC Protection (WIS)

Branch 320
Electromagnetic Effects
and HPEM



Branch Head 320:

Dr. Martin Schaarschmidt



- Introduction WIS
- High-Power Electromagnetics (HPEM)
- Equipment & Facilities
- R&D Projects





General information about the WIS



German Research Map:
Federal Research Institutions

Sven Fisahn



Bundeswehr Research
Institute for Protective
Technologies and
NBC Protection (WIS)

Branch 320

Electromagnetic Effects and HPEM

Mission:

Research, Testing and Advice on
Electromagnetic Effects and HPEM

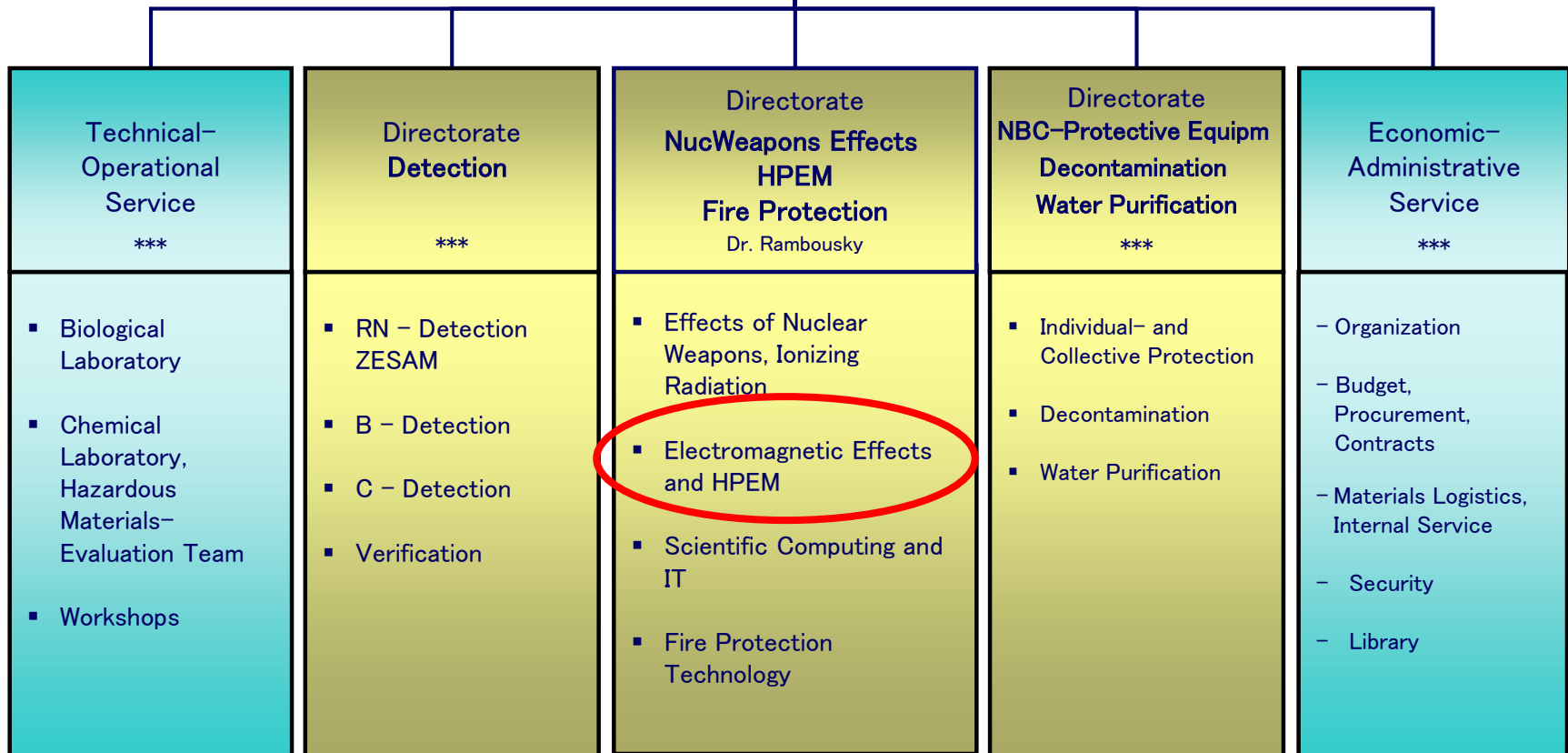


Director

DirProf Dr. Sabath

Staff

R&T-Coordination
 Controlling
 Quality Management
 Occupational Safety
 Public Relations



Mission GF 320 – Electromagnetic Effects and HPEM

- Research & Technology (R&T) Projects on HPEM **Research**
 - Interaction mechanisms of HPEM with electronic components and systems
 - Protection measures against HPEM effects

- Qualification testing to ensure HPEM hardness of military equipment and other security relevant systems and facilities **Testing**
- Assessment of potential HPEM weapons and their effects
- Participation in standardization working groups (national, international, military, civil)

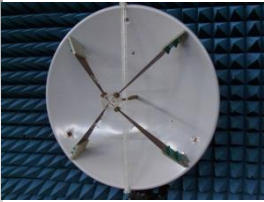
- Guidance to the Armaments Directorate (MoD) concerning protection of military equipment against HPEM attacks **Advice**
- Support of the Armaments Directorate (MoD) concerning HF personnel safety by scientific assessment and measurements

Research & Technology (R&T) – Context / Focus

Numerical EM-Field Simulation
CEM (PROTHEUS)



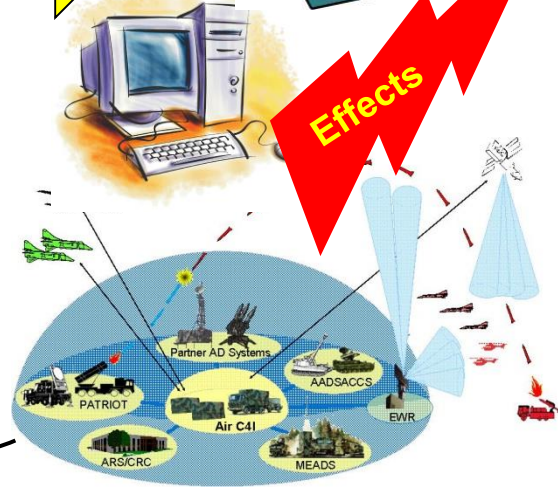
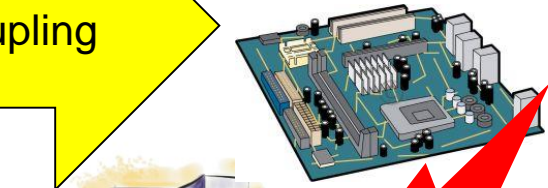
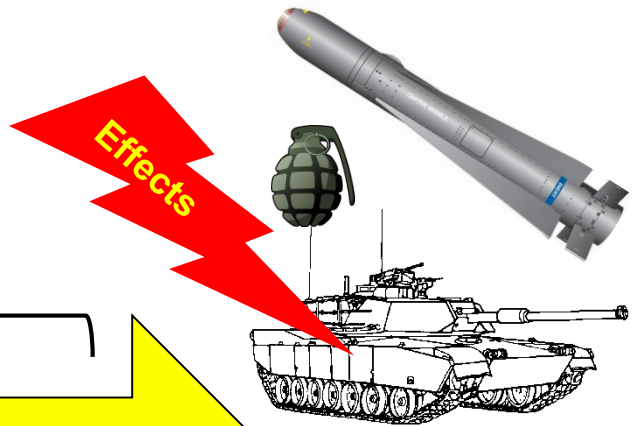
HPEM-Effector



