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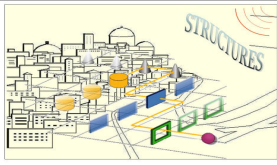
Dawson, J.F. orcid.org/0000-0003-4537-9977, Dawson, Linda, Flintoft, I.D. orcid.org/0000-0003-3153-8447 et al. (1 more author) (2015) *IEMI Detection Systems:A Low Cost IEMI Detector*. In: *Electromagnetic Compatibility (EMC Europe), 2015 International Symposium on:WS26 Workshop on IEMI Effects on Critical Infrastructures: The European Project STRUCTURES*.

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Strategies for the Improvement of Critical Infrastructure Resilience to Electromagnetic attacks

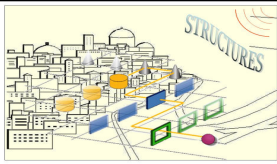
European Commission Grant Agreement FP7-SEC-2011-285257



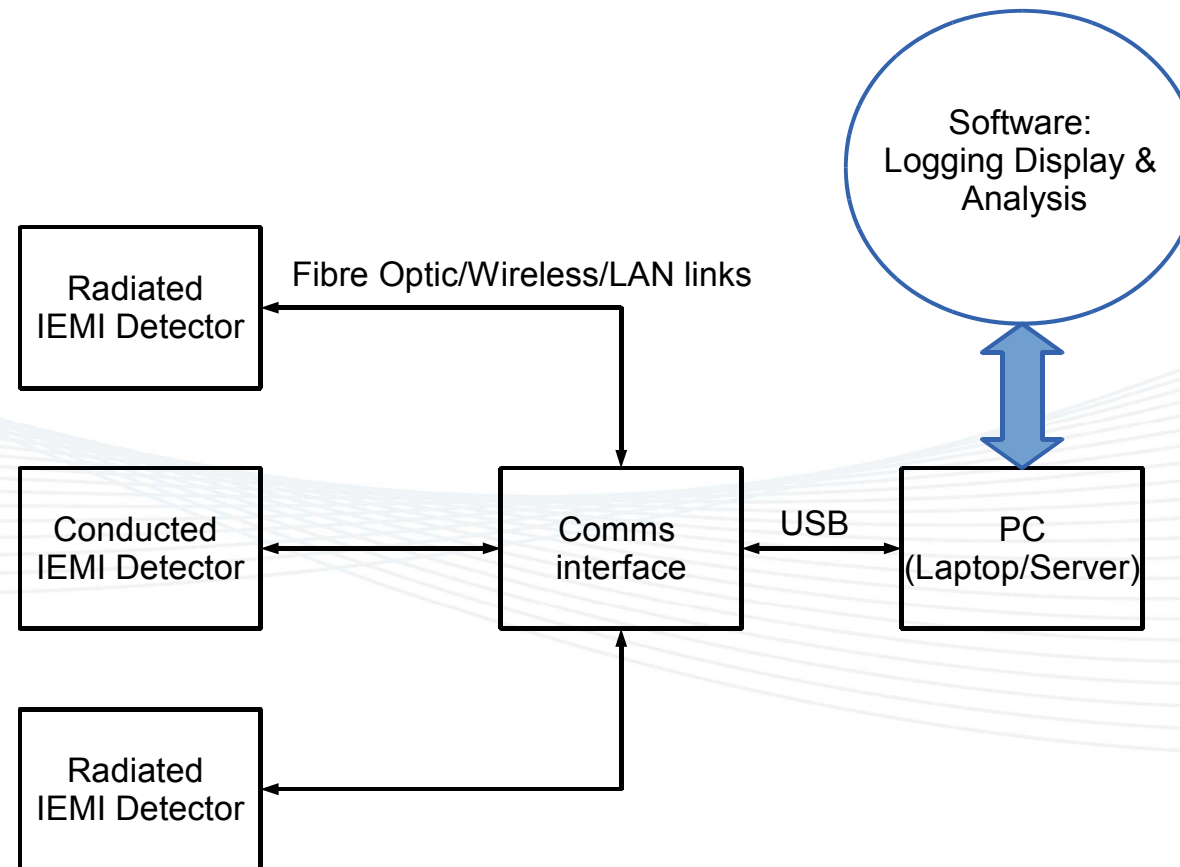
IEMI Detection Systems: A low cost IEMI detector

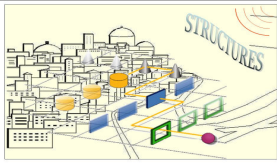
J F Dawson, L Dawson, I D Flintoft, L Rebers,
Michael Camp, Juergen Schmitz, Markus Jung

EMC Europe 2015, Dresden
Workshop 26, Paper 6a



System Concept



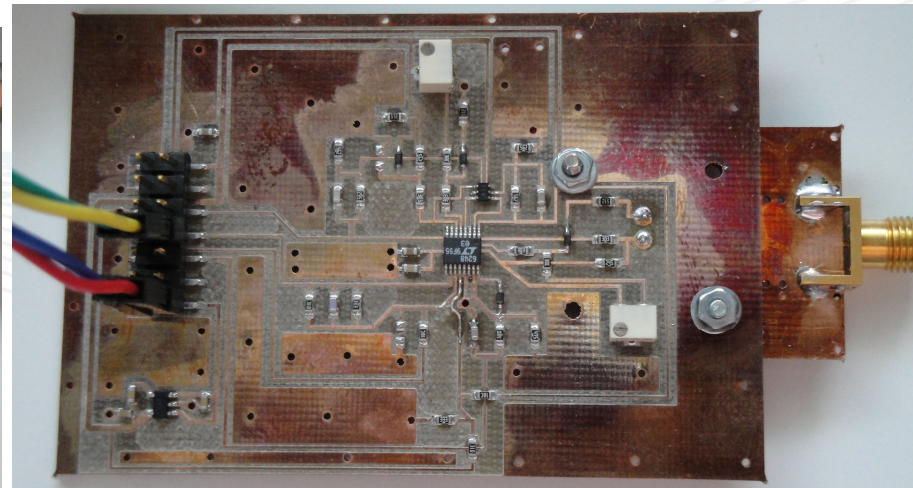
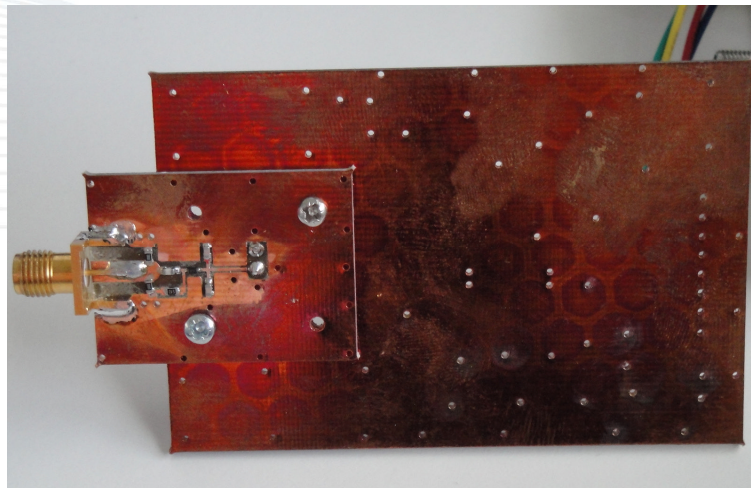
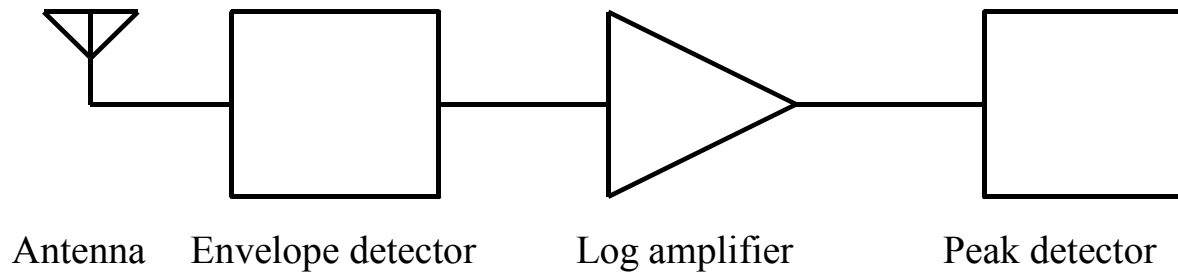


