Time-Domain Near-Field Scanning of Stochastic Emissions:

Application to Wireless Chip-to-Chip Communication Demonstrator

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SECURE CONNECTIONS
FOR A SMARTER WORLD

OUTLINE

- Problem Statement & Motivation
- Objectives & Workplan
- Main results & Discussions
- Concluding Remarks & Observations
- Ongoing Actions & Suggestions
- Dissemination [accepted publications]

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Problem Statement & Motivation

Emergence of connected smart objects puts new requirements on RFIC design, modeling and experimental verification.

Near-Field measurement appears as a bridging gap between circuit design (RFIC-Chip-Package-PCB) and field radiation (Antennas) with the following driving motivations:

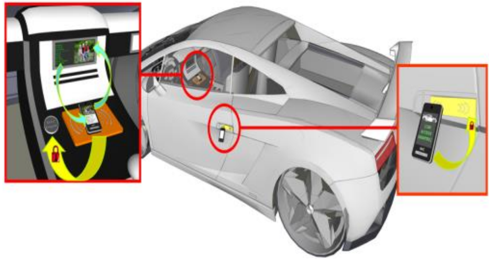
- **Verification of EMC/EMI compliance for product evaluation and qualification (*certification-oriented*).**
- **Diagnosis of Power Integrity (PI), Signal Integrity (SI) and EMC/EMI problems for design improvement (*Debug-oriented*).**
- **Coupled analysis of spatial radiated field distributions and Spectral-domain/Time-domain responses for optimization of dynamic power management (Awareness).**
- **Monitoring of performances as function of environmental uncertainties (Power Spectrum management).**

Stochastic approaches are not only necessary because of our partial or insufficient knowledge of the mechanisms underlying the true physics, they also reflect various uncertainties.

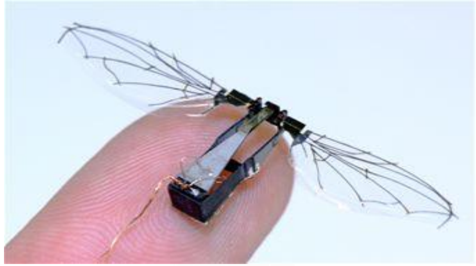
Challenges of proper System-Level Modeling & Predictive Analysis

Security & ID

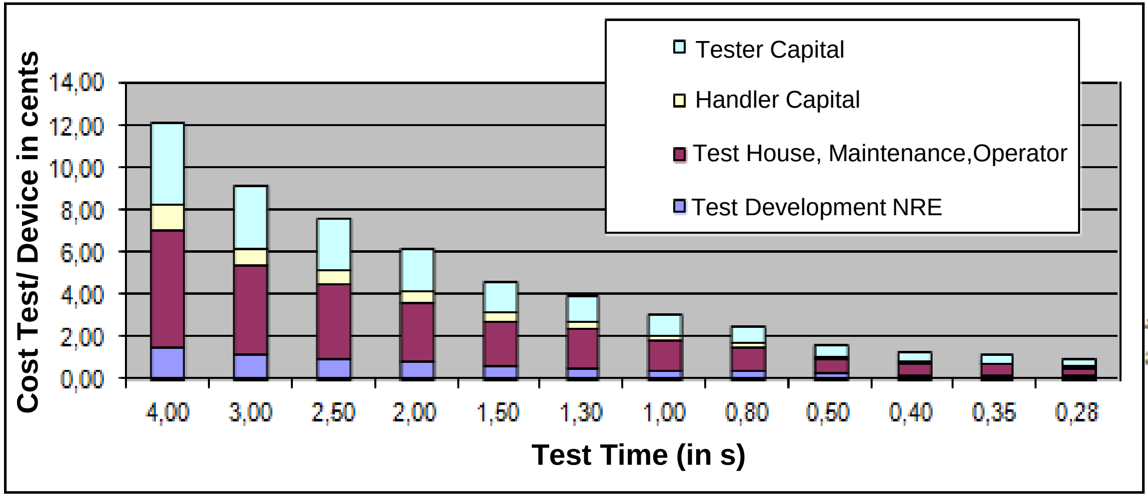
Automotive & IoT



NAV & Moving Objects



Motivation for Near-Field Measurement & Analysis

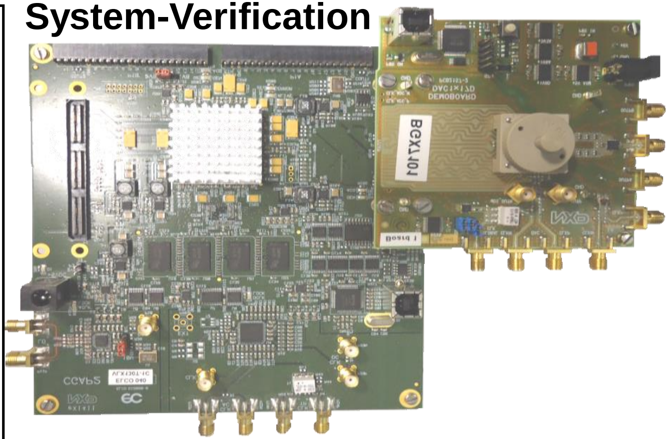


15% to 25% of total product development cost is Test/Debug.

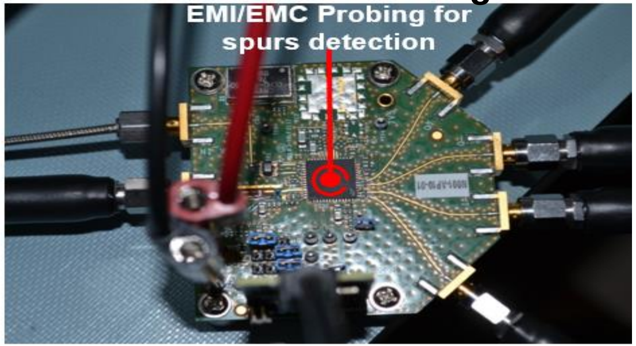
Main factors are:

- Test time: long test list, long test time
- Equipments cost: RF tester > 1 M$
- Operator and maintenance: qualification