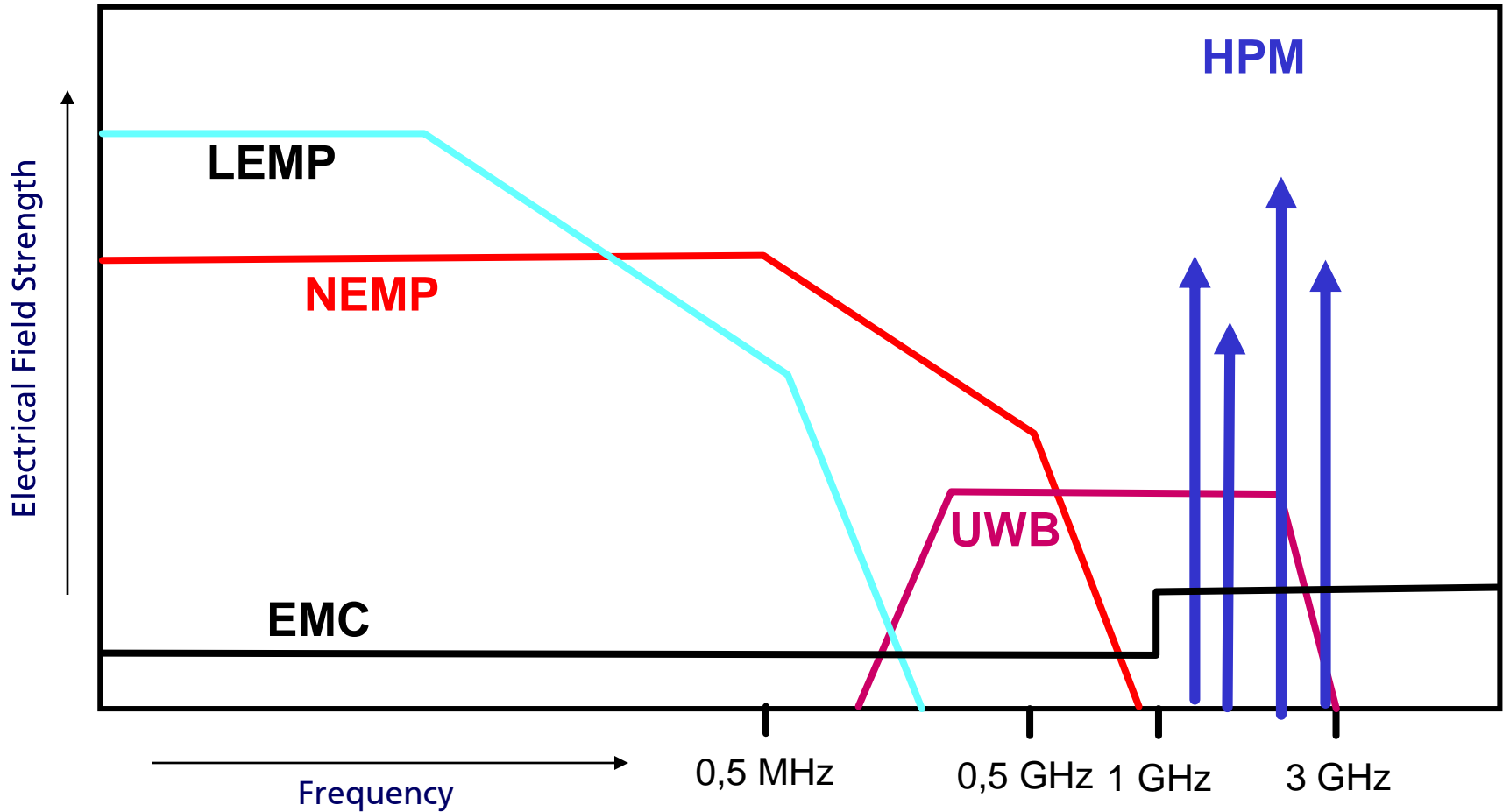
EM-Fields
wave propagation

EM-Coupling

HPEM-Interaction
HPEM-Protection
HPEM-Qualification Testing
HPEM-Standardization



Frequency ranges of electromagnetic effects

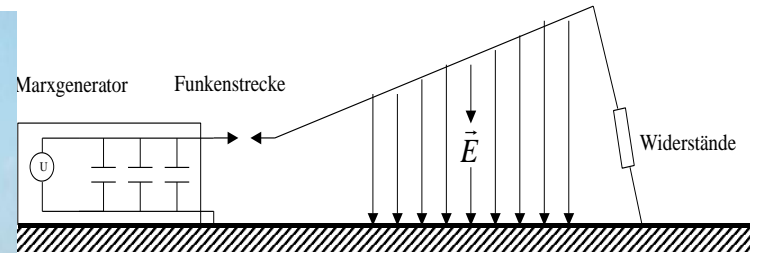


- Introduction WIS
- High-Power Electromagnetics (HPEM)
- **Equipment & Facilities**
- R&D Projects



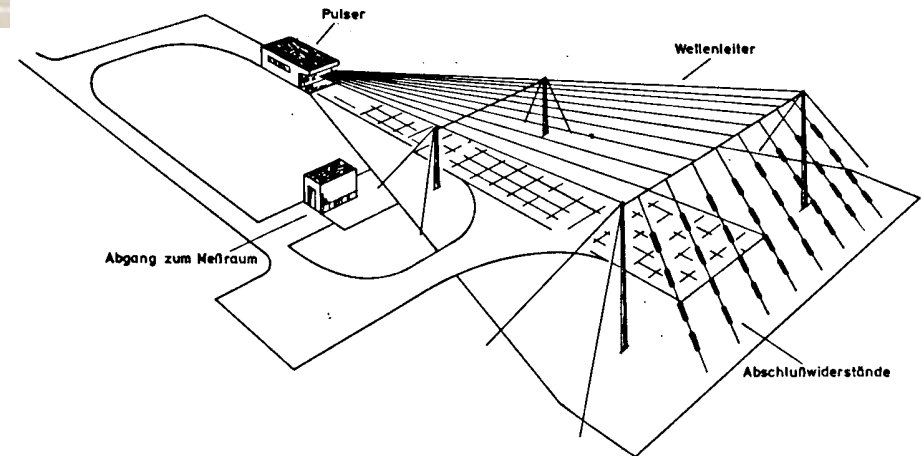
NEMP Simulators – TEM-Waveguide DIESES

Deutsches Impulserzeugungs-
System zur EMP-Simulation



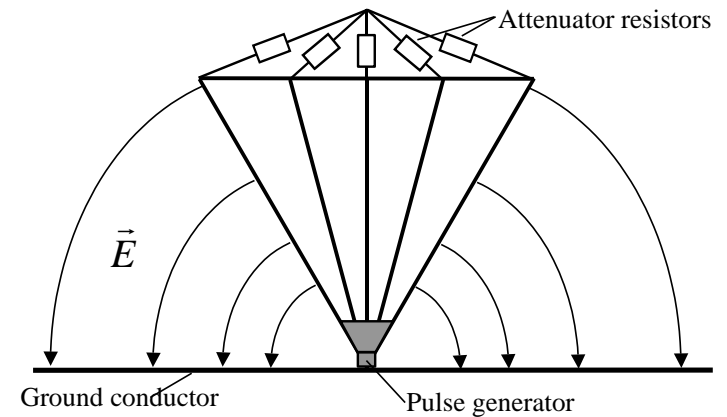
TEM-Waveguide

Rise time: 1.0 - 2.5 ns
Pulse duration: 25 - 50 ns
Amplitude: 1 kV/m - 100 kV/m
Test volume: 10 m x 10 m x 10 m