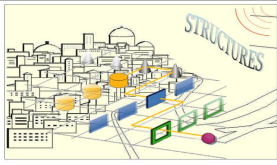
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Radiated IEMI Sensor



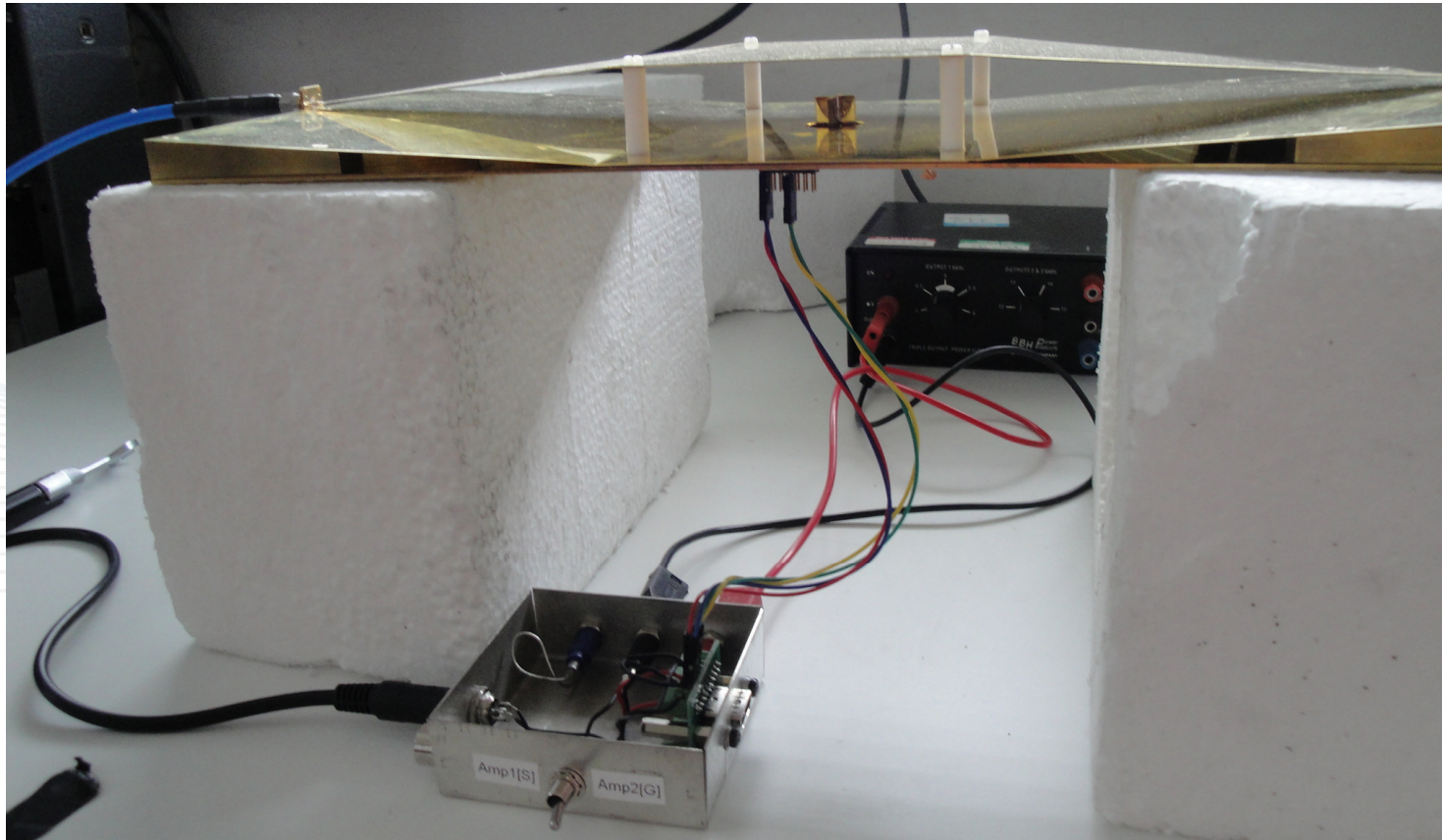


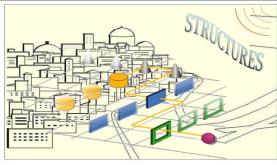
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Sensor in 25mm Stripline





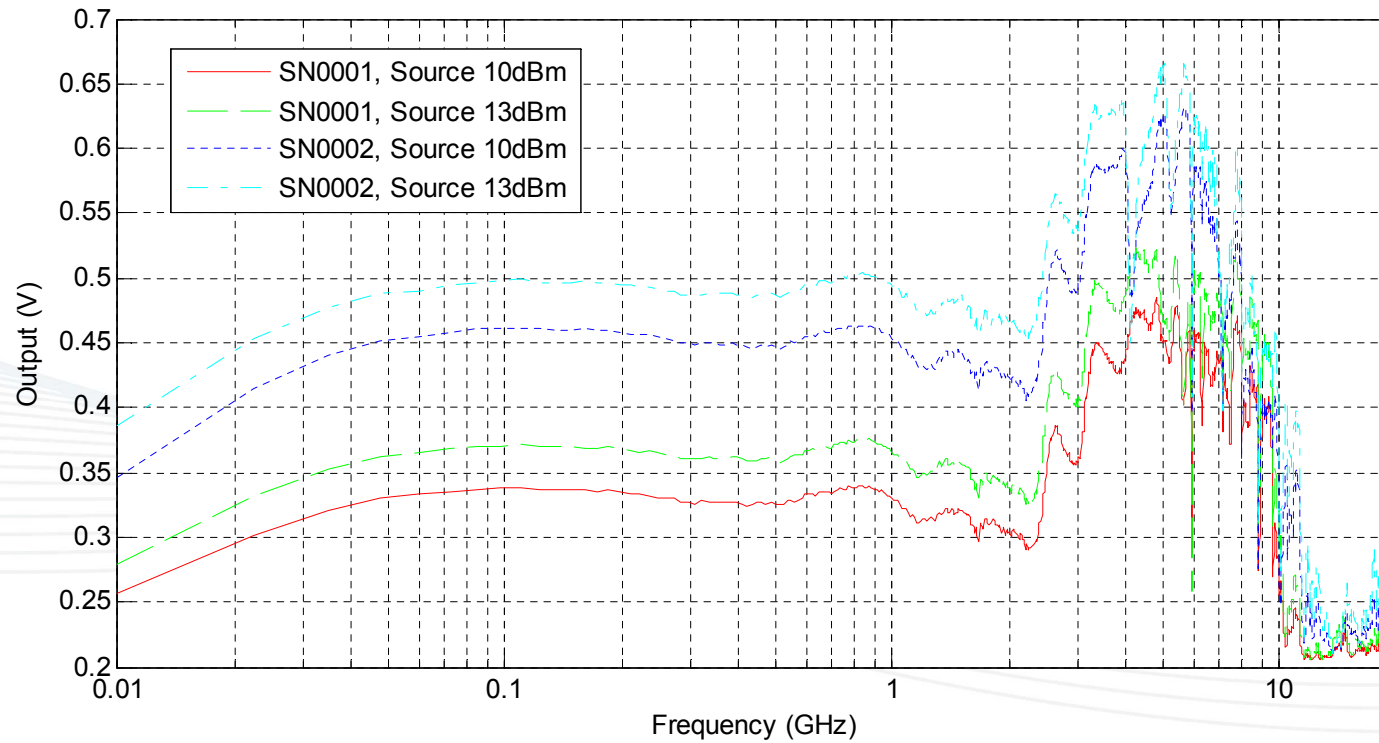
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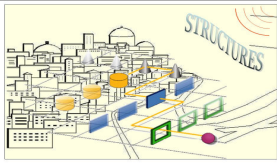
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Sensor Frequency Response