System-Verification



Near-Field Probing



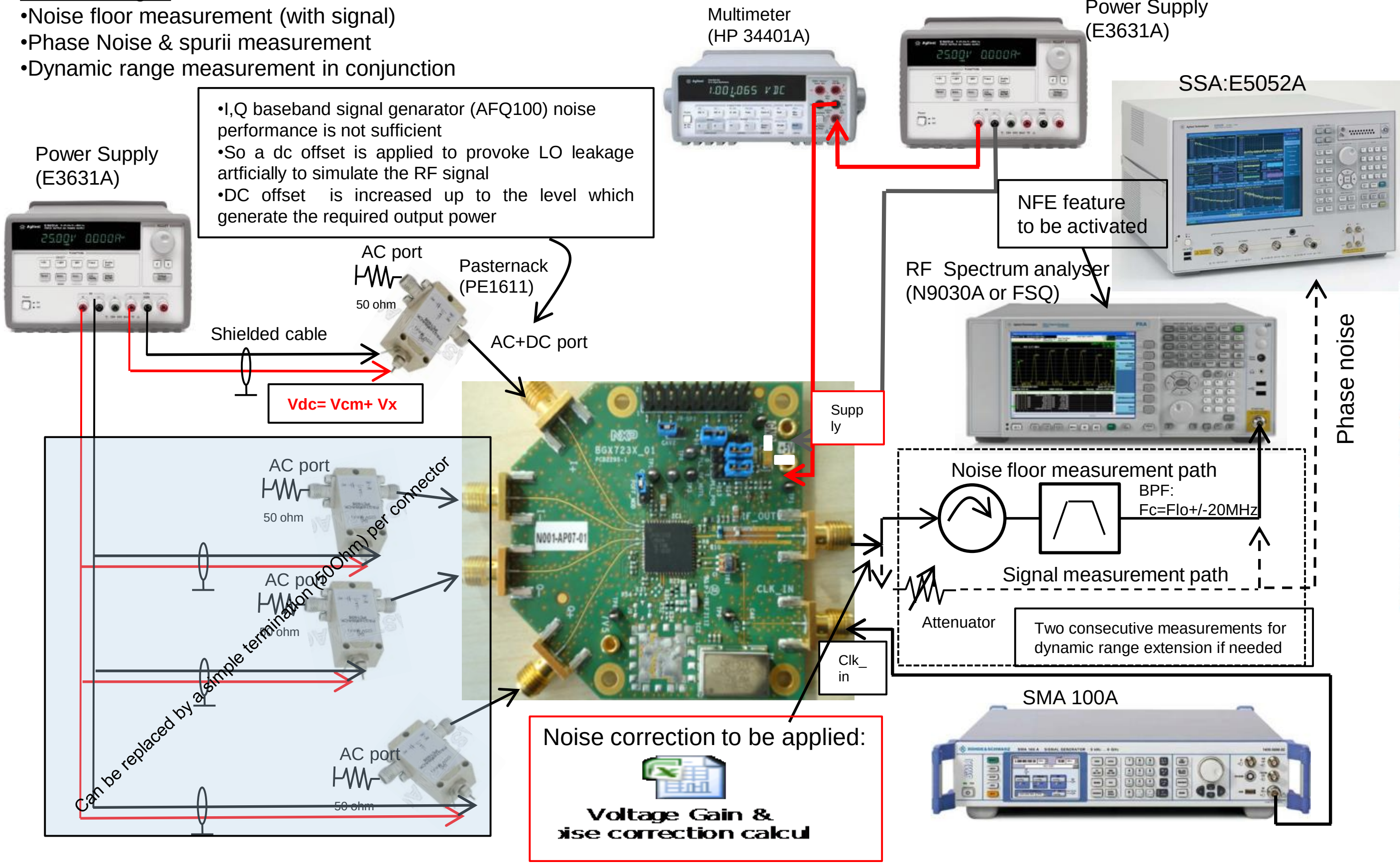
Near-Field Measurement as enabler for contact-less Verification & Qualification

System-Level Test & Verification Coverage

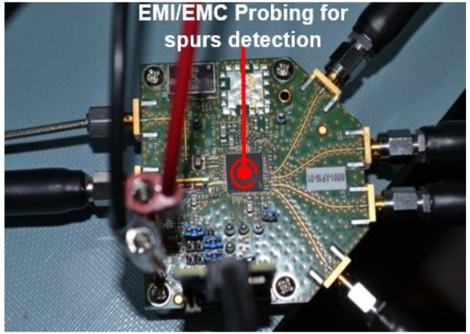
Test coverage:

- Noise floor measurement (with signal)
- Phase Noise & spurii measurement
- Dynamic range measurement in conjunction

- I,Q baseband signal genarator (AFQ100) noise performance is not sufficient
- So a dc offset is applied to provoke LO leakage artficially to simulate the RF signal
- DC offset is increased up to the level which generate the required output power

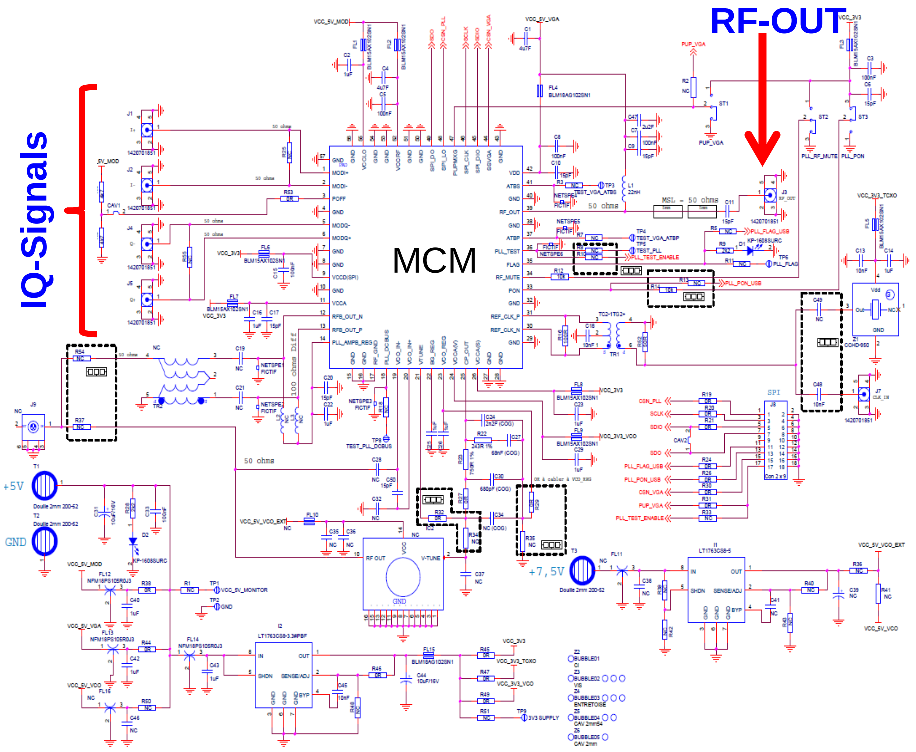


Near-Field Probing

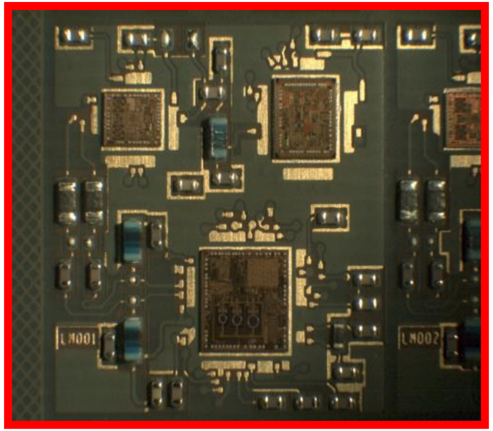


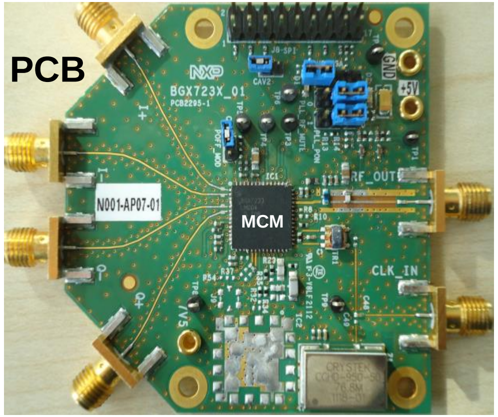
RF Chip-Package-PCB Verification

System-Level-Test-bench



MCM





Signals which are in general Multi-scale, Multi-harmonic, a-periodic can be continuous or transient and impulsive. Necessity of Time domains analysis.