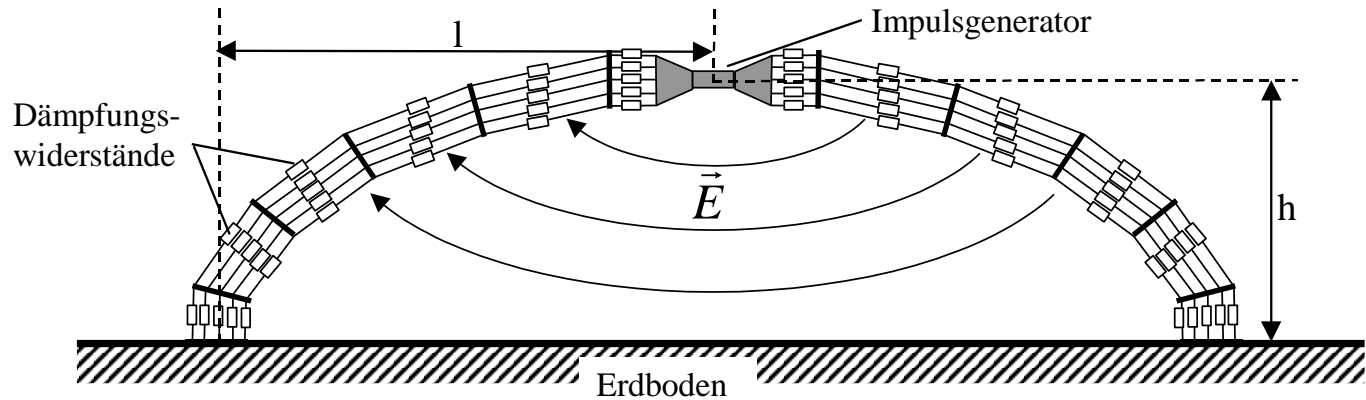


Vertical Polarizing Dipole (VPD)

Rise time:	2.5 ns
Pulse duration:	25 ns
Amplitude:	1 kV/m - 15 kV/m
Test volume:	10 m x 10 m x 6 m



NEMP Simulators – HPD



Horizontal Polarizing Dipole (HPD)

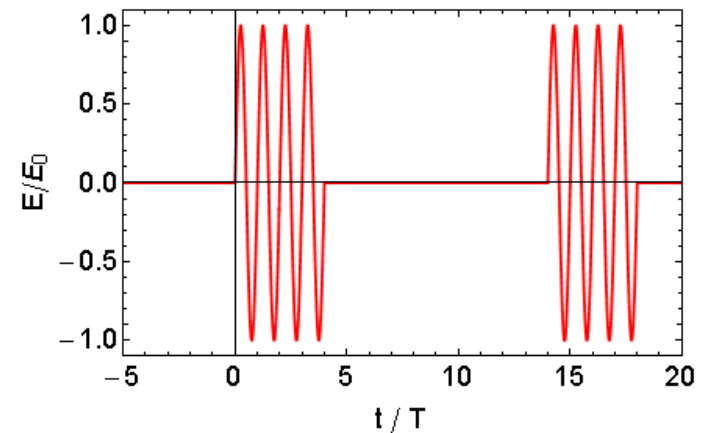
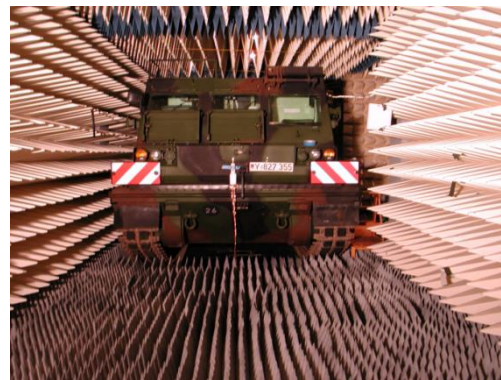
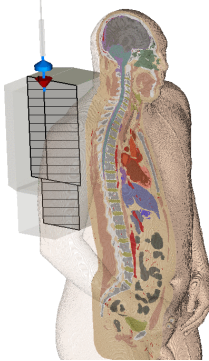
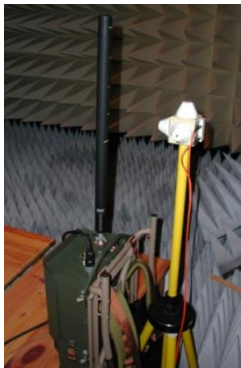


- Rise time: 1 ns - 3 ns
- Pulse duration: 10 ns - 20 ns
- Amplitude: 1 kV/m - 50 kV/m
- Test volume: 10 m x 10 m x 6 m

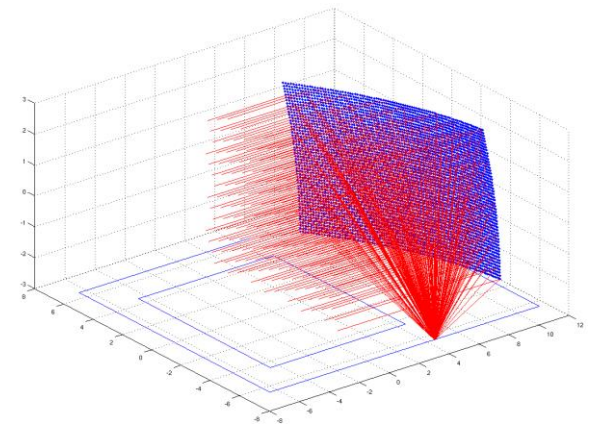
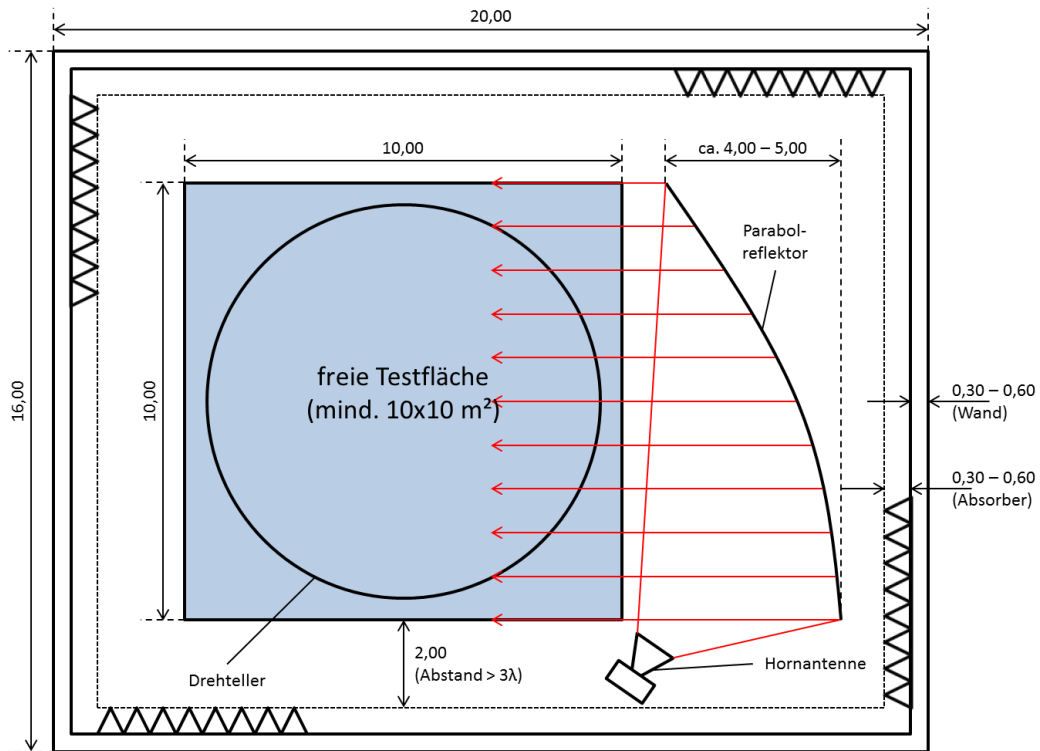