Detector and log amp dc output for detector in stripline





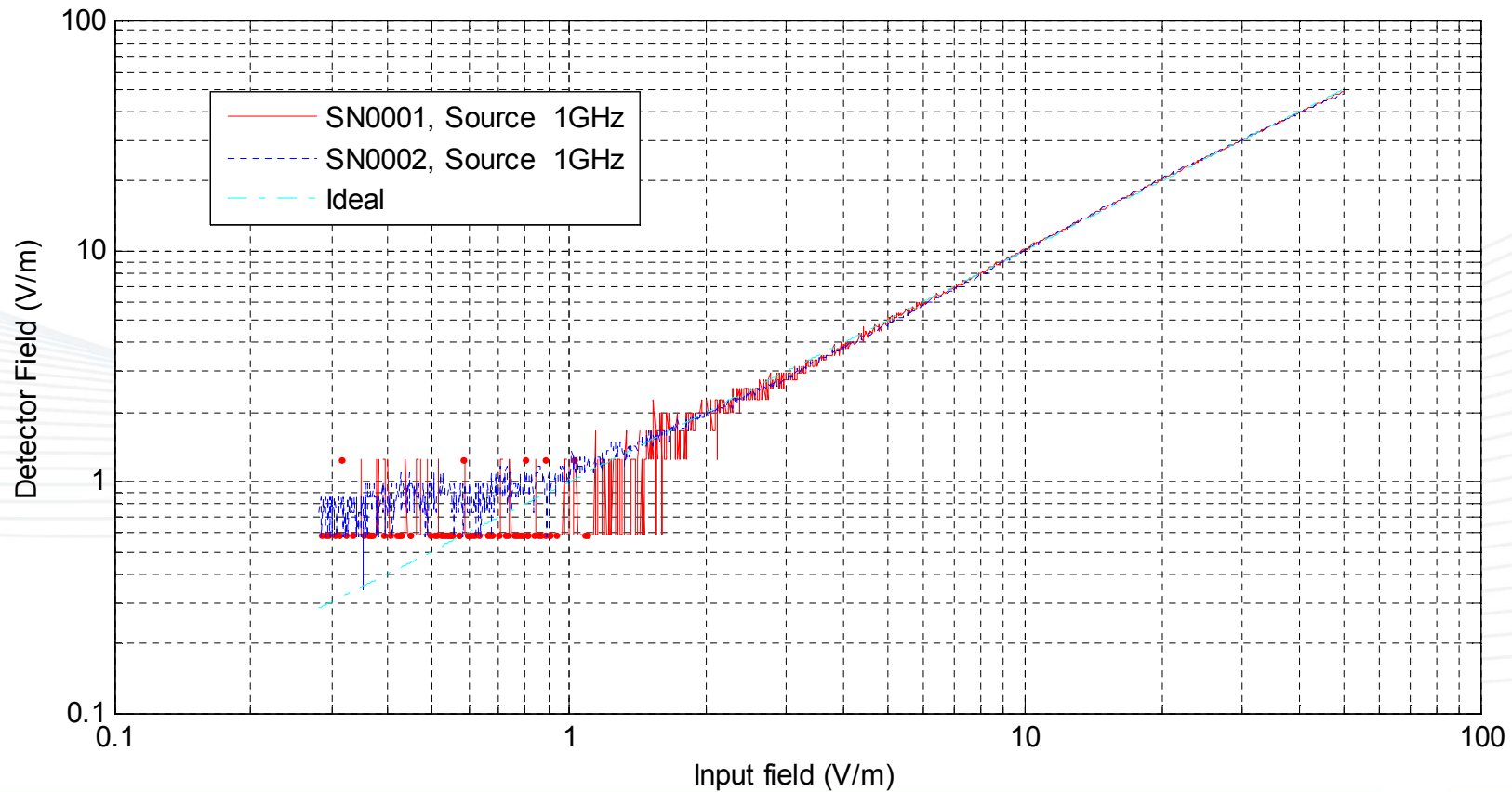
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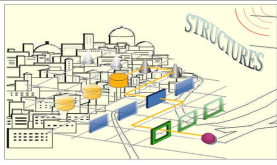
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Sensor CW Dynamic range

Detector and log amp field in stripline fitted cal and computed AF



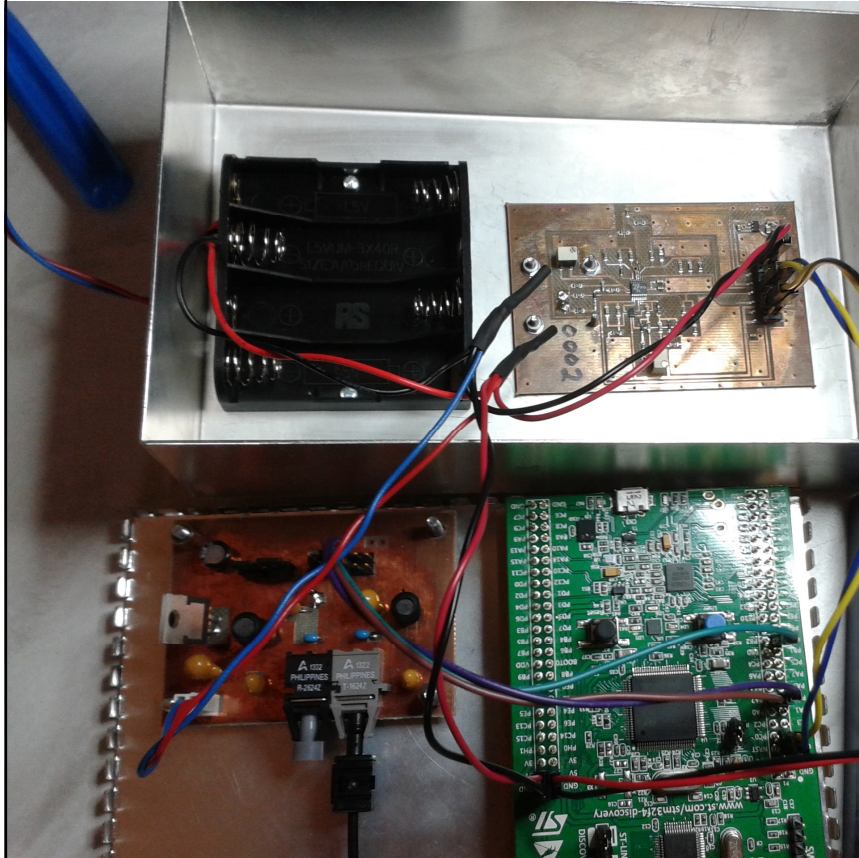


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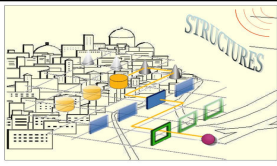
Detector Assembly



