LUMILOOP

Application of Fast Laser-Powered Electric-Field Probes

General Information
June 13, 2019

Gefördert durch:

Existenzgründungen aus der Wissenschaft

Bundesministerium für Wirtschaft und Energie

aufgrund eines Beschlusses des Deutschen Bundestages

Europäischer Sozialfonds für Deutschland

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Application of Laser-Powered Field Probes

- Part 1 – Introduction
  - *Battery-powered vs. laser-powered electric-field probes*
- Part 2 – Avoiding Common Issues of Laser-Powered Probes
  - *Power density on fiber cables, burn-in defect & mechanism*
  - *Use and intention of sacrificial cable kits*
  - *Handling recommendations and cleaning of fiber connectors*

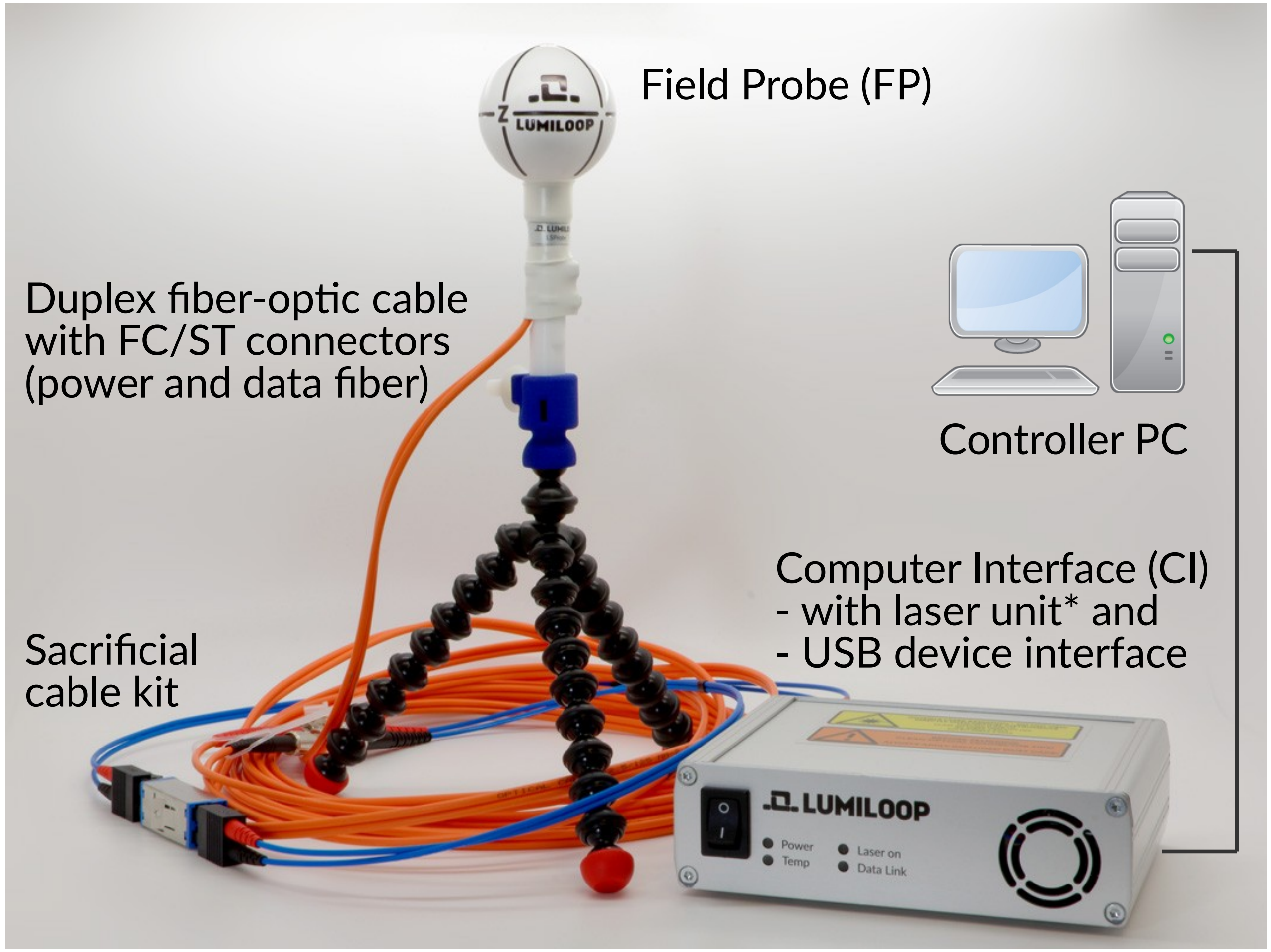
Part 3 – Enhanced EMC Testing Examples
  - *Fast sweep measurements (e.g., for IEC 61000-4-3 field calibration)*
  - *Radar pulse measurements (e.g., Ford EMC Spec FMC1278)*
  - *Use of multi-probe systems (e.g., for IEC 61000-4-21, ISO 11451-2)*

Part 1 – Battery- vs. Laser-powered Probes

	Battery-powered	Laser-powered
Unlimited duration of use	✗	✓
Low maintenance (charging & replacing batteries, replacing probes)	✗	✓
Low risk of burn-in defects due to contamination of fiber connector end-faces	✓	✗
Support of long fiber cables and multiple couplers	✗	✓ *
High sampling rate	✗	✓
Support of high dynamic range	✗	✓ *

*) LSProbe 1.2 Field Probe

Laser-Powered Field Probe - LSProbe 1.2



*) Class 1M laser, automatic power reduction, turned off within 1ms, 830 nm, temperature controlled within laser's safe operating range

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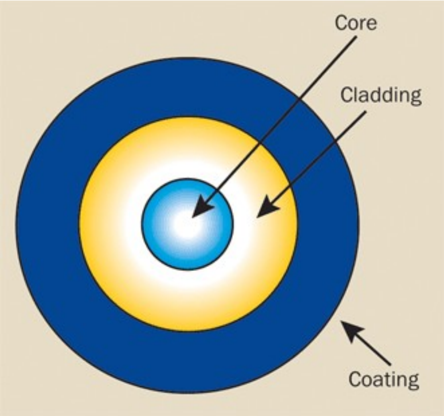
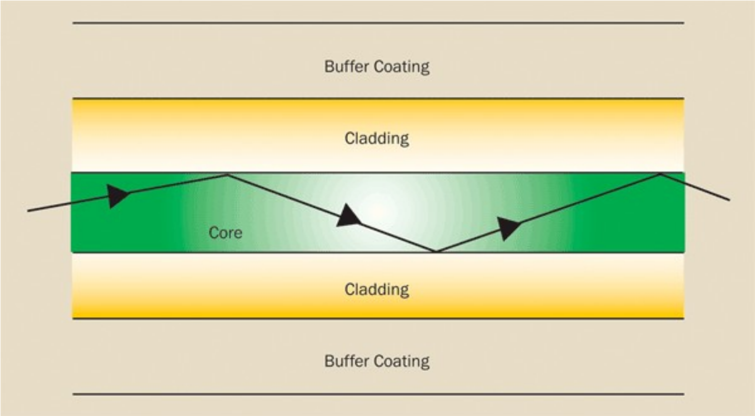
Basics of Fiber-Optic Cables

- Optical fiber
  - Used to transmit light signals over long distances
  - Strand of pure glass about the diameter of a human hair
  - Consists of glass core, glass cladding and buffer coating
  - Core has higher refractive index than cladding (few percent)
  - Difference in refractive index yields total internal reflection, light is confined within the core, critical angle about 82°