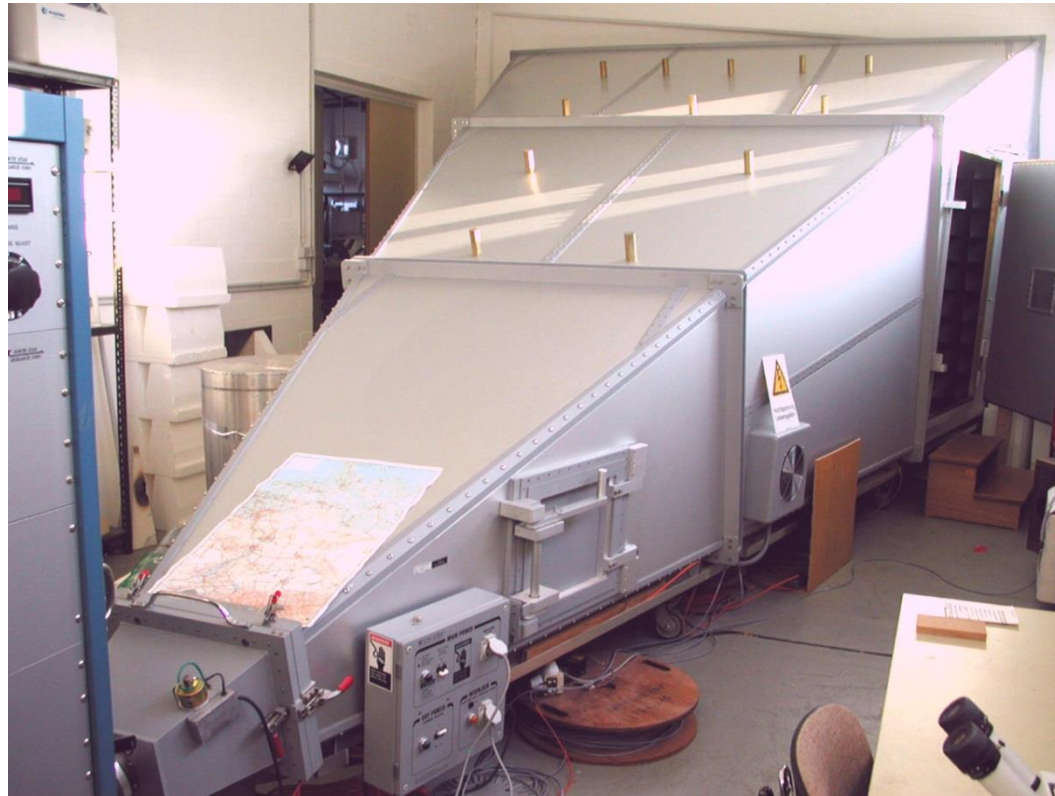
High-Power Microwave Facility – SUPRA

- 8x super reltrons
- frequency range: 685 MHz – 3 GHz
- mean power: 100 MW bis 500 MW
- effektive field in 15 m distance: >50 kV/m
- illumination area in 15 m distance: 4 m x 3 m
- pulse duration: > 300 cycles
- Pulse repetition frequency: up to 10 Hz
- Pulses per Burst: <100



High-Power Microwave Facility – SUPRA – Projected Extension





- Dimensions: (7,8 x 2,8 x 4,1) m
- Frequency range: 0 Hz – 18 GHz
- Input for pulsed signals up to 50 kV (e.g. NEMP pulse)

HPEM-Laboratory – Open TEM Waveguide

- obere Grenzfrequenz: 8 GHz
- max. Eingangsspannung: 50 kV
- integrierte Feldsensoren (E-Feld)
- Testvolumen: 1 m x 1 m x 1 m



Mobile HPM-Source



PBG3:

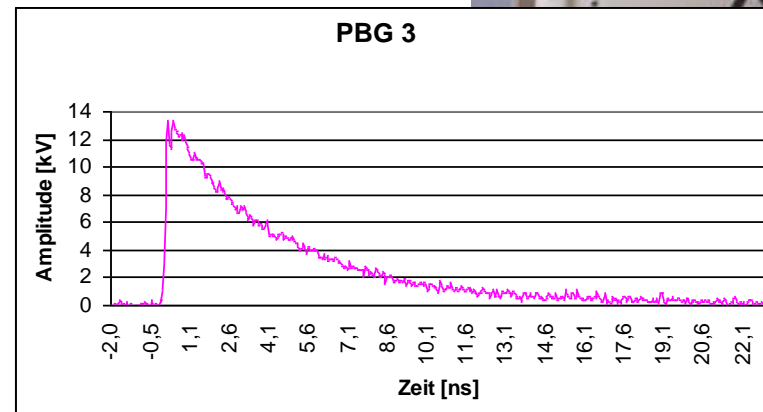
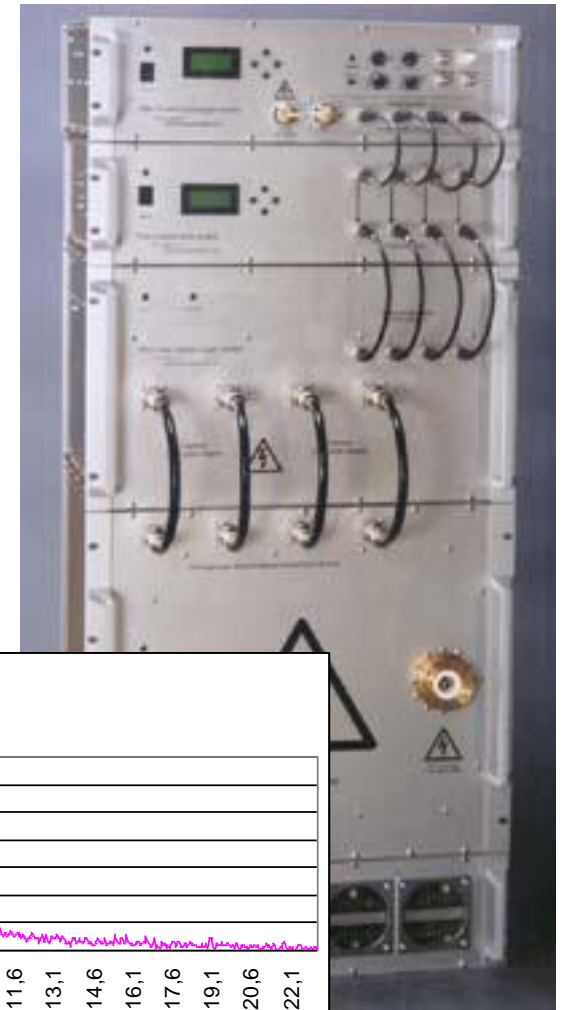
- Multifunktionaler UWB-Pulsgenerator auf Halbleiterbasis
- Ausgangsspannung: 12 kV
- Ansteigszeit: 100 ps
- Pulsdauer: 5 ns
- Wiederholrate: 100 Hz