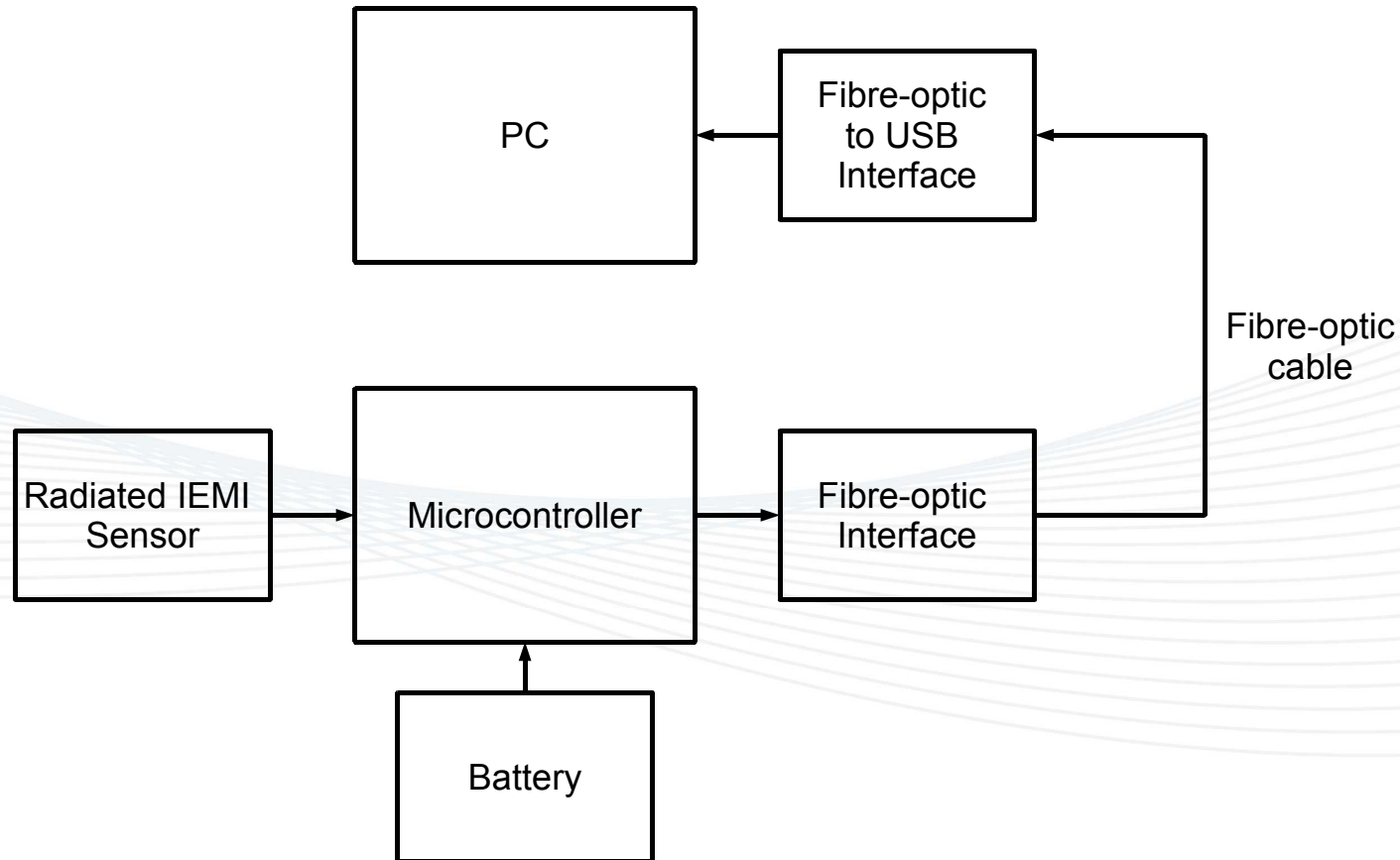
Prototype detector, microcontroller, optical link, and batteries in shielded enclosure

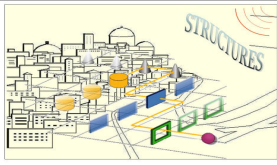
Antenna close up





High Field Tests at RMW



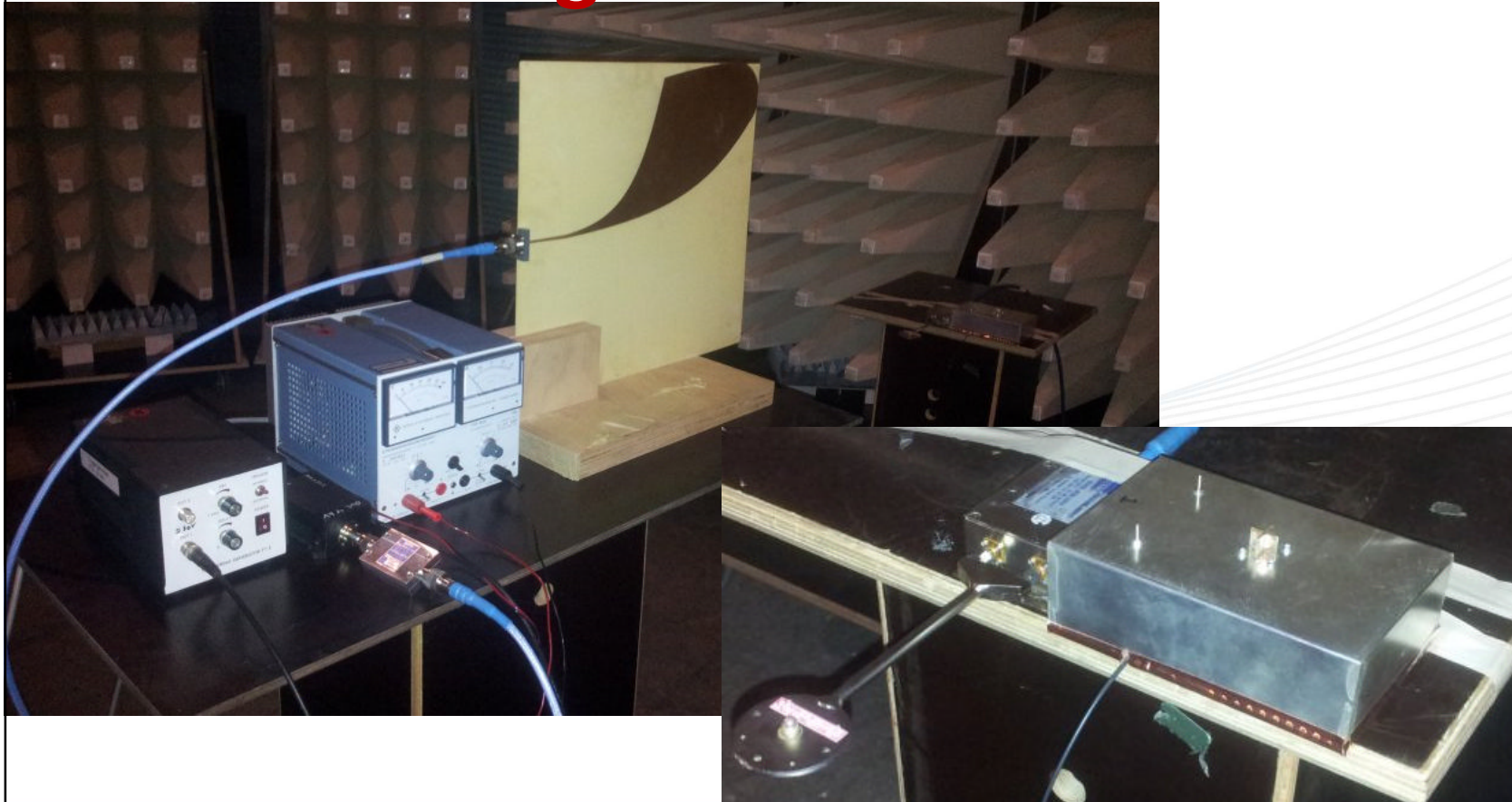


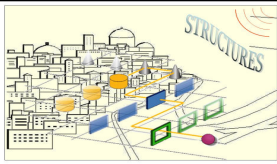
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High Field Tests