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Objectives & Workplan

The workplan of the STSM is the following:

- **Time-Domain Near-Field measurement of stochastic emissions radiated from wireless link demonstrator board [Chip-to-Chip Communication].**
- **Assessing effects of identified noise sources (e.g., Crystal Oscillators) on induced Near-Field levels.**
- **Evaluating impact of Pre-Amplifiers and feeding cables on the sensitivity of Near-Field measurements including influence of calibration: [including assessment of sensitivity and dynamic range of used Near-Field probes].**
- **Measuring couplings (to be completed with radiation patterns) between antennas with various separation distances using anechoic chamber facilities in the perspective of MIMO systems for 5G applications and beyond.**
- **Studying possibilities to further reduce measurement time and data processing steps in the perspective of industrial test and qualification of assembled circuits and systems.**

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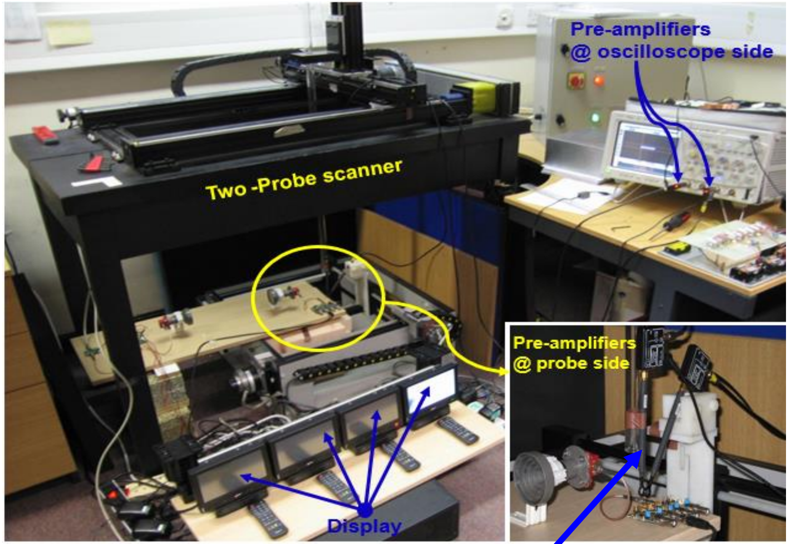
Near-Field Measurement in Time-Domain

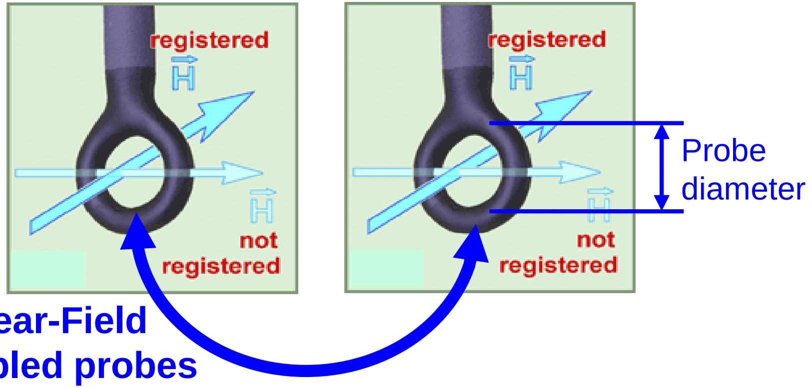
Time-Domain Scanner



Moving probes

Preamplifier

Langer Probes solution



Near-Field Coupled probes

- **Two-probe time-domain scanner with multi-channel digital oscilloscope (*4 Gsa/s*).**
- **One million sample points are captured per channel and used to extract field-field auto-correlation and cross-correlation functions.**
- **The probes can be moved in the XY plane by monitoring step motors.**

Langer Near Field Probes

XF Near Field Probes to 6 GHz

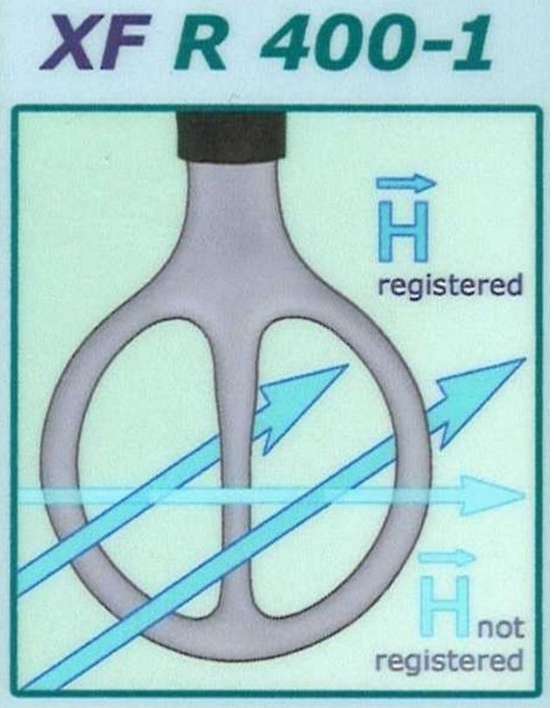
Langer Near Field Probes

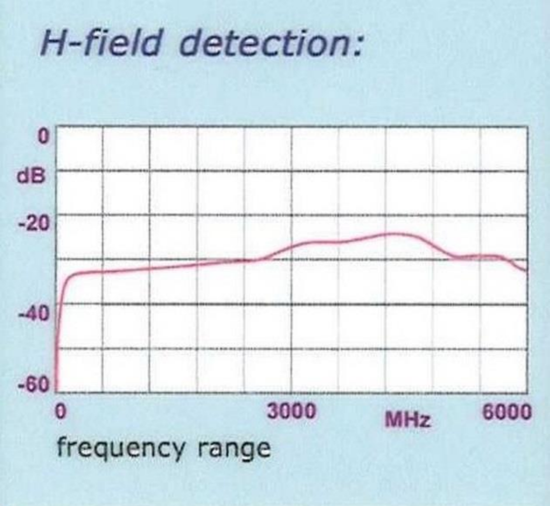
XF Near Field Probes to 10 GHz

Evaluation of Measured Stochastic Field as function of RF Probes size [planned]

Langer Near Field Probes

XF R 400-1 (6 GHz)