From: *www.photonics.com/Articles/Fiber_Optics_Understanding_the_Basics/a25151*

Basics of Fiber-Optic Cables

- Specified by outer diameters of the core, cladding and coating, e.g., 62.5/125/150 refers to 62.5 µm, 125 µm and 150 µm
- Protected by strengthening (aramid) fibers and cable jacket (PE)
- Simplex / duplex fiber cable with single / two strand(s) of glass
- Single / multi-mode fibers
  - Multi-mode: larger core diameter (50 / 62.5 µm) allows multiple modes of light to propagate
- Step-index / graded-index fibers
  - Step-index: light only reflected at core-cladding interface
  - Graded-index: refractive index of the core decreases gradually and allows a curved light path within the core

→ LSProbe 1.2: duplex, multi-mode (62.5 µm), graded-index

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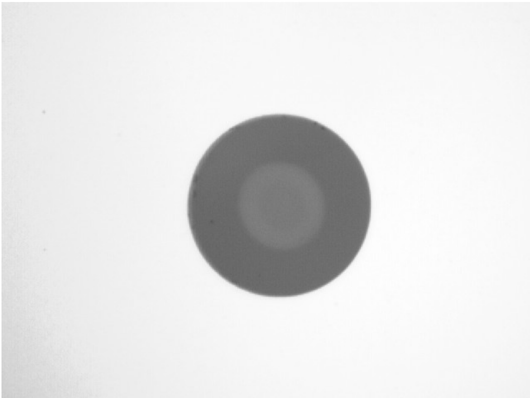
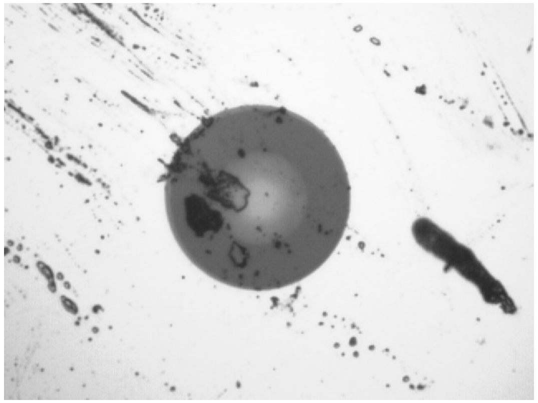
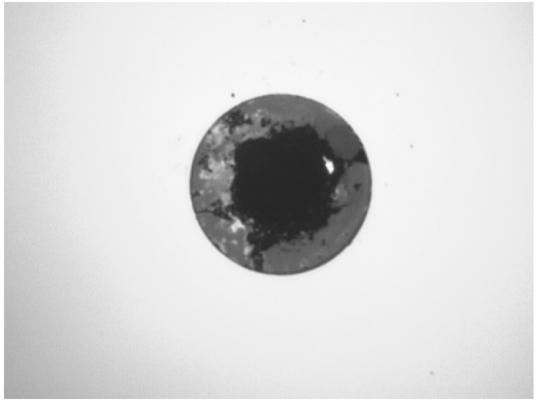
Part 2 – Avoiding Common Issues

- Common issue of most laser-powered field probes:
  - Contamination of fiber connector end-faces
    - → System failures, or in worst case,
    - → Burn-in defects.

- For illustration, the fiber end-faces of a clean, contaminated and defective fiber connector (left to right):



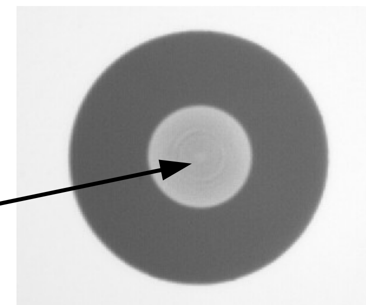




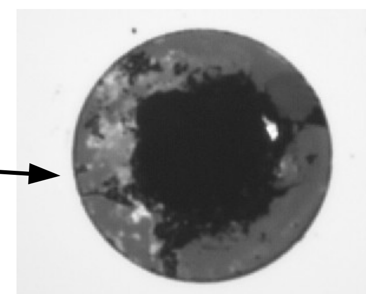
Burn-In Defects

- For comparison: Midday at equator, solar electromagnetic radiation per unit area is approx. **1 kW/m².**

- Rough approximation:
  Transmitting 1 W using a fiber-optic cable with diameter of 60 µm yields a power density of approx. **300 MW/m².**

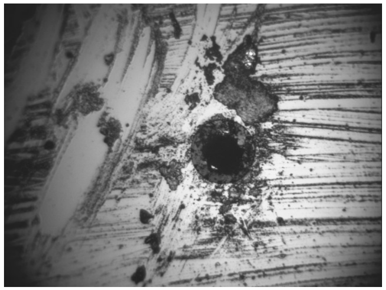
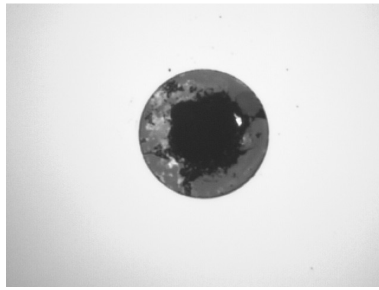
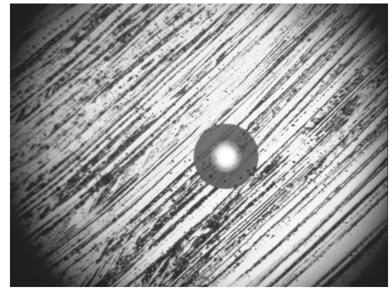
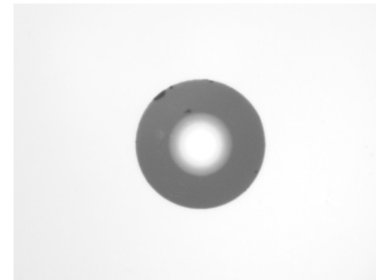


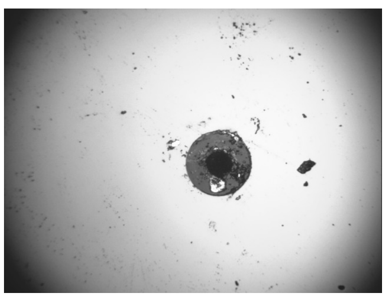
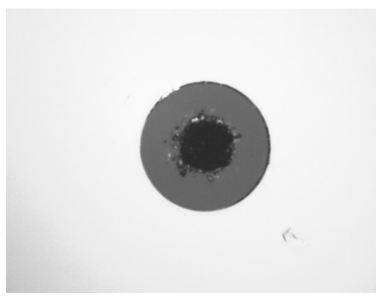
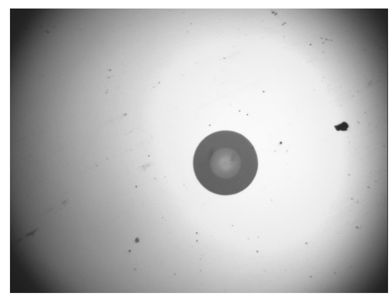
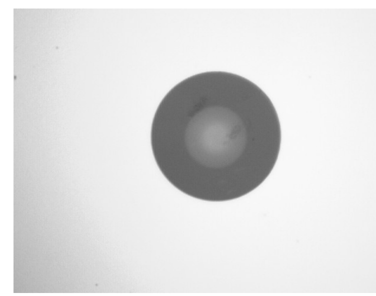
- If fiber connector is contaminated, the particles will absorb the energy.
  → This can lead to **burn-in defect**!