PBG7:

- Multifunktionaler UWB-Pulsgenerator auf Halbleiterbasis
- 4 Ausgänge je 12 kV, $t_{\text{rise}} = 100 \text{ ps}$ (für Phased-Array-Systeme)
- oder ein Ausgang 45 kV, $t_{\text{rise}} = 150 \text{ ps}$, Pulsdauer 3 ns
- Wiederholrate: 500 Hz

Verwendbare Antennensysteme:

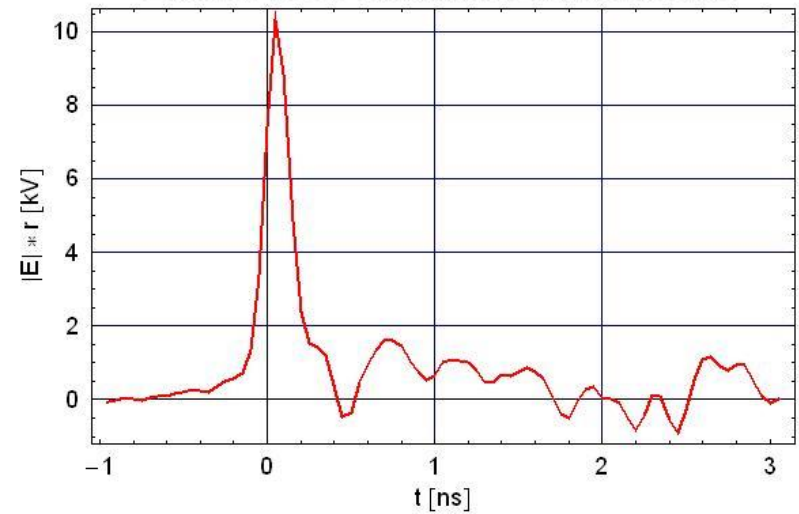
- Impuls Radiating Antenna (IRA)
- Half Impuls Radiating Antenna (HIRA)
- Hornantennen
- TEM-Wellenleiter



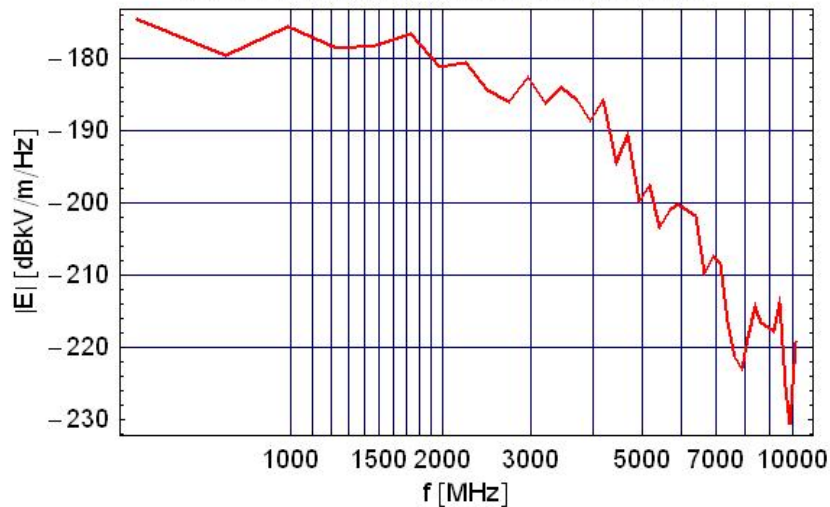
HPEM-Laboratory – Horn Antennas

- obere Grenzfrequenz: 4,5 GHz
- max. Eingangsspannung: 13 kV
- 4 Antennen vorhanden

Zeitverlauf des auf 1 m normierten elektrischen Feldes



Amplitudengang eines abgestrahlten UWB-Impuls mit der Hornantenne 2 in 5 Meter Entfernung

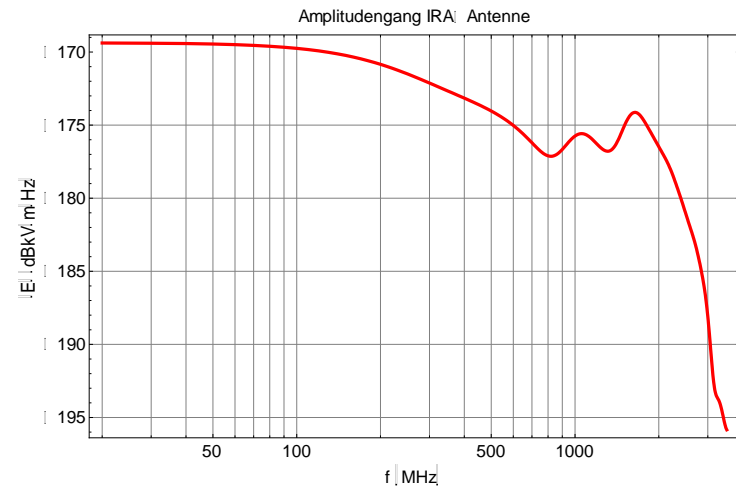
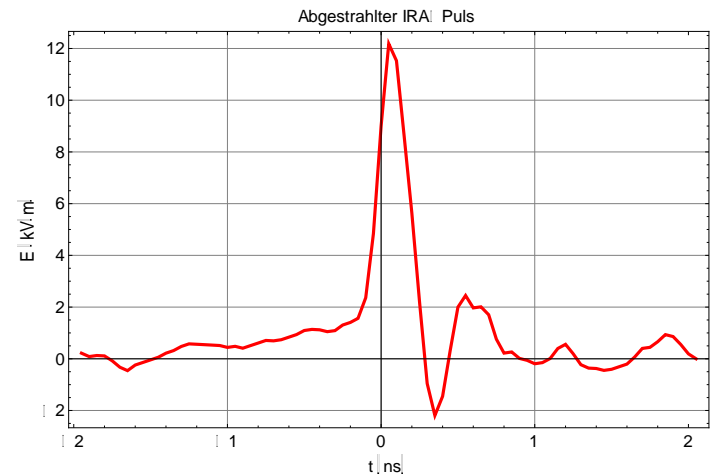
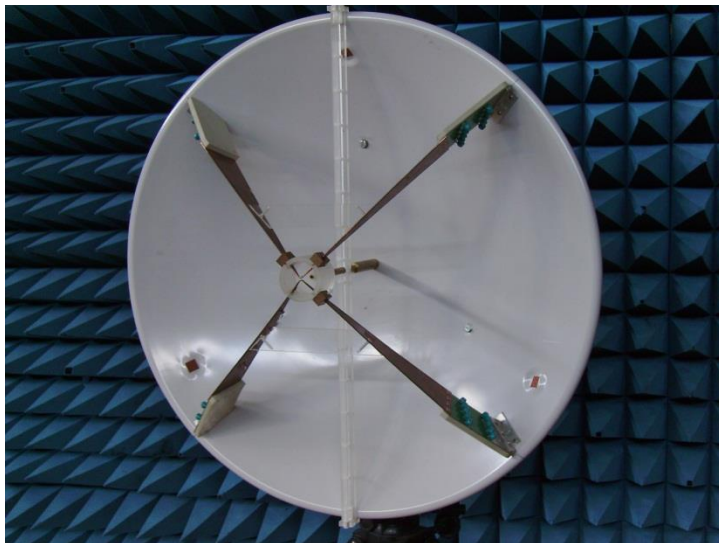