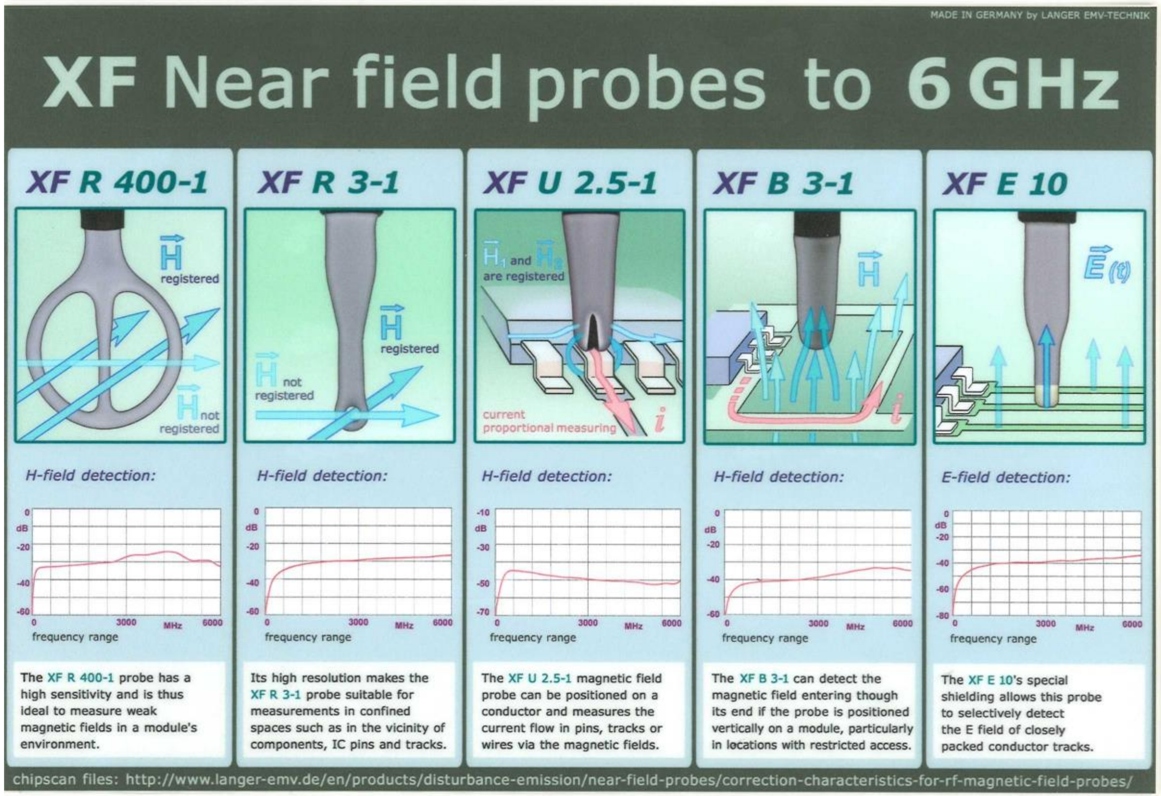




The **XF R 400-1** probe has a high sensitivity and is thus ideal to measure weak magnetic fields in a module's environment.

Langer **Near Field** Probes

XF Near Field Probes to 6 GHz



XF Near field probes to 6 GHz

XF R 400-1

H-field detection:

The XF R 400-1 probe has a high sensitivity and is thus ideal to measure weak magnetic fields in a module's environment.

XF R 3-1

H-field detection:

Its high resolution makes the XF R 3-1 probe suitable for measurements in confined spaces such as in the vicinity of components, IC pins and tracks.

XF U 2.5-1

H-field detection:

The XF U 2.5-1 magnetic field probe can be positioned on a conductor and measures the current flow in pins, tracks or wires via the magnetic fields.

XF B 3-1

H-field detection:

The XF B 3-1 can detect the magnetic field entering though its end if the probe is positioned vertically on a module, particularly in locations with restricted access.

XF E 10

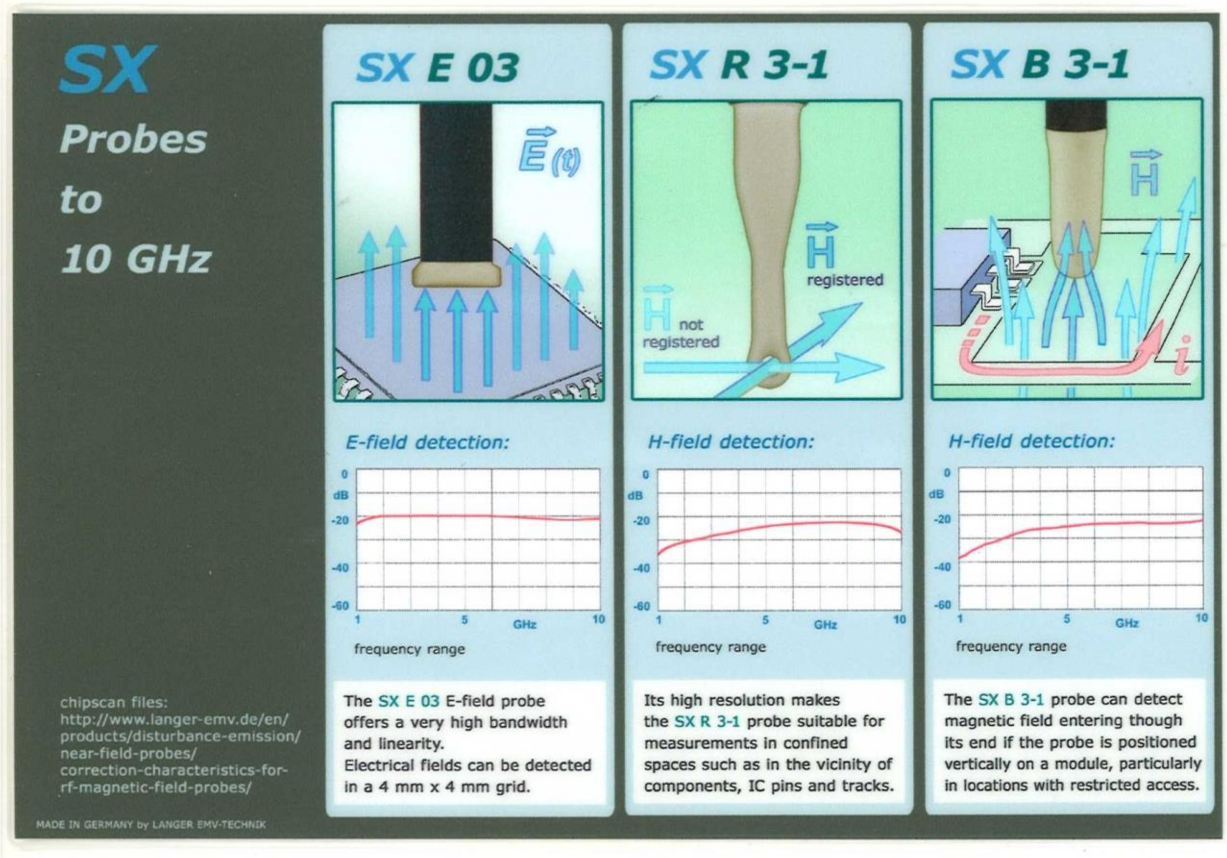
E-field detection:

The XF E 10's special shielding allows this probe to selectively detect the E field of closely packed conductor tracks.

chipscan files: http://www.langer-emv.de/en/products/disturbance-emission/near-field-probes/correction-characteristics-for-rf-magnetic-field-probes/

Langer Near Field Probes

SX Near Field Probes to 10 GHz



SX
Probes
to
10 GHz

chipscan files:
http://www.langer-emv.de/en/products/disturbance-emission/near-field-probes/correction-characteristics-for-rf-magnetic-field-probes/

SX E 03

E-field detection:

frequency range

The SX E 03 E-field probe offers a very high bandwidth and linearity.
Electrical fields can be detected in a 4 mm x 4 mm grid.

SX R 3-1

H-field detection:

frequency range

Its high resolution makes the SX R 3-1 probe suitable for measurements in confined spaces such as in the vicinity of components, IC pins and tracks.

SX B 3-1

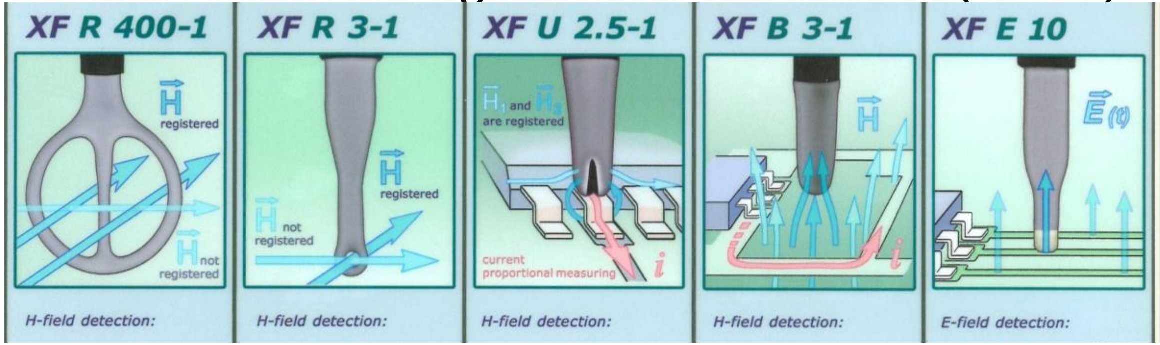
H-field detection:

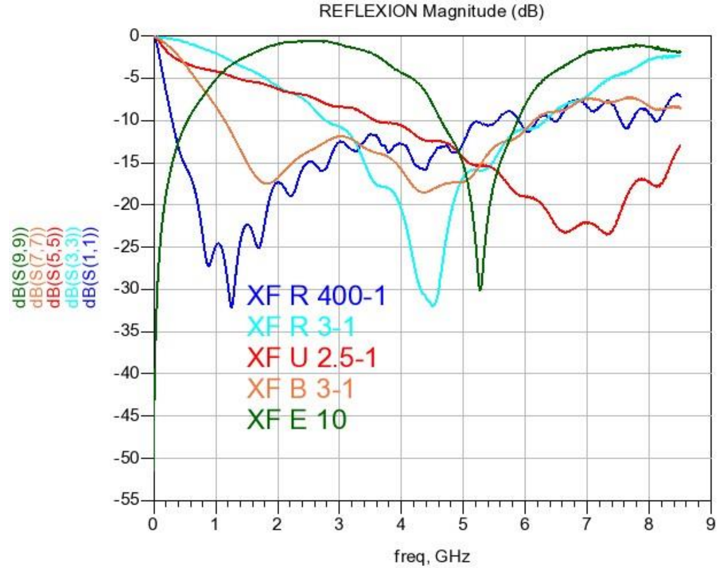
frequency range

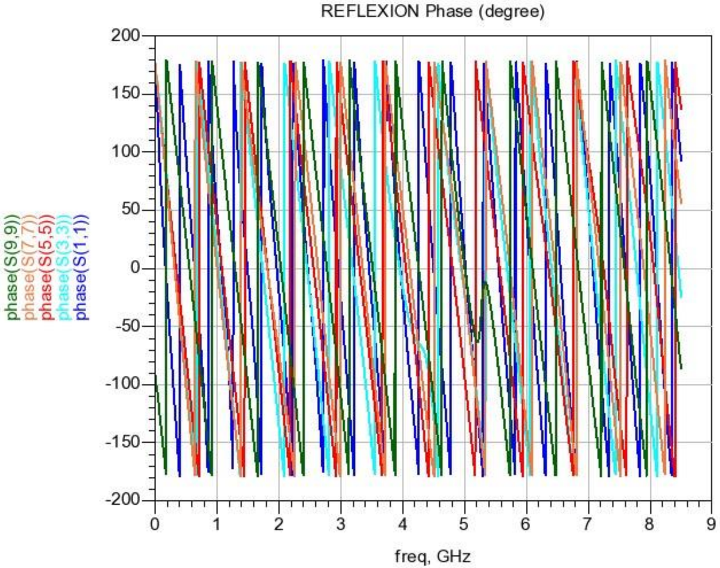
The SX B 3-1 probe can detect magnetic field entering though its end if the probe is positioned vertically on a module, particularly in locations with restricted access.

MADE IN GERMANY by LANGER EMV-TECHNIK

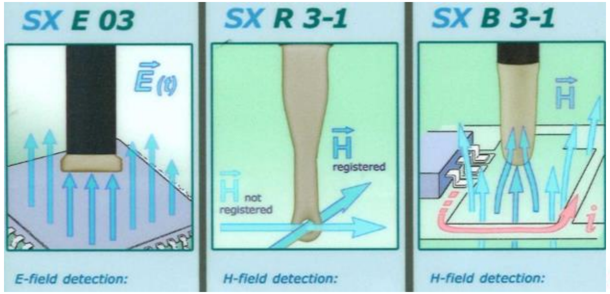
S Parameters on Langer Near Field Probes (6 GHz)



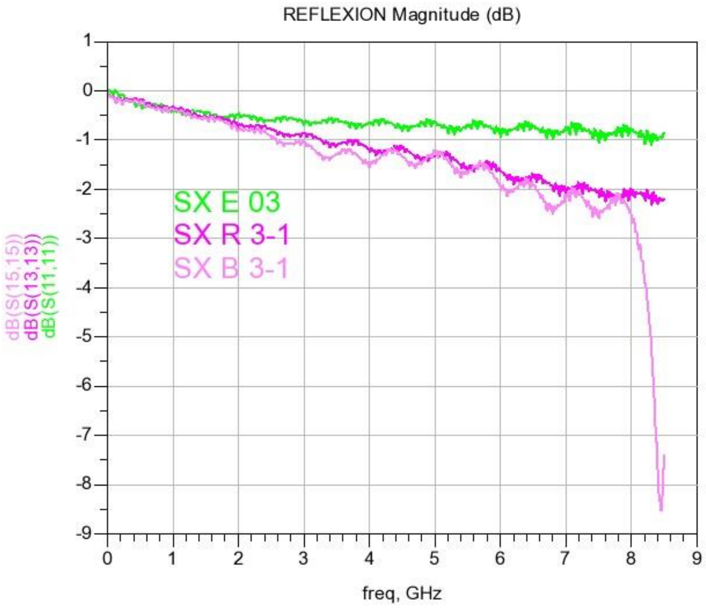


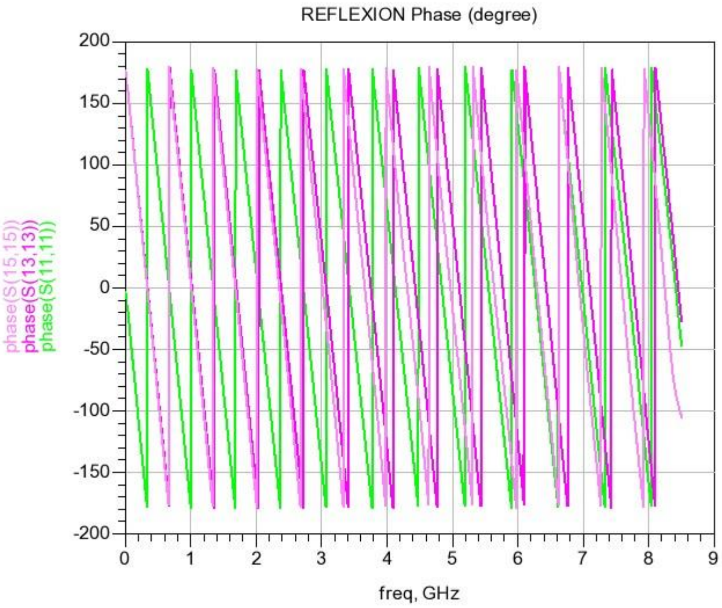


S Parameters on Langer Near Field Probes (10 GHz)