Example for Burn-In Defects

Fiber end-faces at joint between field probe and extension cable:

Field Probe			
Power fiber (FC) before/after cleaning		Data fiber (ST) before/after cleaning	
			

Extension Cable			
Power fiber (FC) before/after cleaning		Data fiber (ST) before/after cleaning	
			

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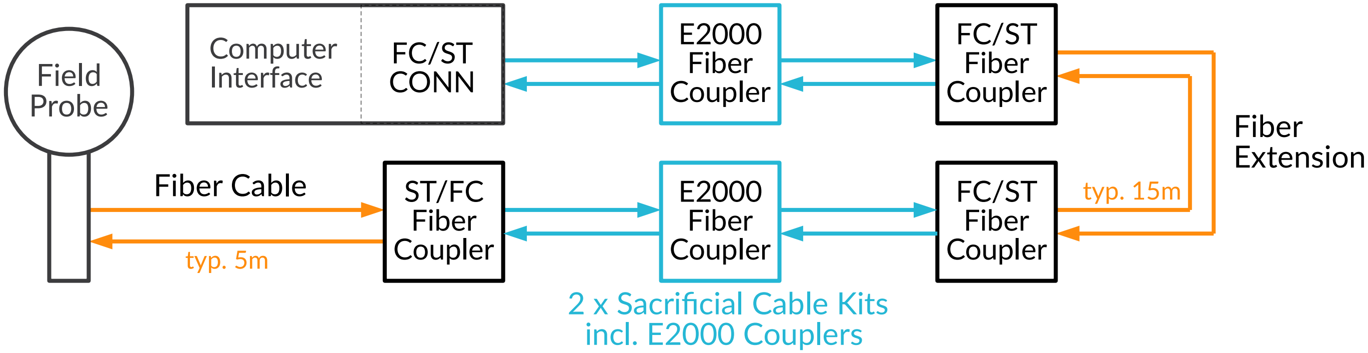
Sacrificial Cable Kits – Intension and Use

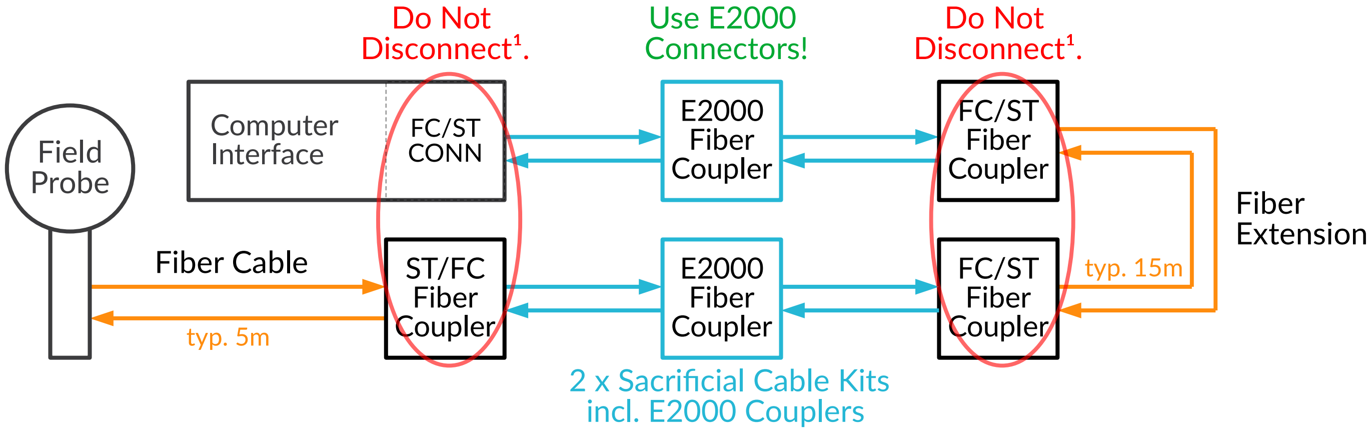
- Components:
  - A pair of short fiber cables with FC/ST connectors at one end and E2000 connectors at the other end.
  - E2000 adapter to connect the two sacrificial cables.

- Typical setup to connect:
  - the Computer Interface with the extension cable and
  - the extension cable with the Field Probe.



Sacrificial Cable Kits – Intention and Use

- Objectives of the implemented E2000 connectors:
  - Two defined and convenient points for disconnecting the Field Probe from and the Computer Interface.
  - Integrated shutters, which open and close automatically and therefore reduce the risk of contamination.
  - The connection should not be opened at the FC/ST connectors of the Computer Interface and Field Probe.



1) Except when replacing the sacrificial cables.

Handling Recommendations

- Use field probe as delivered, with the sacrificial cable kits!
- For disconnecting the field probe from the computer interface, only use the E2000 connectors of the sacrificial cable kits.
- The connection must not be opened directly at the FC/ST fiber connectors of the computer interface or the field probe.
- However, if disconnected directly at the FC/ST connectors, cover the connectors with the supplied dust caps.
- Before reconnecting any of the connectors, carefully clean the connectors and double-check them using a fiber microscope.
- In the case of a burn-in defect at one of the E2000 connectors, replace the complete sacrificial cable kit (both cables).

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Cleaning of Fiber Connectors

- Recommended sequence:
  - Inspect the connector / ferrule end-faces for contamination using a fiber microscope.
  - Clean the connector end-faces.
  - Reinspect the end-faces (if necessary clean and inspect again).
  - Finally, connect the respective fiber connectors.
- Cleaning methods:
  - Dry cleaning for minor contaminations.
  - Wet-to-dry cleaning for major contaminations and dried residues, e.g., resulting from skin oils, skin flakes, dust particles.
  - Wet cleaning can leave alcohol residues if left to air dry, therefore, it should directly be followed by dry cleaning.

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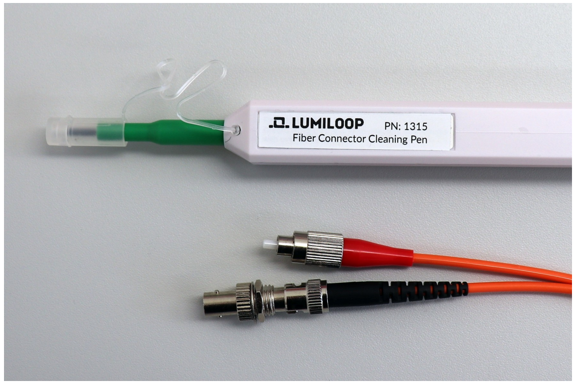
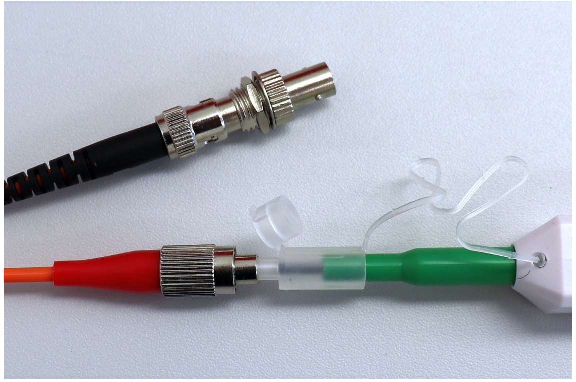
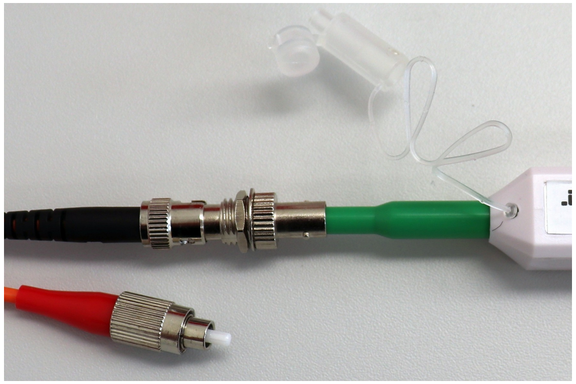
Cleaning of Fiber Connectors

- One-click cleaners (cleaning pens)
  - To clean the connector end-faces place the adapter on the tip of the cleaner, insert the fiber end-face (ferrule) into adapter and push both ends together until you hear a click.
  - To clean the fiber end in a bulkhead adapter, remove the adapter from the tip of the on-click cleaner, insert the tip into the bulkhead and press until you hear a click.