HPEM-Laboratory – Impulse Radiating Antenna (IRA)

Impulsabstrahlende Reflektorantennen

Durchmesser Apertur:	0,9 m	1,8 m
Max. Spannung:	12,5 kV	50 kV
Obere Grenzfrequenz:	2,5 GHz	n.n
Bandbreite:	1,5 GHz	n.n
r E:	10 kV	n.n

Impuls Radiating Antenna (IRA)



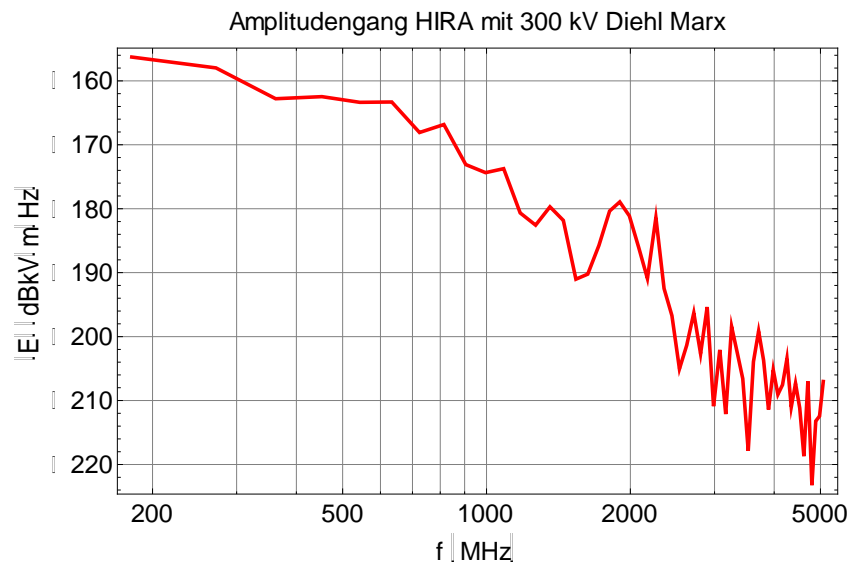
HPEM-Laboratory – Half Impulse Radiating Antenna (HIRA)

Impulsabstrahlende Reflektor-Halbantenne

Durchmesser Apertur: 1,8 m
Max. Spannung: 600 kV
Obere Grenzfrequenz: 2,2 GHz
Bandbreite: 1 GHz
r E: 790 kV

Adaption an verschiedenste Impulsquellen des WIS
(Marxgeneratoren, pulserzeugende Netzwerke)

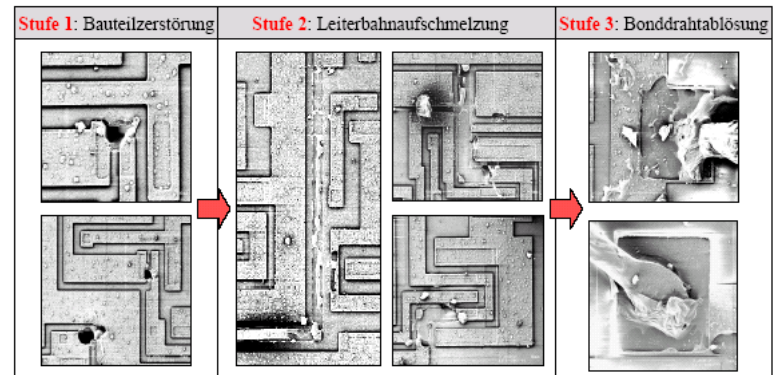
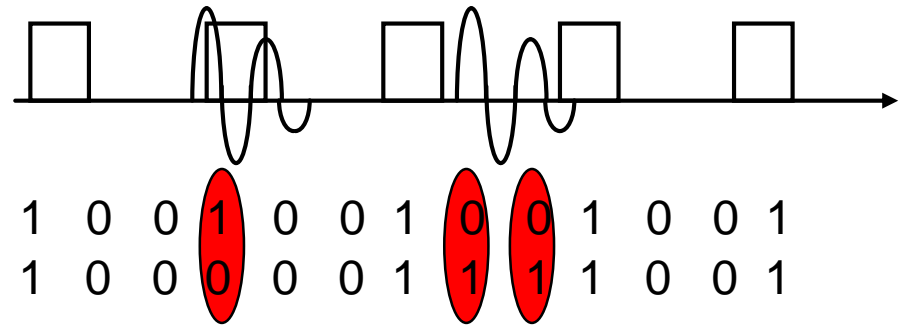
Half Impuls Radiating Antenna (HIRA)



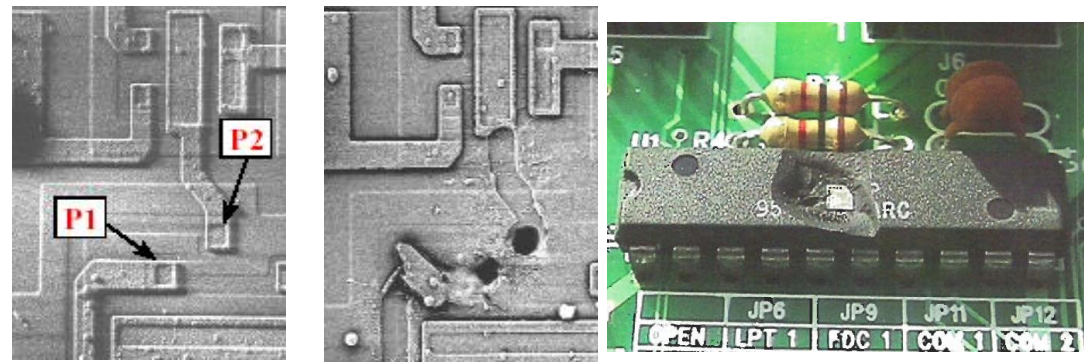
- Introduction WIS
- High-Power Electromagnetics (HPEM)
- Equipment & Facilities
- **R&D Projects**