SX E 03 SX R 3-1 SX B 3-1

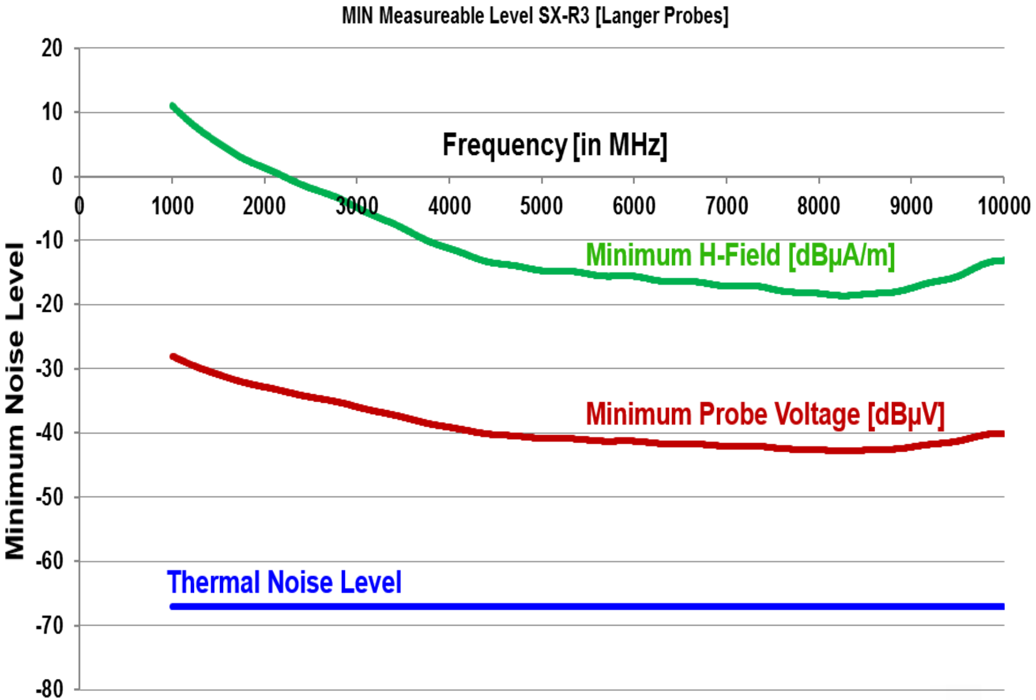




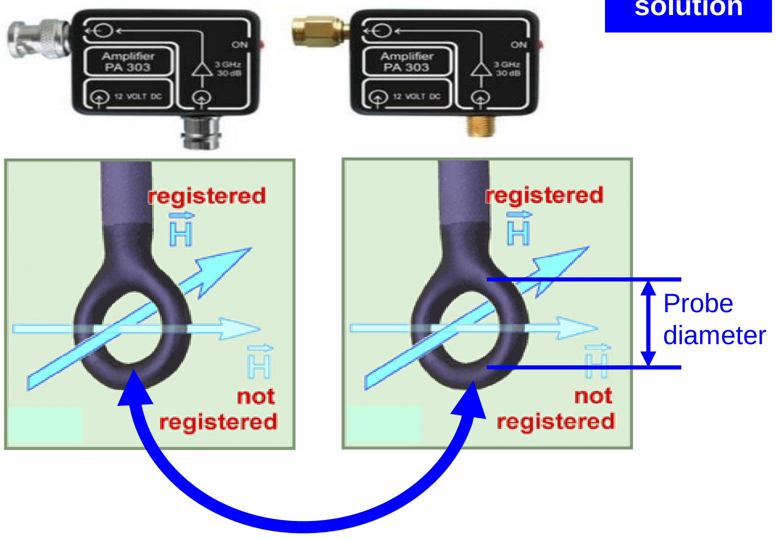
Near-Field Measurement in Time-Domain

[Sensitivity Analysis]

Langer Probes solution



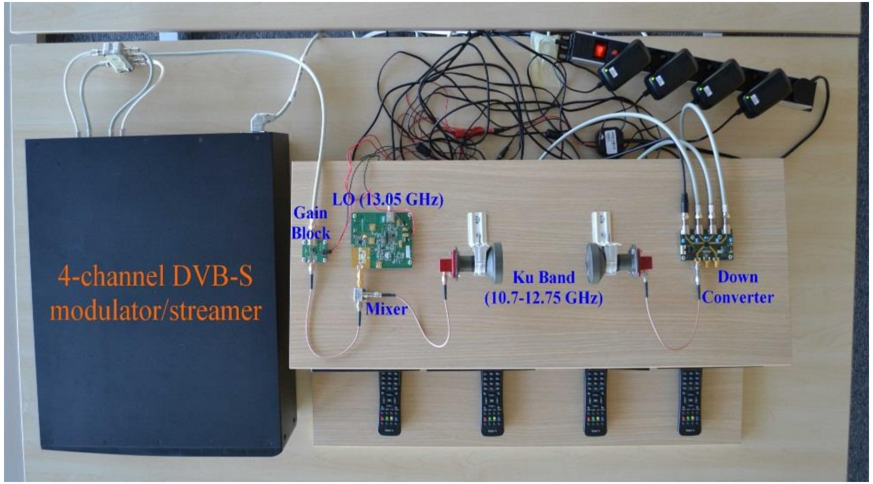
Preamplifier



Near-Field Coupled probes

- **Variation of the detected Near-Field emission @1GHz (Dipole antenna as DUT).**
- **Near-Field scanner sensitivity detected around -135dBm (Pre-amplified).**

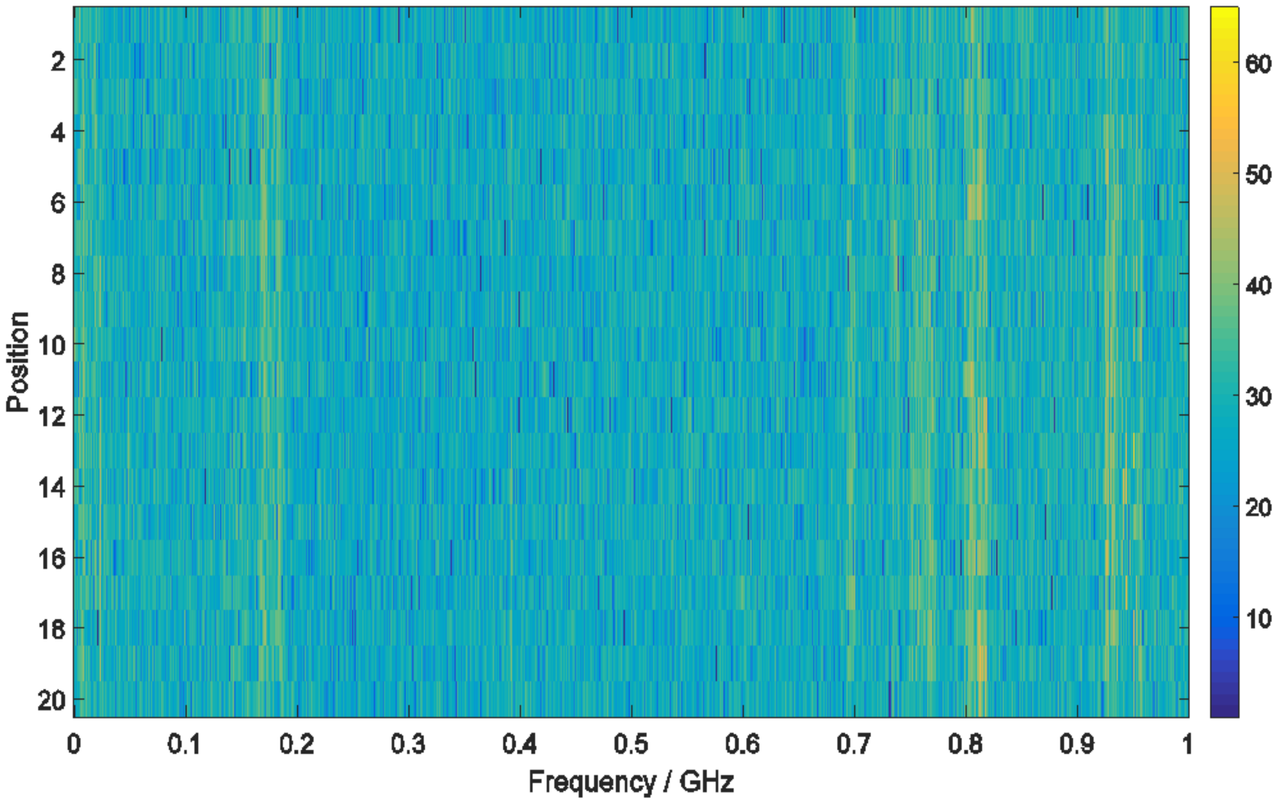
Measurement of Near-Field Radiated Emissions from Chip-to-Chip Communication Link