Cleaning of Fiber Connectors

- Cleaning kits:
  - Lint-free cleaning wipes
  - Cleaning solution (isopropanol)

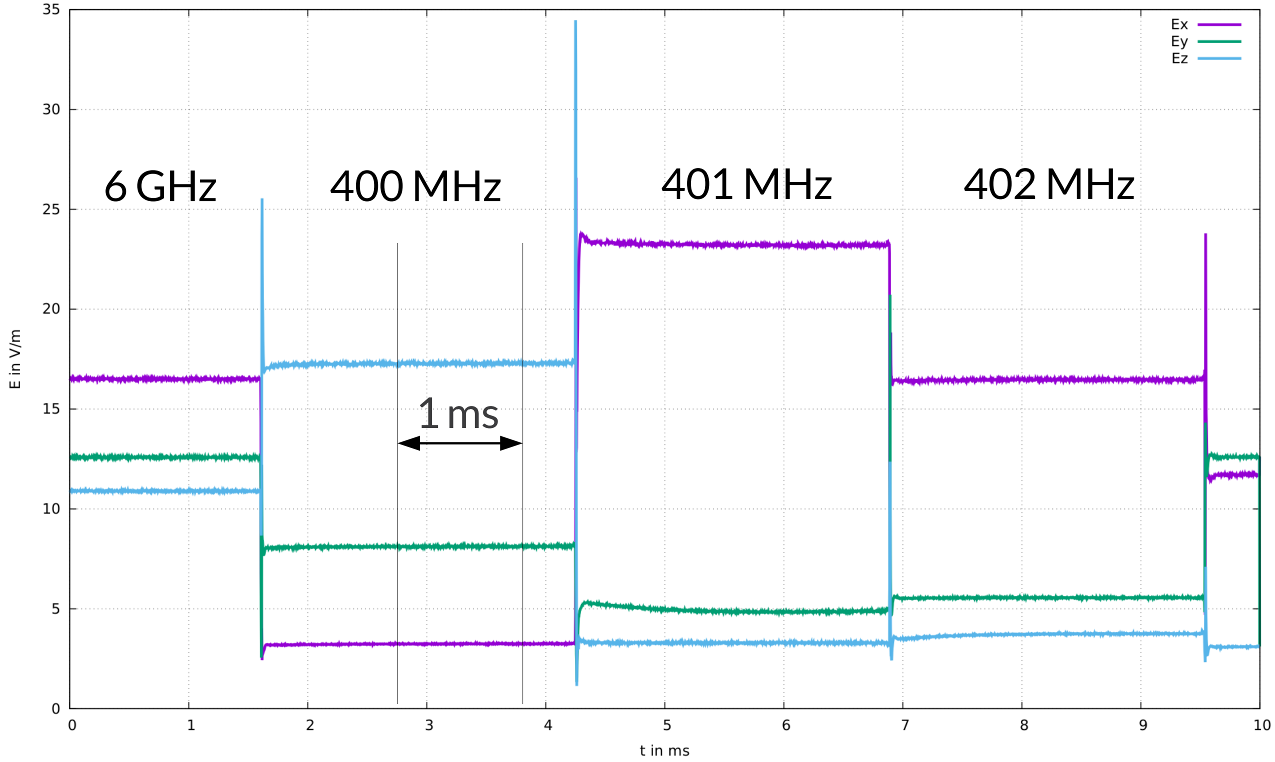
- Wet-to-dry cleaning:
  - To clean the fiber end-faces moisten a corner of the cleaning wipe with the cleaning solution,
  - hold the end-face perpendicular to the wipe and
  - glide with the connector end-face over the wipe, firstly over the moistened area and secondly over a dry area of the wipe.
- Fiber microscopes:
  - Camera-based (USB) variants
  - Optic variants

Part 3 – Enhanced EMC Testing Examples

- Fast sweep measurements
  - IEC 61000-4-3 Immunity to radiated radio-frequency fields
- Radar pulse measurements
  - Ford Component EMC Specifications FMC1278
- Use of multi-probe systems
  - ISO 11451-2 Road vehicles – Vehicle test methods, Part 2 - Off-vehicle radiation sources
    - → Vertical reference line with 4 field probe positions
  - IEC 61000-4-21 Reverberation chamber test methods
    - → 8 field probe positions at corner points of testing volume

Fast Frequency Sweep Example

- Measurement in a RC with 2.5 ms per frequency
- Field-strength components over time, sampling rate 500 kS/s
- Averaging over 1 ms / 500 samples



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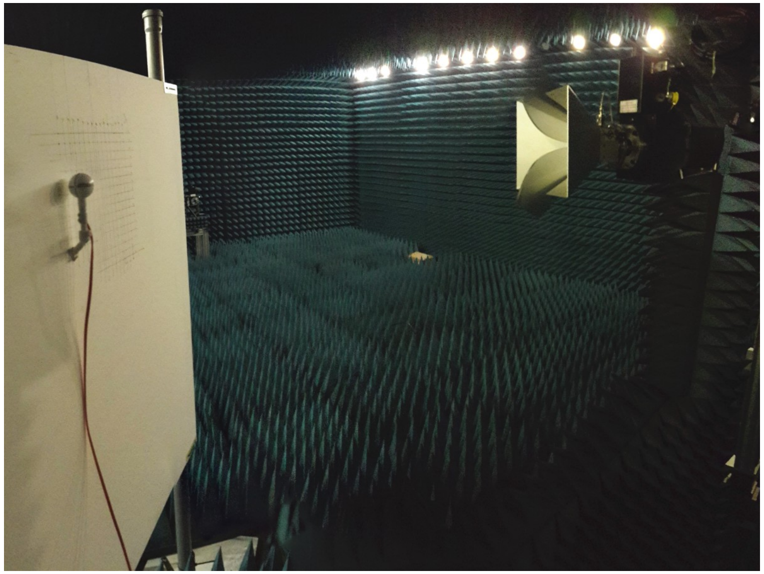
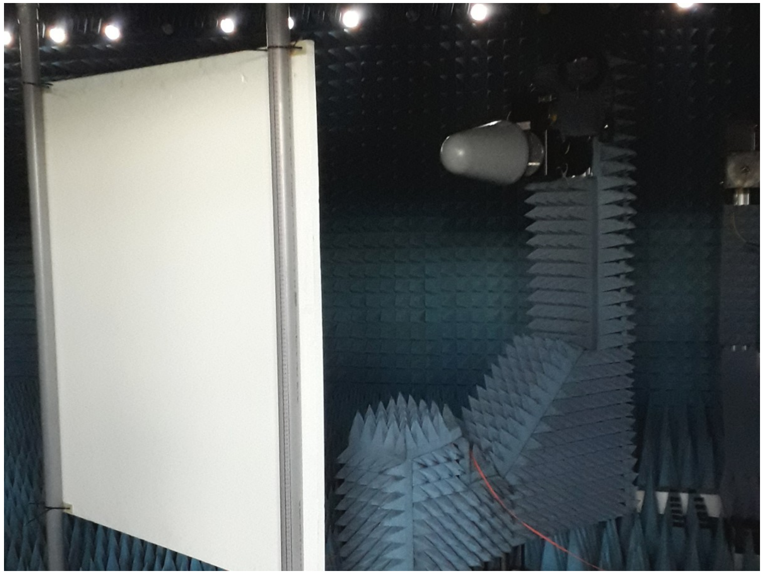
Application for Antenna Evaluations