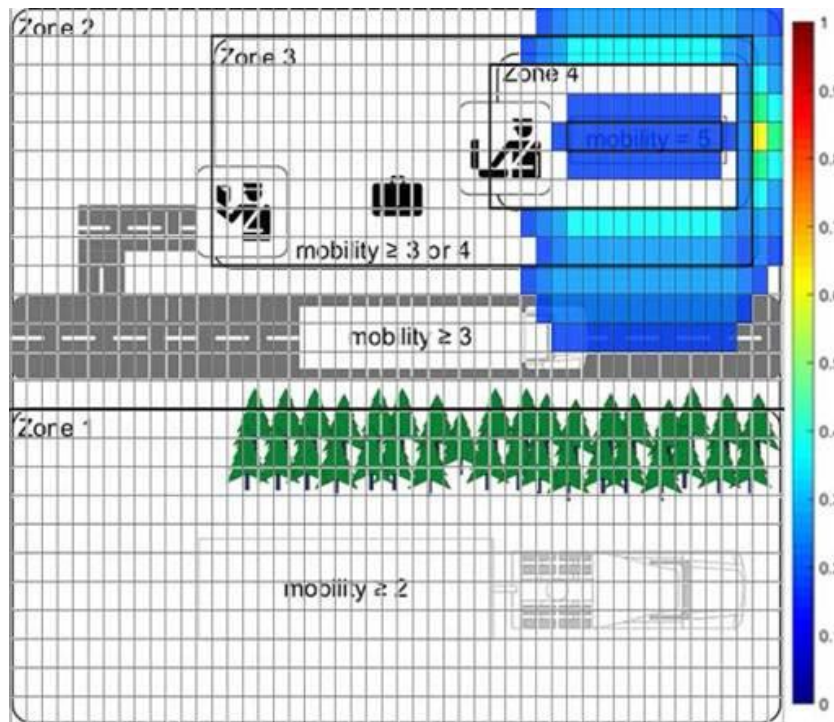


Bit-Flip



Physical Destruction





Example: Airport Check-In

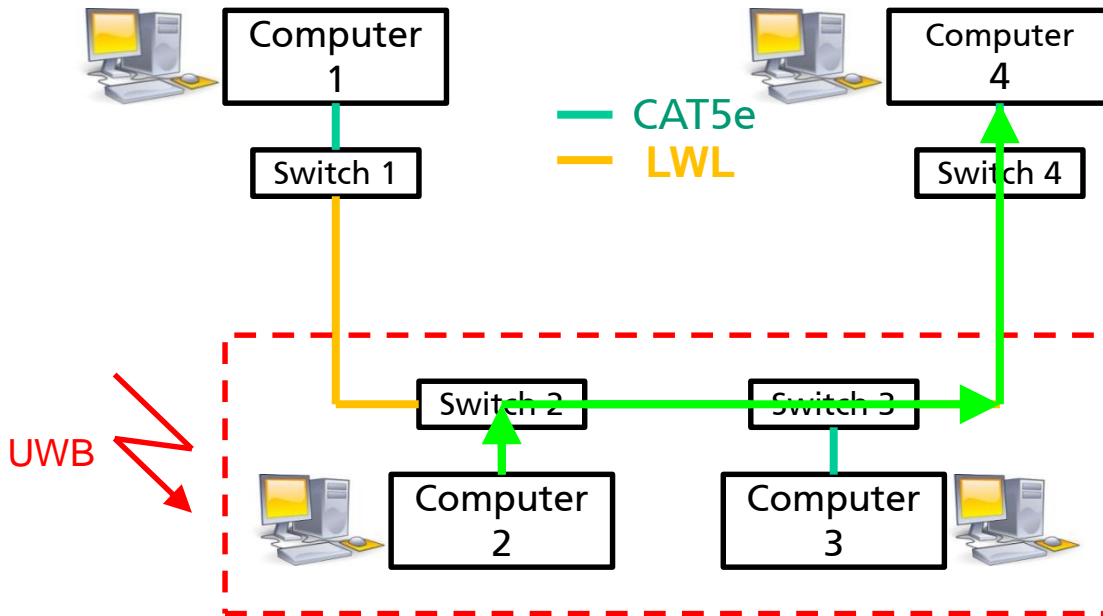
- Fuzzy-Logic based
- Nontechnical parameters
- Expert knowledge
- Information deficit

statistical-theoretical evaluation
Functional description

Intelligent Network Protection



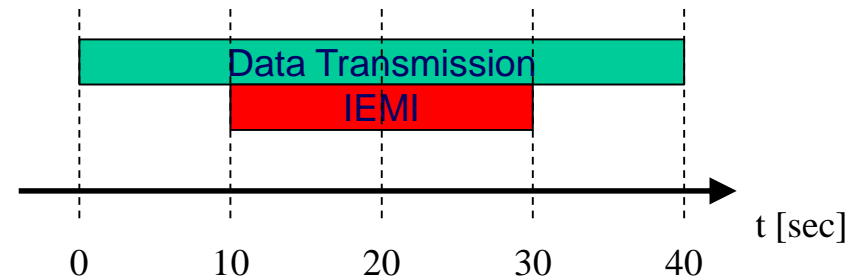
Network Protection - Setup



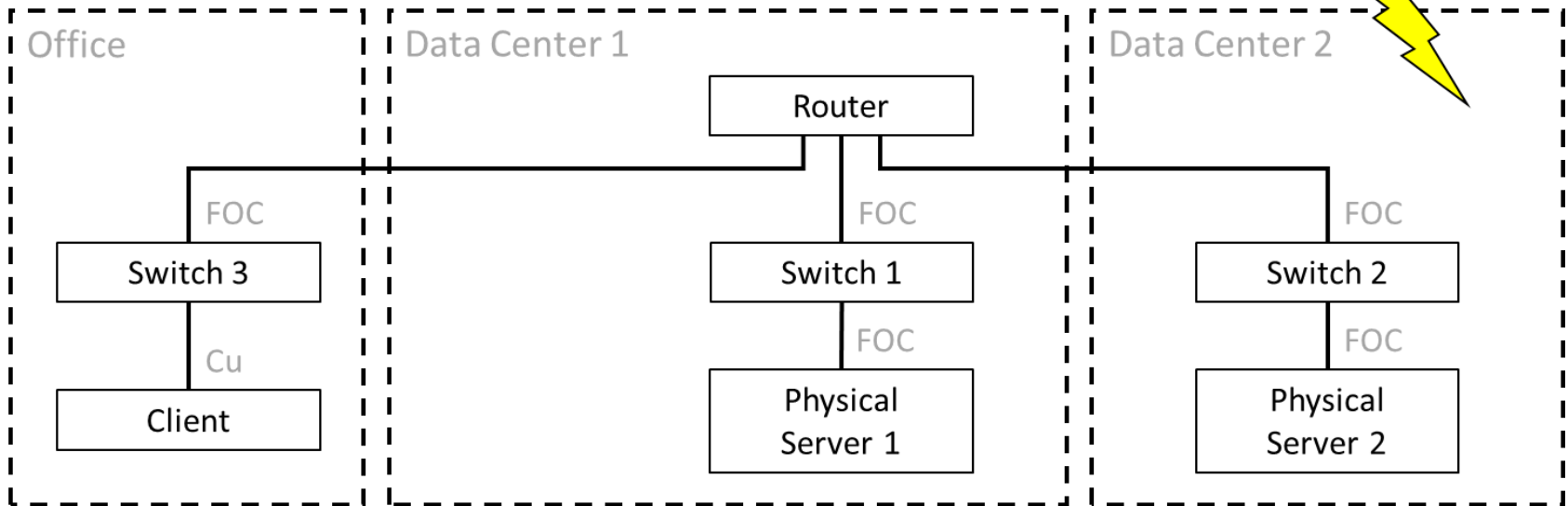
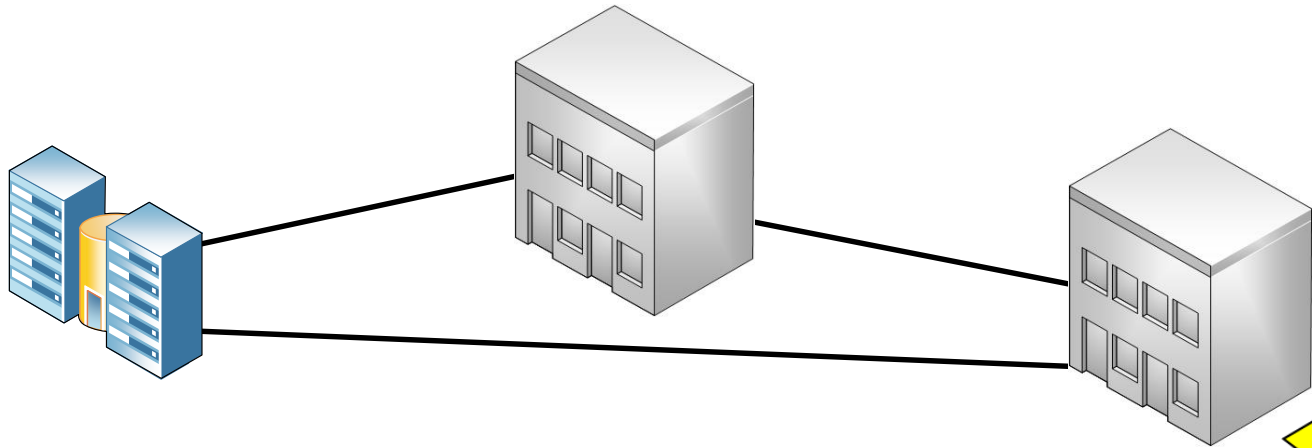
Parameters