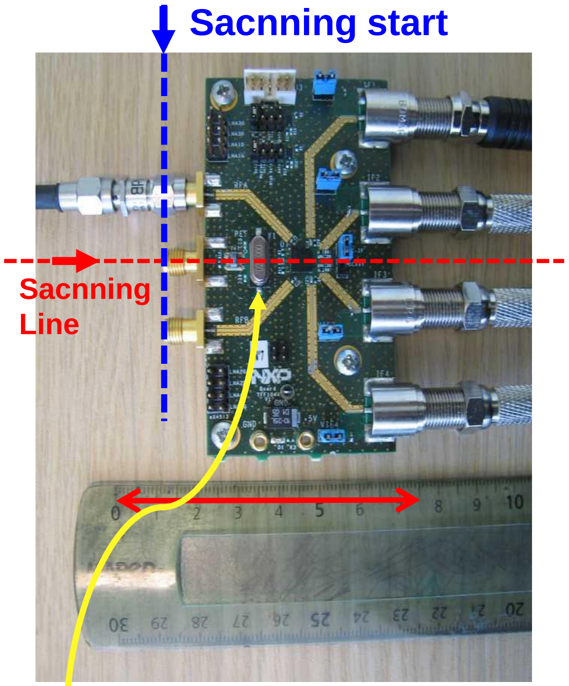


- **The Quadrature Channel (QUAD) Low-Noise Block (LNB) combined in one device.**
- **The Quad RF downconverter has 2 RF inputs, 4 IF outputs in the frequency bands from 950MHz to 1.10 GHz for the Low-Band and from 1.95GHz to 2.15GHz for the High-Band.**
- **Dual LO PLL frequency synthesizer: 9.75 & 10.6 GHz. The PLL circuits use an integrated 25MHz crystal oscillator (with off chip crystal resonator).**

S.Wane , G. French ,A. Erdem, E. Capelleveen, P. Philippe, S. Bardy, O. Tesson, E. Thomas, P. Brousse, D. Leenaerts, J. Lucek, "***Ku Band Down-Converter for QUAD LNB Satellite Applications***", IEEE RFIC Show-Case, Phoenix, 2015.

Measured Spectral Energy Density



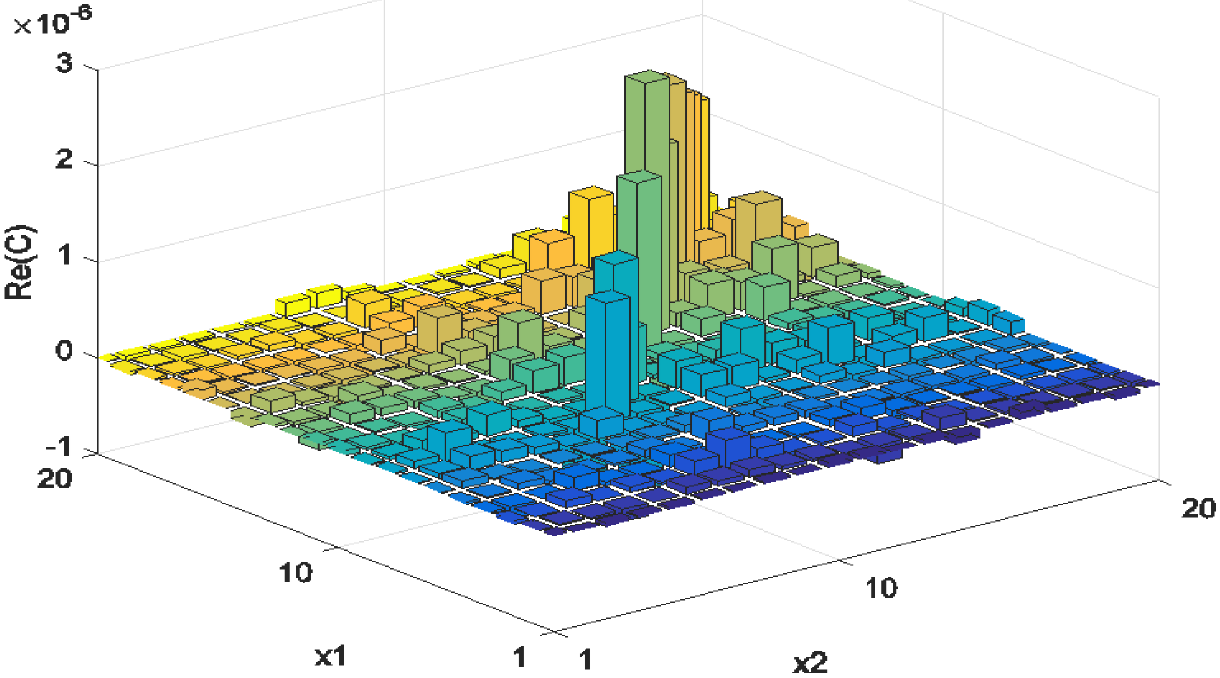


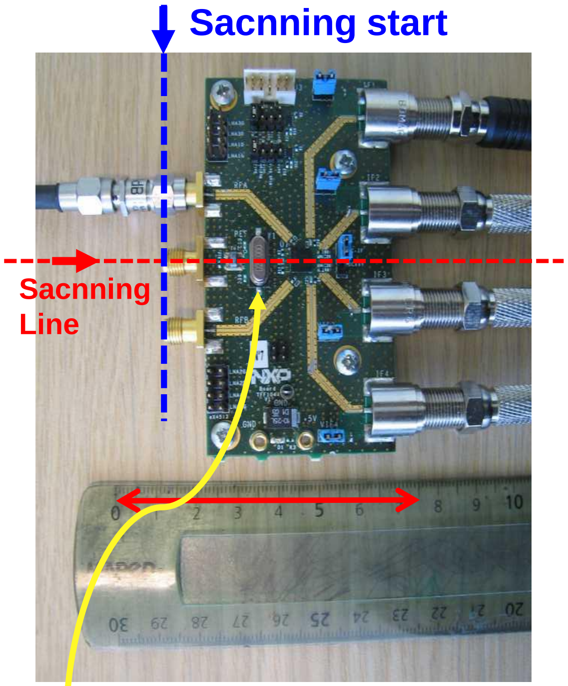
Sacnning start

Sacnning Line

Crystal Oscillator [oscillation @ 25MHz]