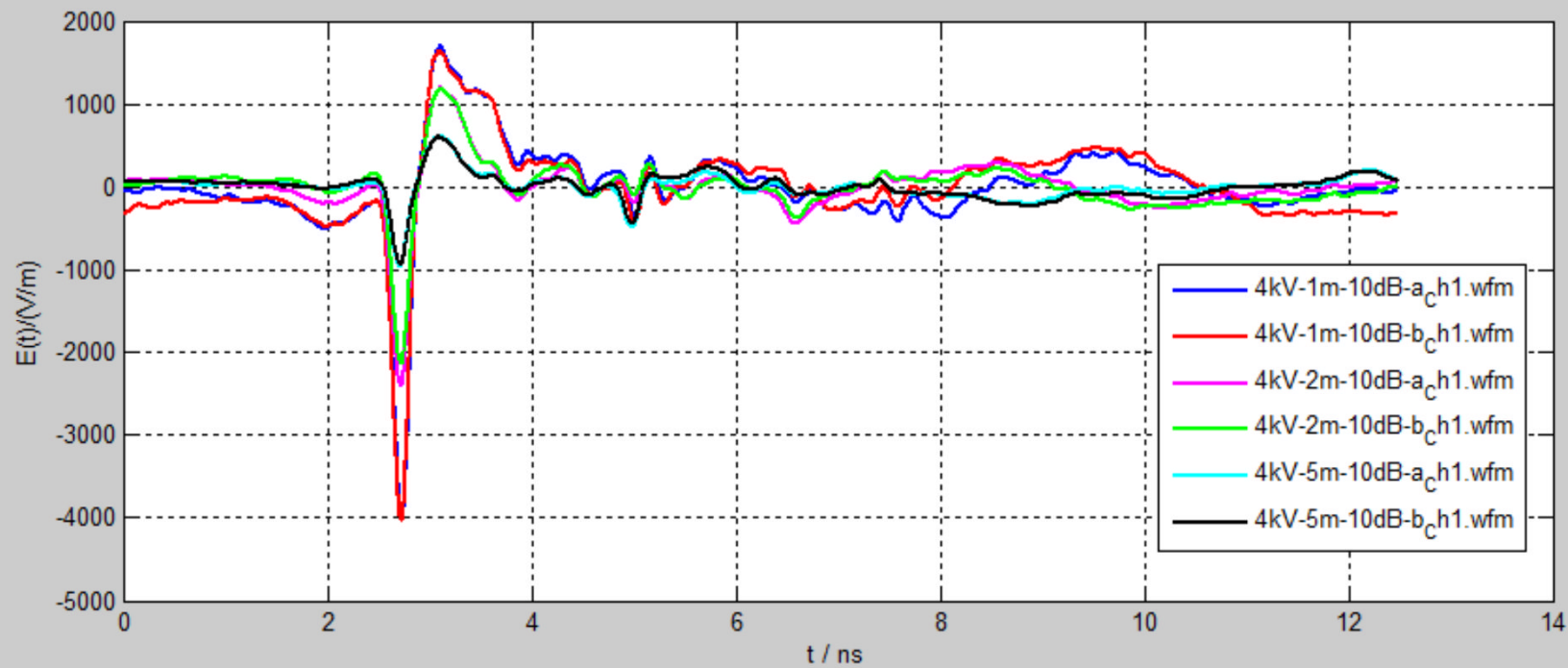


Strategies for the Improvement of Critical Infrastructure Resilience to Electromagnetic attacks

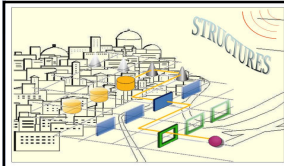
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Integrated D-dot probe output



Tests at Rheinmetall from double exponential pulse generator



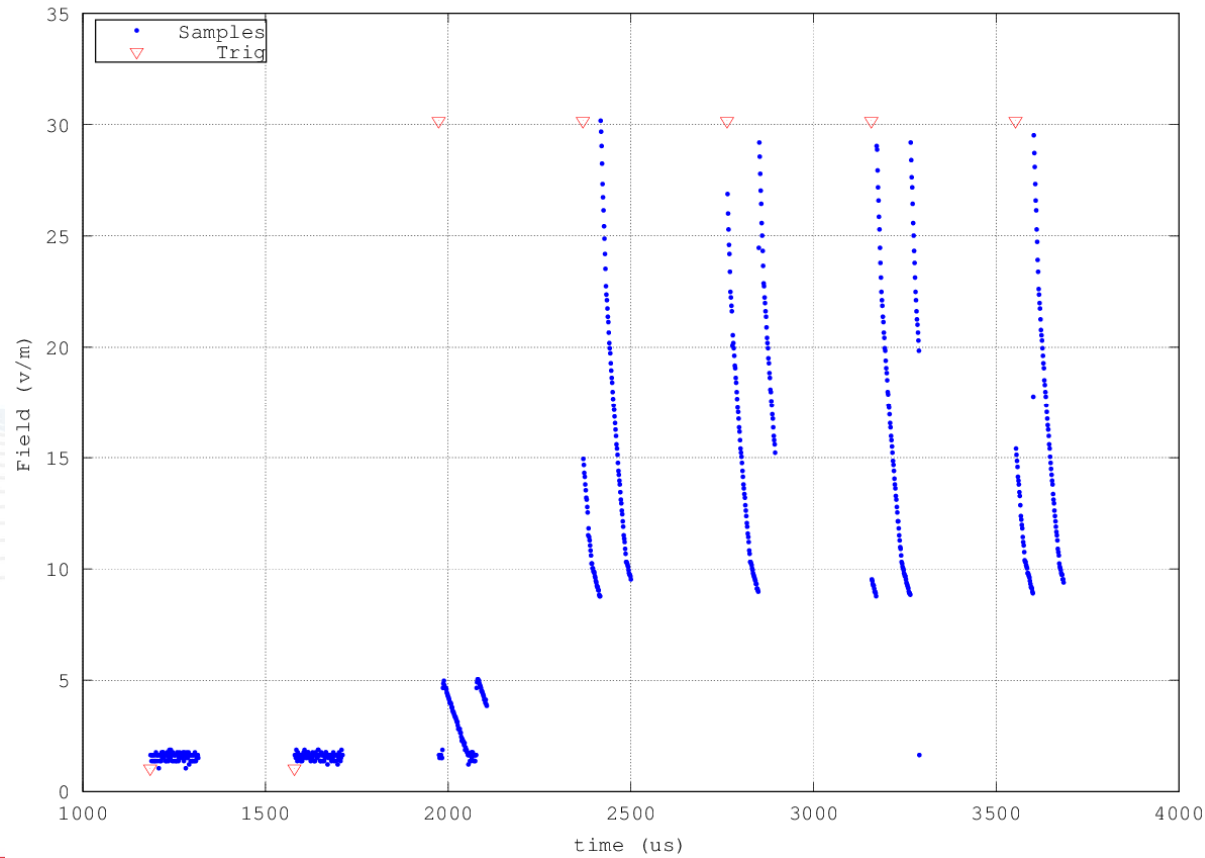
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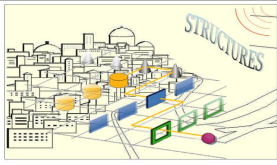
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4kV/m 250ps double Exponential

SN2 4kV 2exp 1m pkdet.log





Low cost detector Status

- Useable Radiated detector up to 6~GHz
- Frequency response flat to 2GHz
 - Sensitive 2V/m to > 4kV/m
- Partial response to short pulses
 - Sensitive 200V/m to > 4kV/m for 250ps pulse
- Potential for low power operation
 - could be solar powered
- A conducted IEMI detector has also been designed using the same hardware



Strategies for the Improvement of Critical Infrastructure Resilience to Electromagnetic attacks

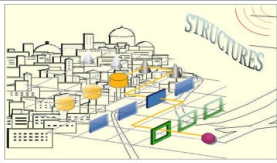
European Commission Grant Agreement FP7-SEC-2011-285257



IEMI Detection Systems: **A system for sensing, localization and** **identification of IEMI attacks**