- Evaluation of antenna's field distribution with fast sampling field probe, e.g., 500 kS/s in combination with fast signal generator
  - ➔ Frequency sweep with 3 ms per frequency
- Example: Comparison of different horn and log.-per. Antennas in the frequency range 800 MHz to 6 GHz





Application for Antenna Evaluations

- Grid with 256 points, grid size (30 x 30) cm with 2 cm increment
- Frequency range (0.8 – 6) GHz, increment 2 MHz, 2601 freq.
  - ➔ approx. 10 s per frequency sweep
- Manual positioning of the probe (open / close chamber door)
  - ➔ approx. 4 h per antenna (polarization)
- Automated positioning system in development
  - ➔ assuming 2 s per positioning step → less than 1 h!
  - ➔ grids with higher resolutions

→ Respective field probes allow to perform fast frequency sweeps, now the positioning of the probe is the bottleneck!

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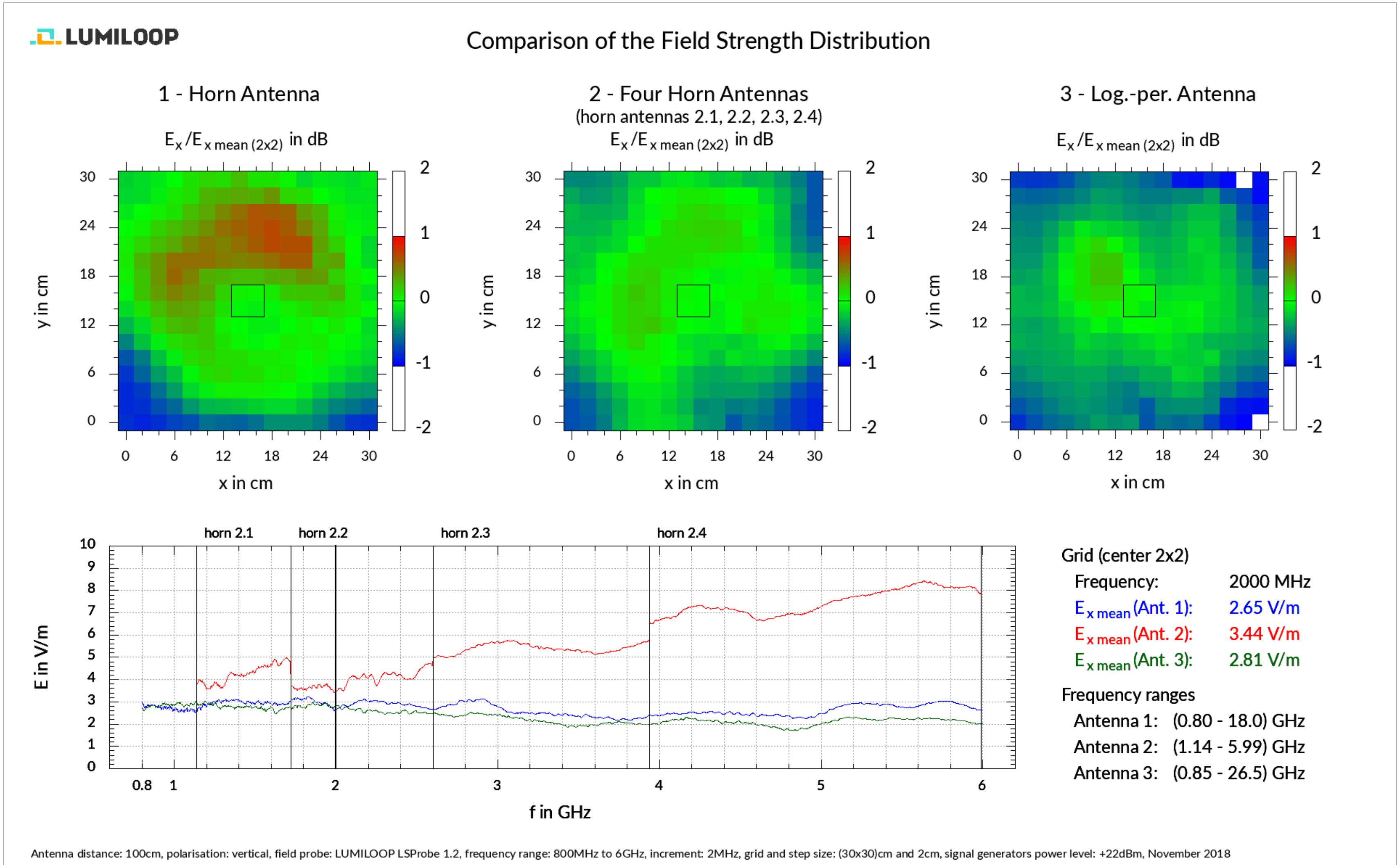
Application for Antenna Evaluations



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Application for Chamber Validation

- Chamber Validation (field homogeneity /uniformity)
- Calibration of the field according to IEC 61000-4-3:
  - Leveling to the target field strength
  - Validation to ensure uniformity, concept of uniform field area (UFA), vertical plane in which the field variations are acceptable small
  - Typical UFA size (1.5 x 1.5) m, spacing 0.5 m, 16 points
  - Uniformity criteria within (-0 - +6) dB of nominal field strength (for not less than 75 % of all points)
- Customer feedback:
  - Calibration 1 to 3 days depending on setup, frequency range, etc.
  - Motivation to use fast sampling field probes
  - Positioning system for field probe requested (further time savings)

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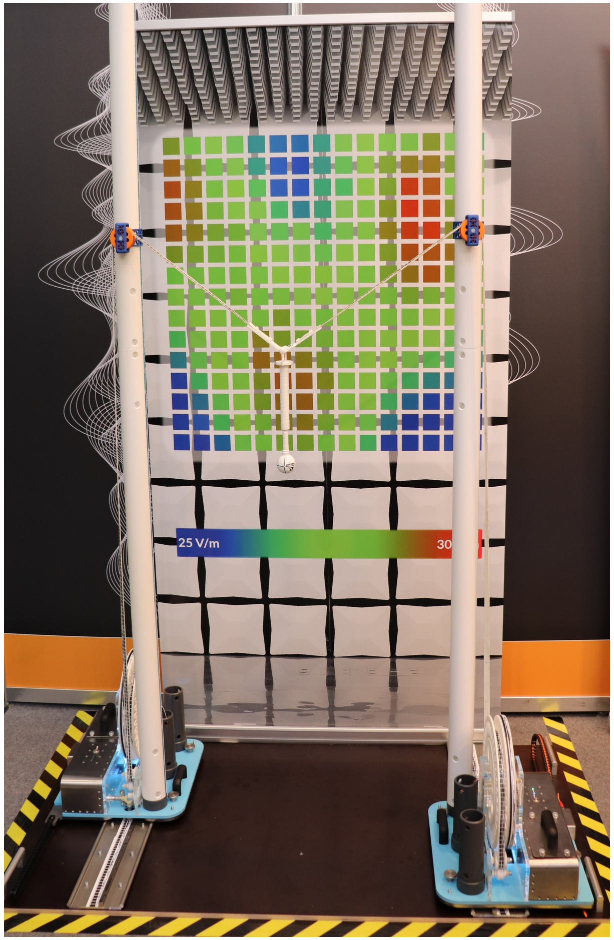
Application for Chamber Validation