- 7,5 kV/m vertikal
- Rep-Rate: 0, 10, 50, 100, 200,..., 800 Hz
- transmission: 40 sec
- Interruption: 20 sec

Resilience of Redundant Server Infrastructure



Resilience of Redundant IT Infrastructure



Defence against UAV/UAS

HPEM capabilities

- jamming
- Sensor interruption
- Processing interruption








UAV = unmanned aerial vehicle

UAS = unmanned aerial system



Spiegel-Online vom 16.09.2013

CotS UAV					
Merkmal	Reely 650 ARF	GAUI 500X-S	Flame Wheel	Phantom	Multicopter 800 S
Beschaffung	DEU	DEU	NATO	NATO	NATO
Anzahl	1	1	4	4	2
Steuerung	35 MHz	2,4 GHz	2,4 GHz	2,4 GHz	2,4 GHz
GPS	nein	ja, externes Modul	ja	ja	ja
Autonomes Landen (Coming Home)	nein	ja	ja	ja	ja
Autonomer Flug (Wegpunktnavigation)	nein	ja	nein	nein	ja
Größe (Linie Motor – Motor entlang der Arme)	66 cm	50 cm	56 cm	35 cm	80 cm
Flugzeit	20 min	20 min	20 min	20 min	15 min
Nutzlast	800 g	1400 g	300 g	150 g	2000 g
Einstufung	Modellbau/ Hobby	Modellbau/ Hobby mit MIKADO vergleichbar	Modellbau/ Hobby	Semiprofessionell	Professionell mit MIKADO vergleichbar

Standardization

NEMP

Nat.: VG Normen
Intern.: AECTP 250/500

Test facilities:
Waveguide „DIESES“
HPD, VPD

R&D Activities:
Interconnected IT-Systems /
TEM-Waveguide
(AF119)

UWB

Nat.: -
Intern.: AECTP 250/500

Test facilities
UWB Pulser + Antenna
DS Pulser
UWB/DS TEM-Waveguide

R&D Activities:
NATO RTO SCI-250
Joint Systems (CF149)

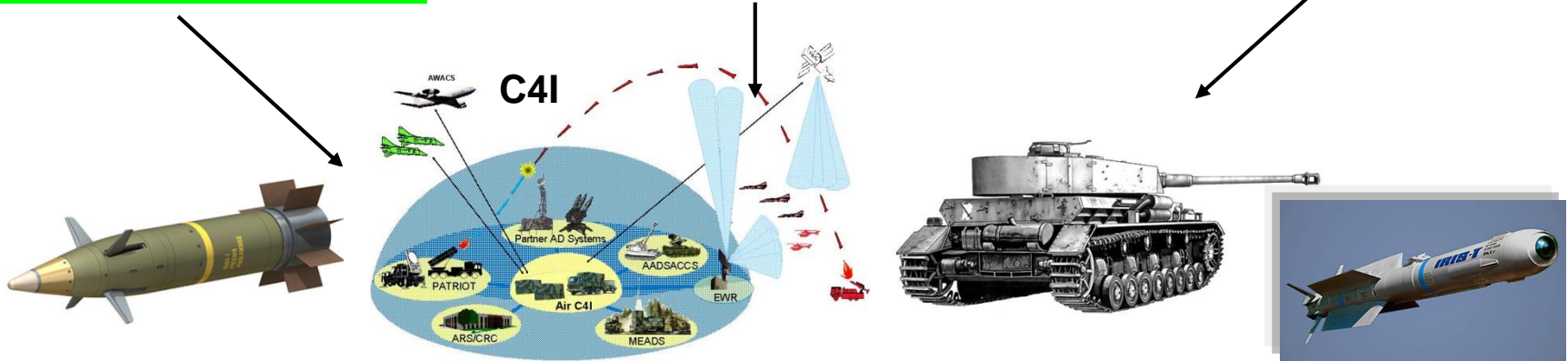
DS

HPM

Nat.: -
Intern.: AECTP 250/500

Test facilities
HPM facility „SUPRA“
Extended anechoic chamber

R&D Activities:
HPM Testprocedures (CF162)
Mobile Source (FF027)



- EMC+SIPI 2021 Virtual:
 - **Tutorial** by Frank Sabath: Modeling of Intentional Electromagnetic Interference (IEMI) Scenarios
 - **Workshop** by Frank Sabath, Dave Giri and Richard Hoad: HPEM Effects on Electronic Systems
 - **Workshop** by Martin Schaarschmidt and Michael Suhrke: Protection of Critical Infrastructure against Intentional Electromagnetic Interference
 - **Technical Session** by Mike McInerney and Frank Sabath: IEMI Generators and Modeling
 - **Technical Session** by Frank Sabath and Mike McInerney: Intentional EMI and HEMP
 - **Technical Session** by Tim Claeys: Risk-based EMC
→ MSCA-ITN „PETER“

- MSCA ITN "PETER - Pan-European Training, Research & Education Network on Electromagnetic Risk Management"
→ <https://etn-peter.eu/>
- Kleinheubacher Tagung 2021 (German forum of the URSI)
 - **Plenary Session** by Frank Sabath: EMI Risk Management
 - **Special Session by Sven Fisahn:** Risk Analysis and German activities within MSCA ITN "PETER - Pan-European Training, Research & Education Network on Electromagnetic Risk Management"

Thank you for your attention!

Questions ?