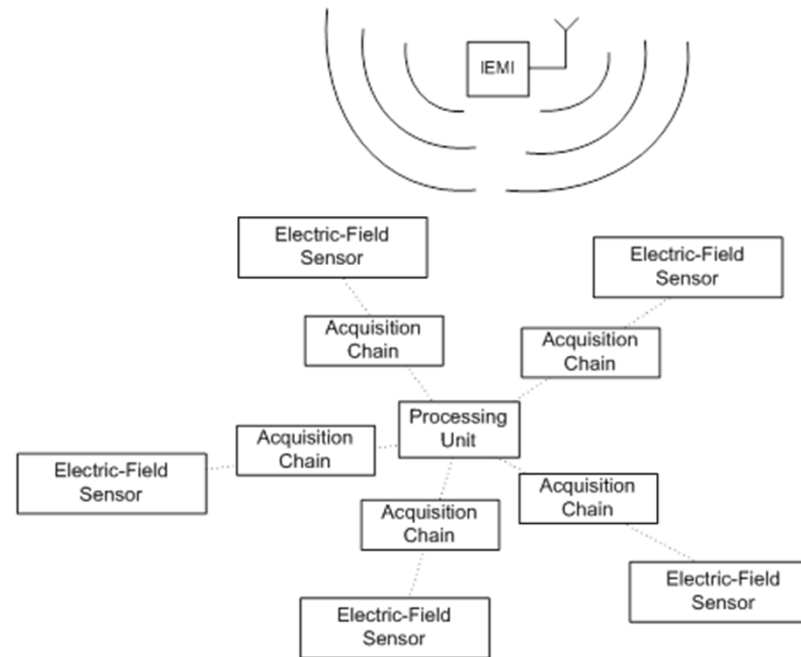
Werner Hirschi, Mirjana Stojilović, Marcos
Rubenstein, Benjamin Menssen, Heyno Garbe

EMC Europe 2015, Dresden
Workshop 26, Paper 6b



Overall Architecture

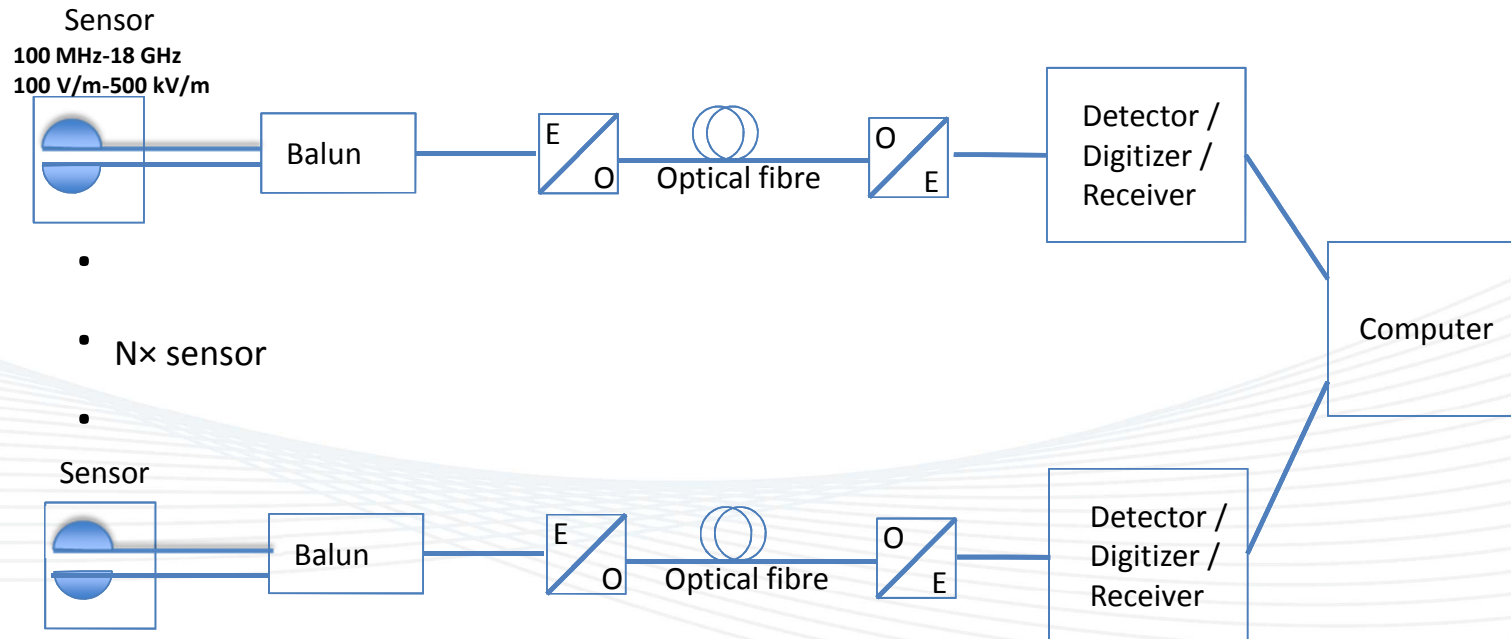
- Localization by the time difference of arrival method
- Identification of IEMI sources by analysis of the received waveforms

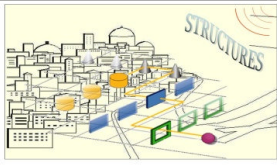


Overall architecture for identification and localization system for IEMI sources



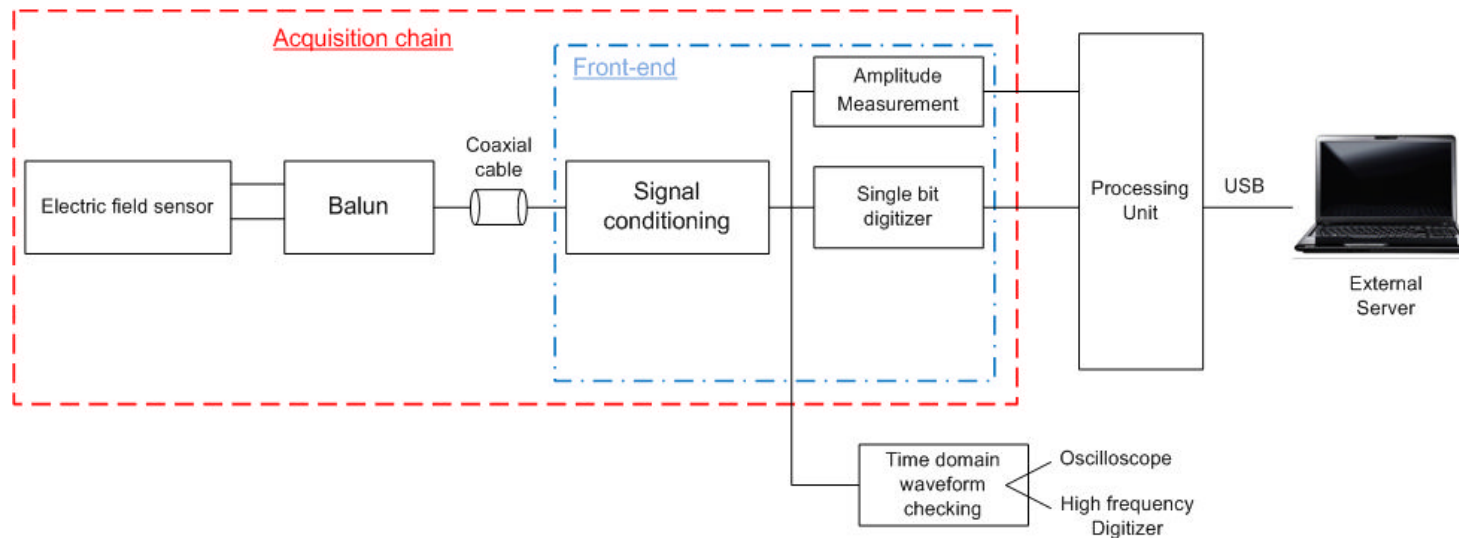
Ideal architecture



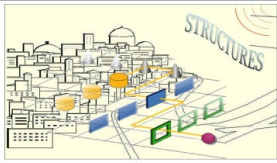


Block Diagram for one sensor

- Electric-field sensor
- Signal Conditioning
- Amplitude Measurement
- Single bit digitizer
- Time domain waveform checking
- Processing unit
- External server