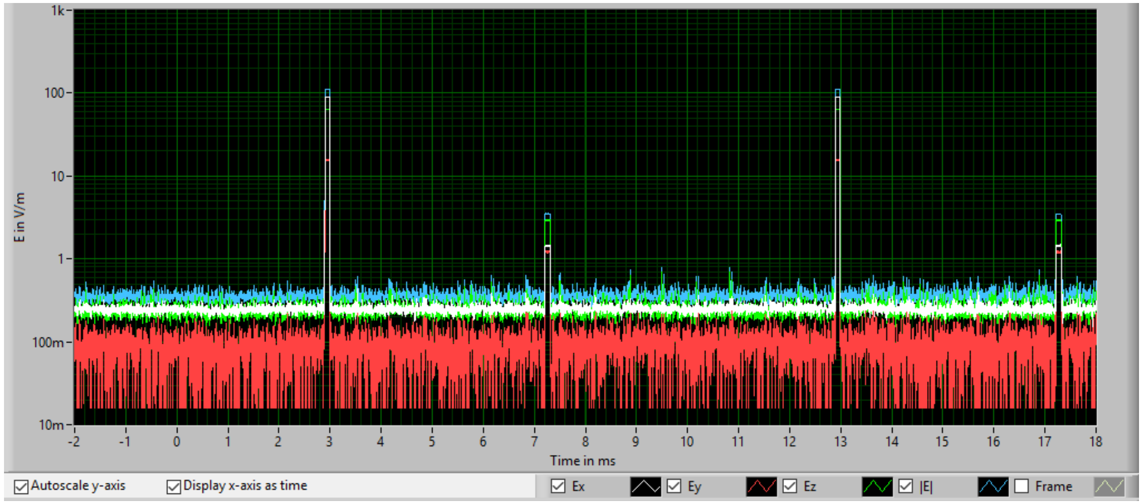
- Field Probe + Positioning System:
  - Use of laser-powered probe
  - Three dimensional testing volume
  - High positioning accuracy
  - No zeroing upon start-up
- Development project:
  - Suspended field probe
  - Straps with integrated fiber cables
  - Gray code for absolute detection of probe position.



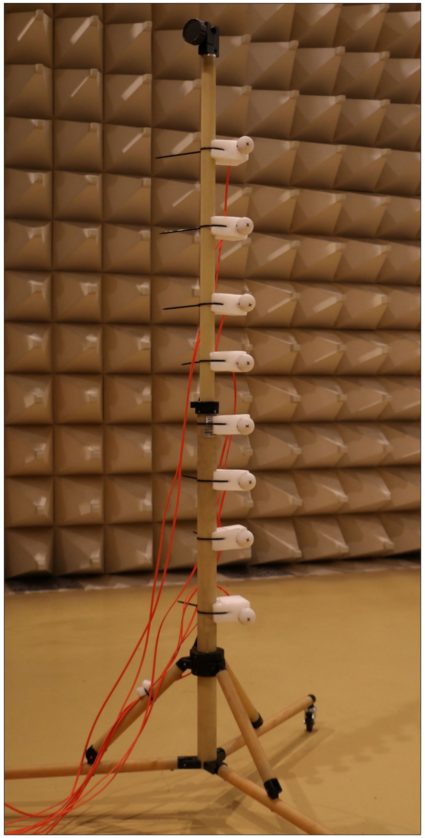
Prototype system, March 2019

Radar Pulse Measurements

- Example: Ford EMC Specification FMC1278 – RI 114 Immunity to RF electromagnetic fields - band 7 & 8:
  - Frequency ranges (1.2 – 1.4) GHz and (2.7 – 3.1) GHz
  - Test level 300 V/m (600 V/m, e.g., for supplemental restraints systems)
  - PM with pulse duration 3us and pulse repetition rate 300 Hz
- Respective requirements for electric-field probes:
  - Usable field strength range up to 600 V/m
  - High sampling rate, e.g., 500 kS/s



Multi-Probe Systems - Examples



Reference Line
with 8 field probes

Reverberation Chamber (RC)
with 8 plus 1 field probes

Vibrating Intrinsic Reverberation
Chamber (VIRC) with 8 probes

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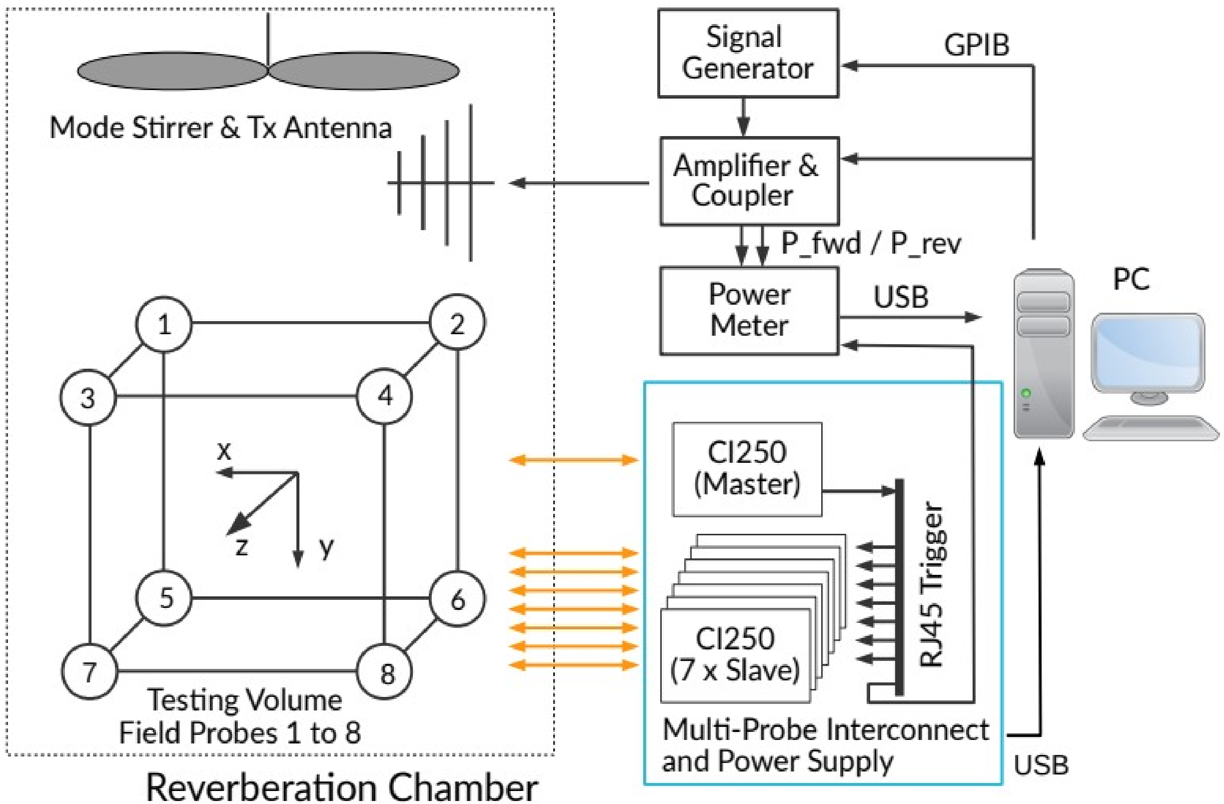
Application for Reverberation Chambers

- Testing volume with 8 field probes at respective corner points
- Synchronized reading of the 24 (8 x 3) field strength components
- IEC 61000-4-21:

→ Validation of the field homogeneity (standard deviations of the field strength components)

→ LSProbe 1.2: Measurement and evaluation feasible in real-time



Application for Reverberation Chambers

- Field probes with high sampling rate for measurements in reverberation chambers (IEC 61000-4-21).
- Customer example for validation of the field homogeneity:
  1 field probe, 400 frequencies (1 s per freq.), 120 stirrer positions (3 s per pos.) and 8 probe positions (60 s per pos.)
  - → more than 100 h per validation!
  - → multi-probe system with 8 probes still more than 12 h
- Fast sampling field probe, e.g., 500 kS/s, in combination with fast power meter and fast signal generator:
  - → 10 ms per frequency, (400 x 0.01 s + 3 s) x 120 = 840 s
  - → approx. 15 min per validation!

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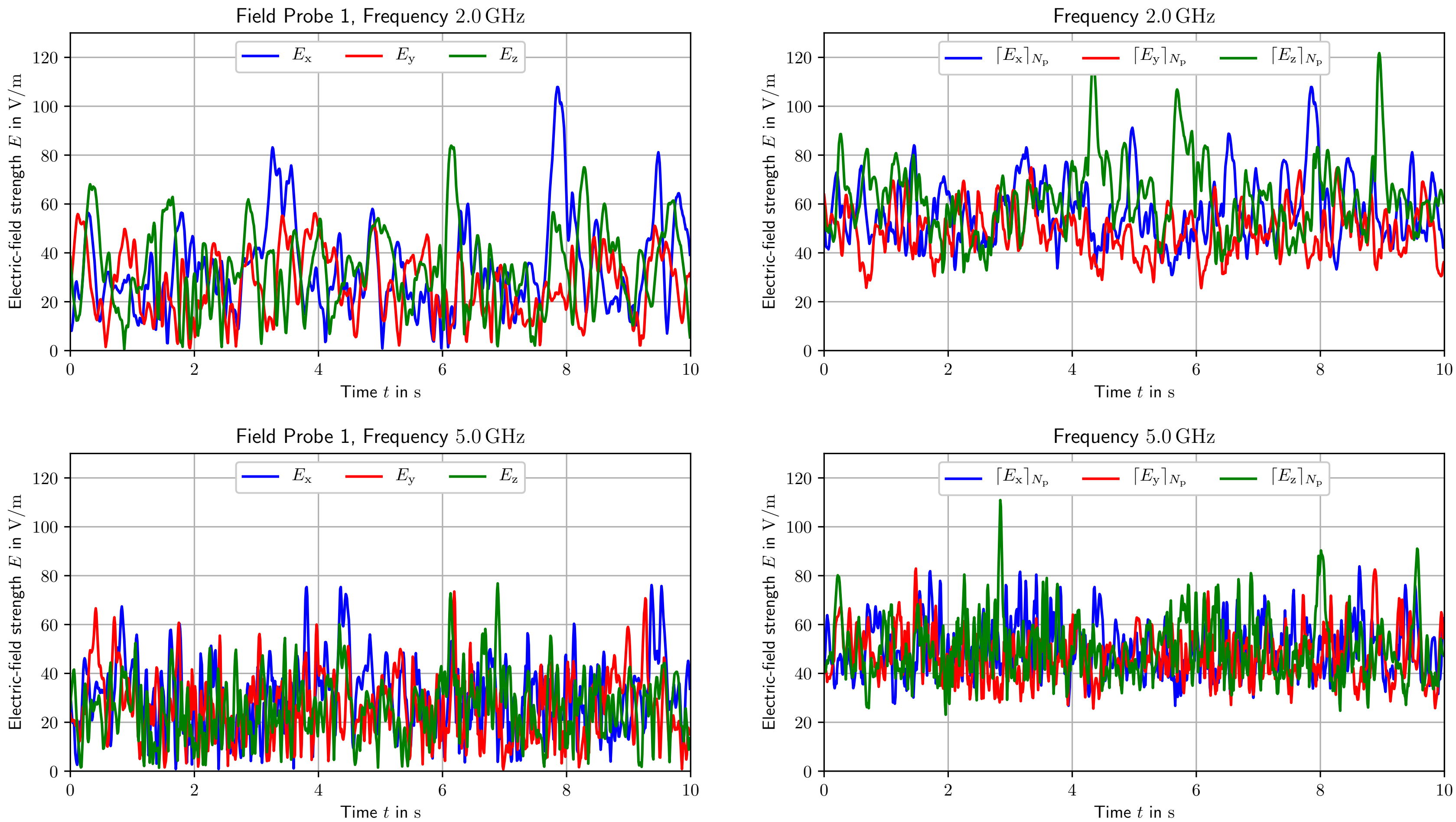
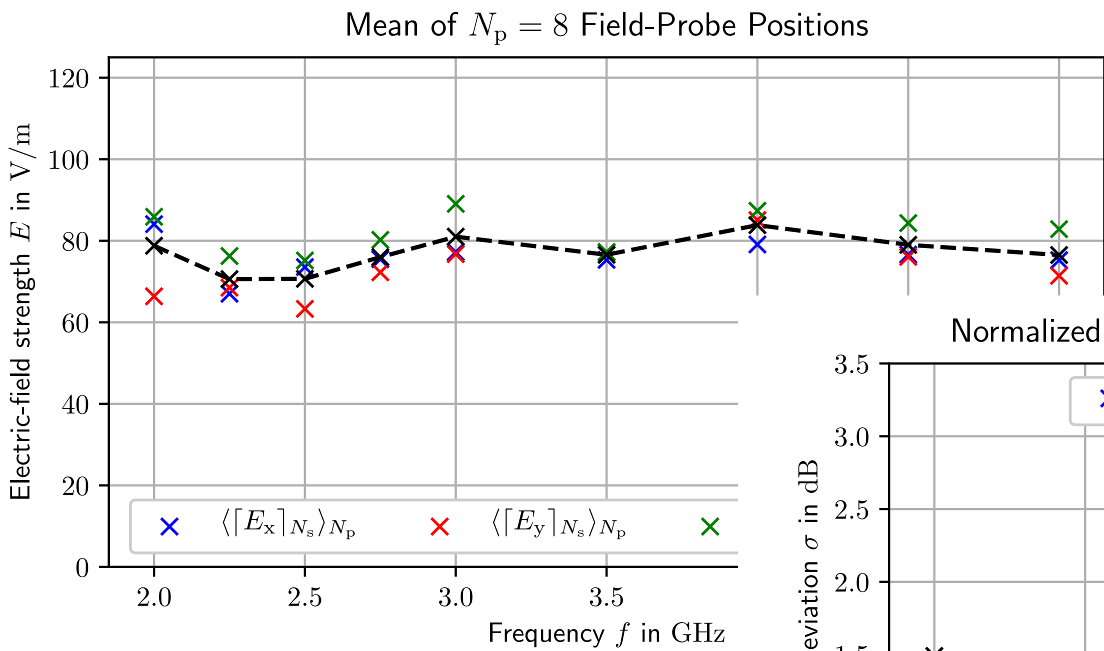
Application for Reverberation Chambers