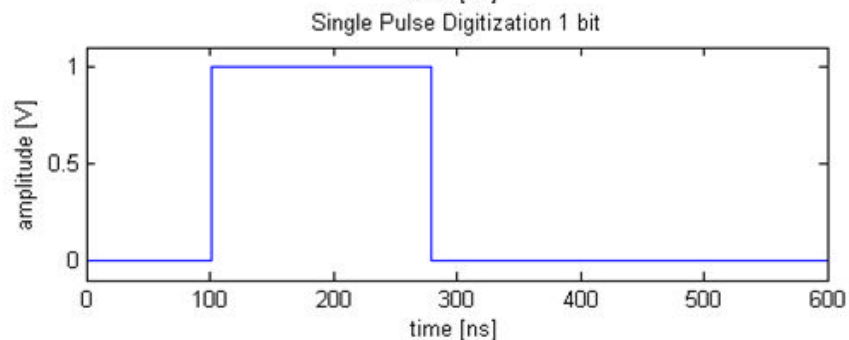
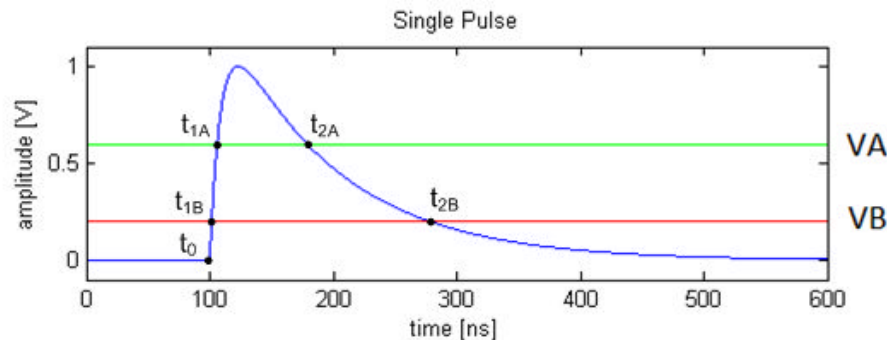
Block diagram for one sensor



Estimations of waveform parameters

Single pulse double exponential

- Estimating time constants
 - From timing two threshold crossings we can obtain the two time constants



$$V_A \cong V_0 e^{-t'_{2A}/\tau_1} \quad V_B \cong V_0 e^{-t'_{2B}/\tau_1}$$

$$V_A/V_B \cong e^{(-t'_{2A} + t'_{2B})/\tau_1}$$

$$\tau_1 \cong (t'_{2B} - t'_{2A}) / \ln(V_A/V_B)$$

$$V_0 \cong \frac{V_A}{e^{-t'_{2A} \ln\left(\frac{V_A}{V_B}\right) / (t'_{2B} - t'_{2A})}}$$

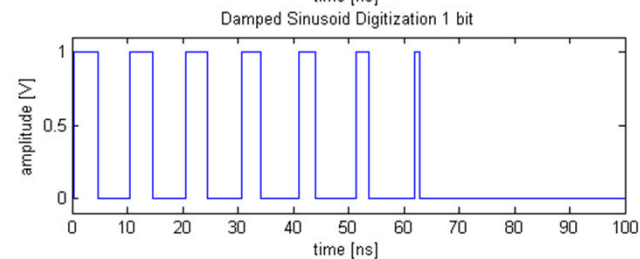
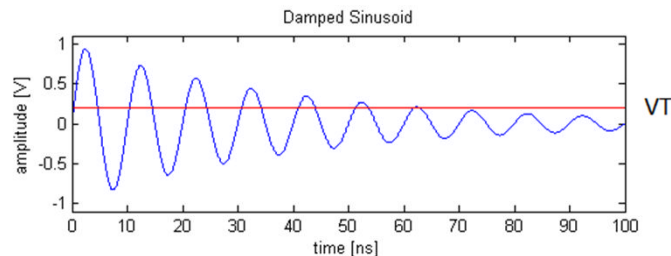
$$\tau_2 = -t'_{1A} / \ln\left(e^{-t'_{1A}/\tau_1} - V_A/V_0\right)$$



Estimations of waveform parameters

Damped sinusoid

- Estimating decay time constant and fundamental frequency



Damped sinusoid

$$t_{Start, m} = m / f$$

$$t_{End, m} = (2m - 1) / 2f$$

$$e^{-t/\tau} \geq V_T$$

$$t \leq -\tau \ln(V_T)$$

$$\frac{2m-1}{2f} \leq -\tau \ln(V_T)$$

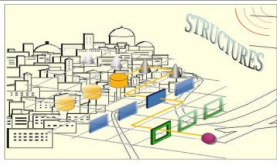
$$\tau \geq -\frac{2m-1}{2f \ln(V_T)}$$

$$x(t) = \sin(2\pi ft)e^{-t/\tau}$$

$$\sin(2\pi ft)e^{-t/\tau} = V_T$$

$$f = \frac{n-1}{2\Delta t} \quad \text{if } n > 1$$

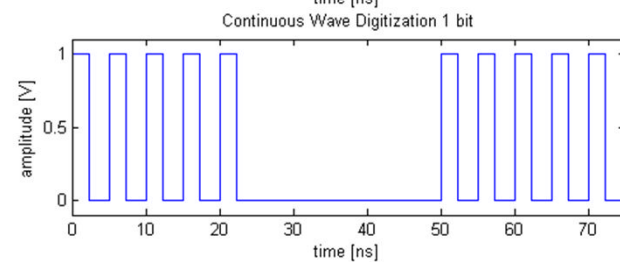
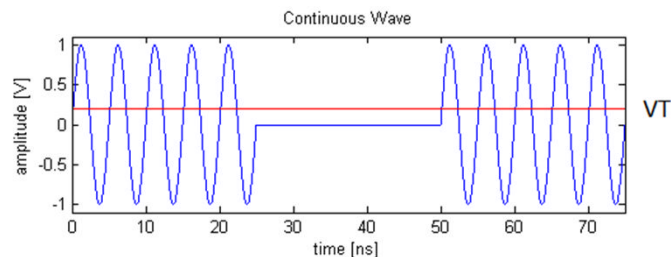
$$f \approx \frac{p-1}{2\Delta t_{n, V_T \neq 0}}$$



Estimations of waveform parameters

Continuous wave

- Estimating fundamental frequency



Continuous Wave

$$\Delta t_n = \frac{(n-1)\pi}{2\pi f} \quad \text{If } n \text{ is odd}$$

$$\Delta t_n = \frac{\pi - 2 \arcsin(V_T) + (n-2)\pi}{2\pi f} \quad \text{If } n \text{ is even}$$

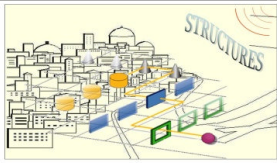
$$f = \frac{n-1}{2\Delta t_n} \quad \text{If } n \text{ is odd}$$

$$f = \frac{\pi - 2 \arcsin(V_T) + (n-2)\pi}{2\pi\Delta t_n} \quad \text{If } n \text{ is even}$$



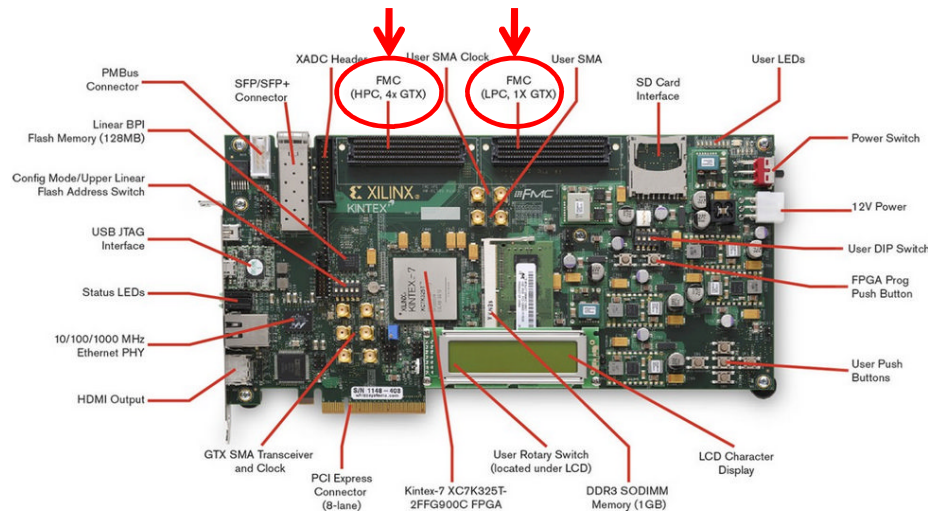
Specifications of the demonstrator

- System able to accept large dynamic in amplitude & frequency
 - Amplitude dynamic range : min 100 V/m; max 20 kV/m
 - Frequency dynamic range : a few hundred Hz -> 1 GHz
- Amplitude measurement with fast transition and rise time in case of the pulse signal
 - lowest rise time = 300 ps
 - lowest duration 50% = 1 ns