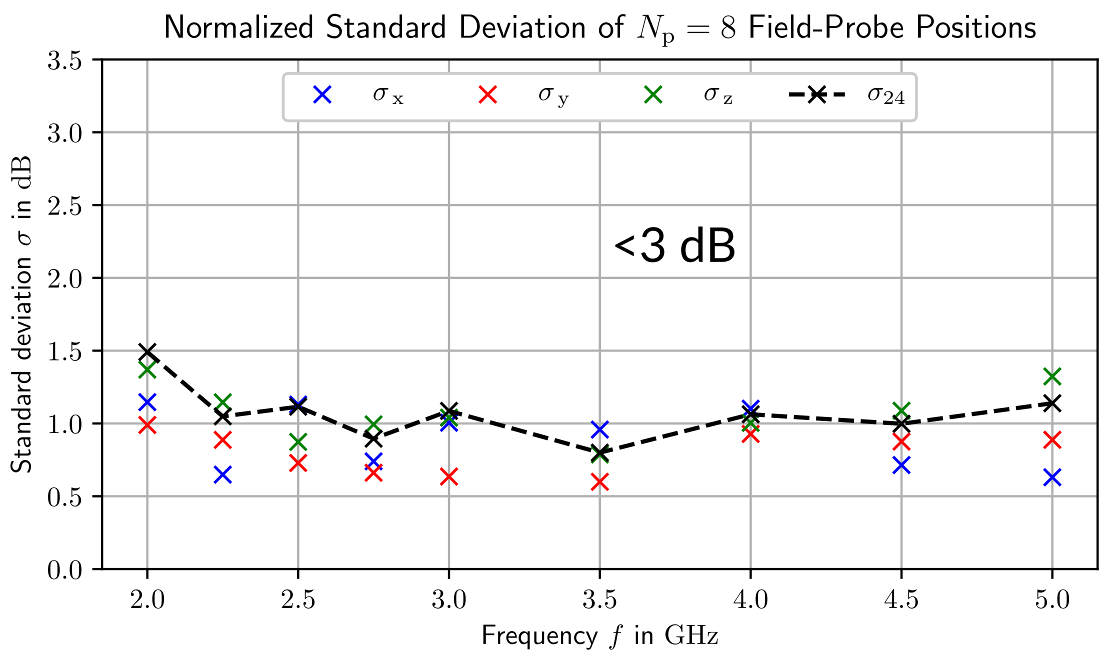
- Field strength over time (single probe, maximum of 8 probes)



Application for Reverberation Chambers

- Example for the validation of the field homogeneity

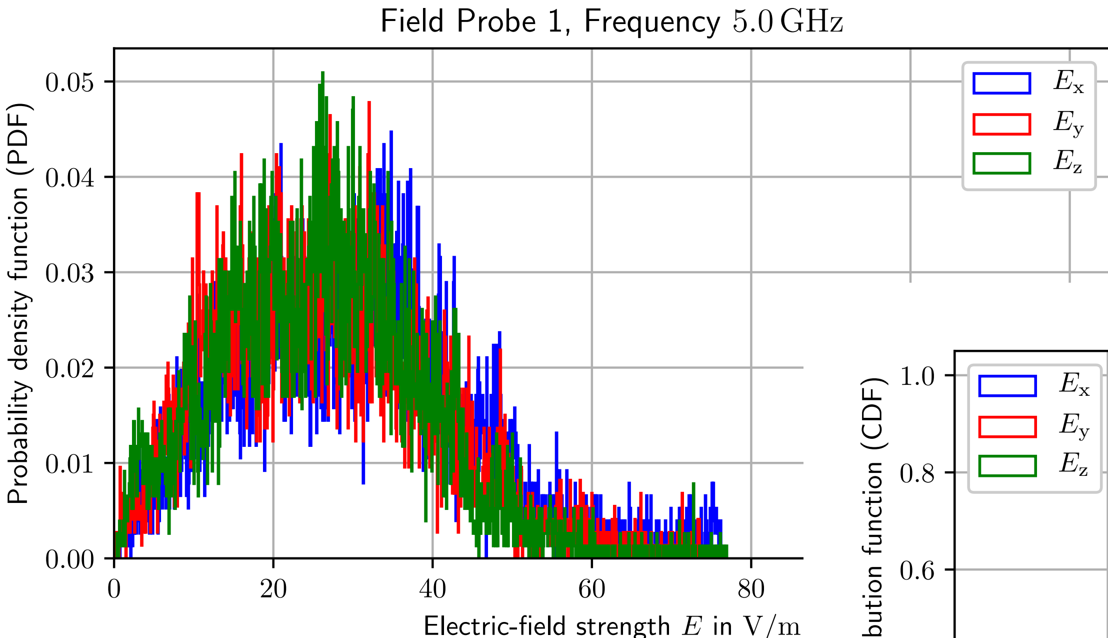


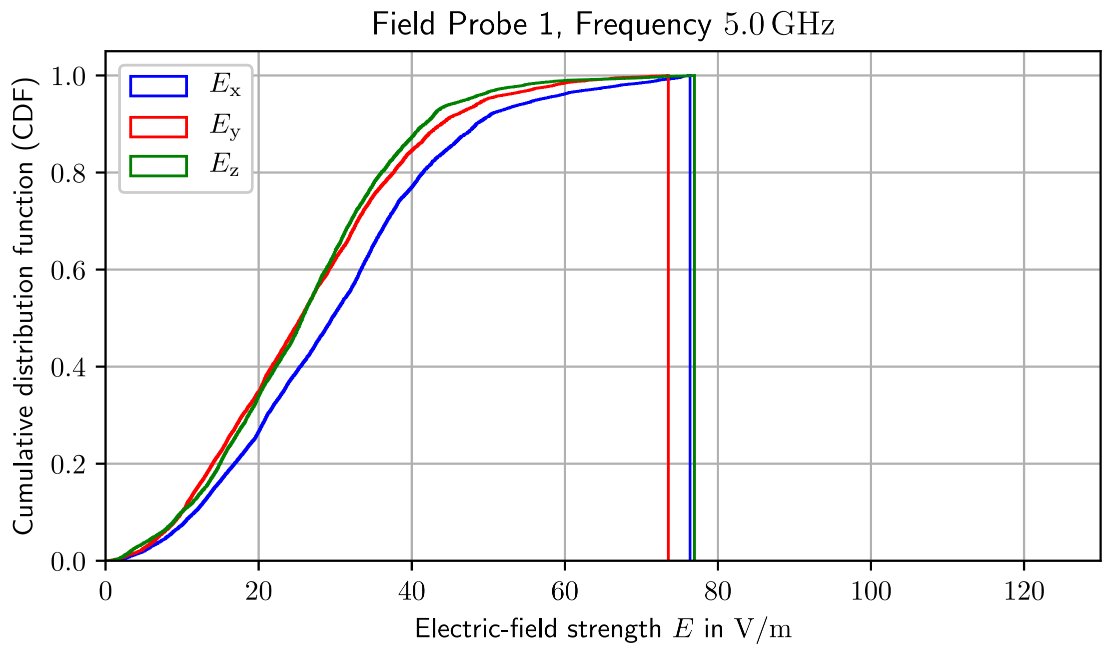


- Comparison of the calculated standard deviations with the limit given in IEC 61000-4-21
- Evaluation feasible in real-time

Application for Reverberation Chambers

- LSProbe 1.2 provides built-in statistical functions





Accompanying Measuring Instruments

- Application of fast sampling field probes
- Need for accompanying measuring instruments
  - Fast signal generators
  - Fast power meters, e.g., LSPM 1.0 with sample rate 2 MS/s

LSPM 1.0 + LSProbe 1.2:

→ Field calibration / validation
- IEC 61000-4-3
- IEC 61000-4-21

→ Significant time-savings

→ Synchronized readings

→ Real-time evaluation

Thank You.

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