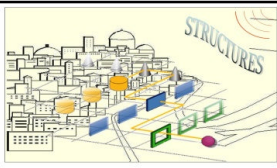


KC705 Evaluation Board for the Kintex-7 FPGA

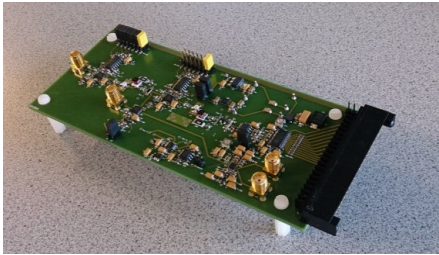
- Main reason for the choice



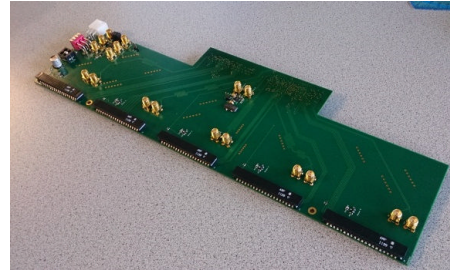
- High-performance transceivers capable of up to 12.5 Gb/s; the demonstrator of the Structures project runs at 8 Gb/s
- Extremely cheap multi channel high speed digitizing system



System assembly



Sensor board



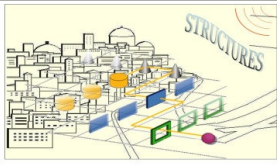
Interface Board



FPGA

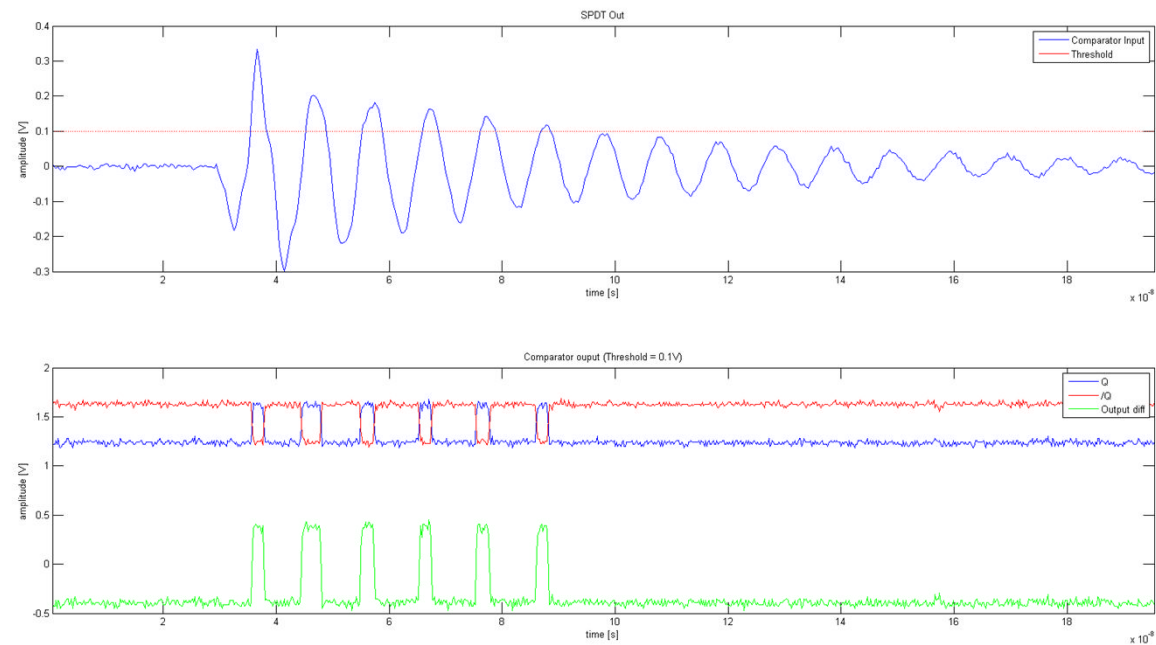


Integrated equipment

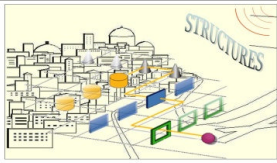


Hardware results & measurement

- Comparator measurement

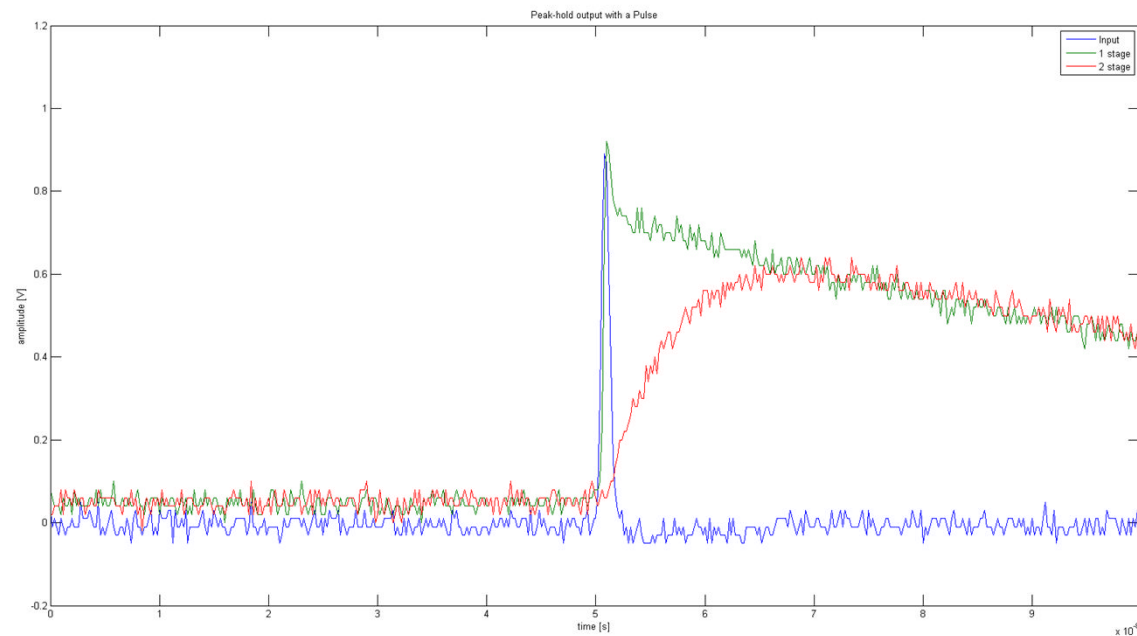


Comparator result (Damped Sinus 100MHz)

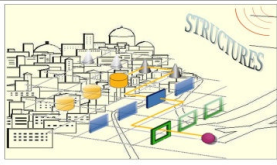


Hardware results & measurement

- Peak-hold measurement



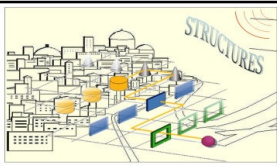
Peak-hold with pulse signal



Algorithm: Localization

Time Difference of Arrival (TDoA)

- Calculating the time difference between the received signals at the different sensor locations using the cross correlation algorithm
- 5 sensors are used of which one is considered as reference
- Using 5 sensors, the set of equations can be linearized
- Solving the source location by linear algebra methods



Localization and identification system Status

- Prototype detection and identification system demonstrated