Correlation Matrix Visualization @24.9853MHz



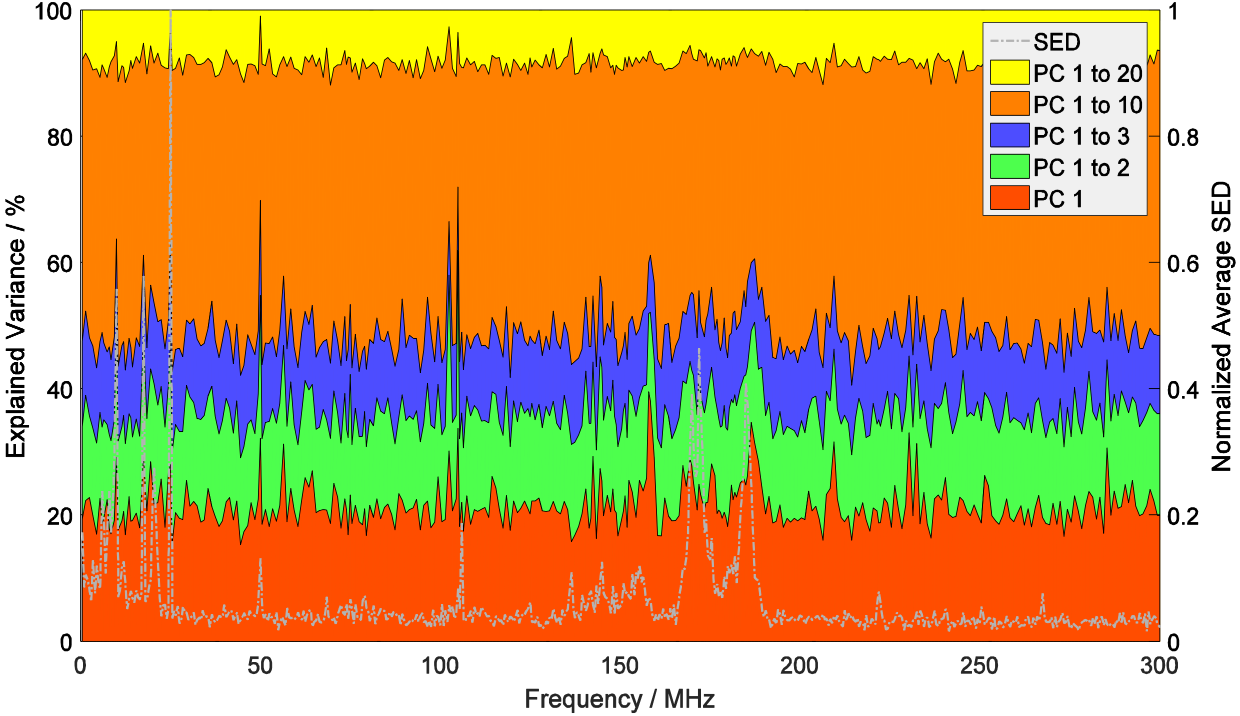

Sacnning start

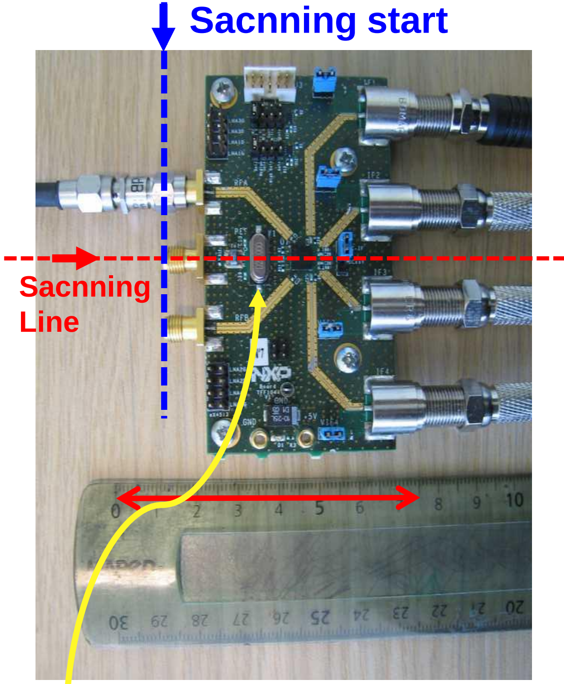
Sacnning Line

Crystal Oscillator [oscillation @ 25MHz]

Maximum correlation observed around Crystal Oscillator resonant frequency

Measured Spectral Energy Density as function of Cumulative Principal Components





Crystal Oscillator [oscillation @ 25MHz]

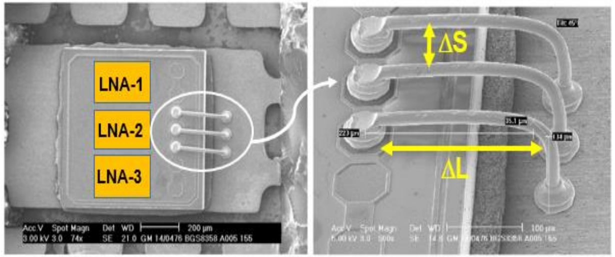
- **More than 90% of Spectral Energy Density carried by the first 10 principal components [directions for complexity reduction by filtering].**
- **Effects of Broadband Probe-Preamplifier matching ?**

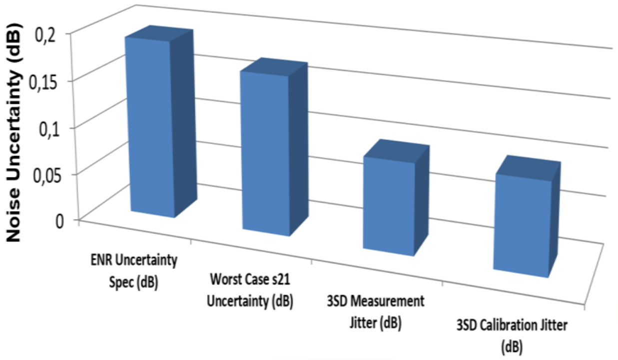
LNA-Probe Co-Design

Frequency-domain and time-domain Near-Field scanning solutions are evaluated for the measurement of radiated emissions from wireless chip-to-chip communication links. Both scanning systems reveal importance of proper Probe-Pre-amplifier co-design. Perspectives for distributed Chip-Package LNA-Probe array co-design are proposed for Multi-probe Near-Field sensing.

Preliminary prototyping shows promising performances (*noise figure uncertainty including Monte-Carlo Standard Deviation: SD*) when On-Chip LNA pre-amplifiers are co-designed with Bond-Wire loop sensors implemented at package level. Prototype circuits tested using On-Chip LNA modules co-designed with Bond-Wire loop arrays.

The Bond-Wire loops in the order of 100µm equi-spaced by a separation distance less than 40µm lead to very high spatial resolution suitable for Near-Field scanners.





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Concluding Remarks

- **Move from Qualitative to Quantitative evaluation of Stochastic Near-Field Emissions:**
  - **Need for proper calibration of Near-Field Probes in Time-Domain**
  - **Need for bi-univocal transformation of Voltages/Currents into Fields [SED]**
  - **Sensitivity/Resolution of Near-Field Probes [Min/Max Power]**
- **Challenges for industrialization:**
  - **Test time [maybe parallel processing could be used]**
  - **Use in production design & verification flow**
  - **Repeatability**
- **Benchmarking & Directions for Improvement:**
  - **Benchmarking Frequency and Time-Domain Near-Field solutions**
  - **Evaluation of Optical probing [reduced couplings, less invasive probes]**
  - **Co-Design of LNA-Probe arrays using distributed Chip-Package solutions [improved resolution]**

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Ongoing Actions & Suggestions

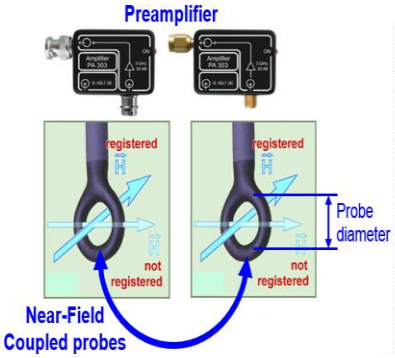
- X-rays analysis of Near-Field probes for properly mapping measured Voltages/currents into EM Field values

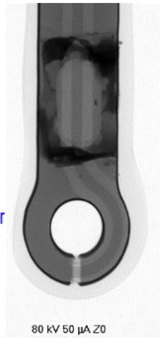
- Evaluation of Broadband Noise/Sensitivity performances of used LNA+Probes system [variation as function of probes size) as function of software statistical activity

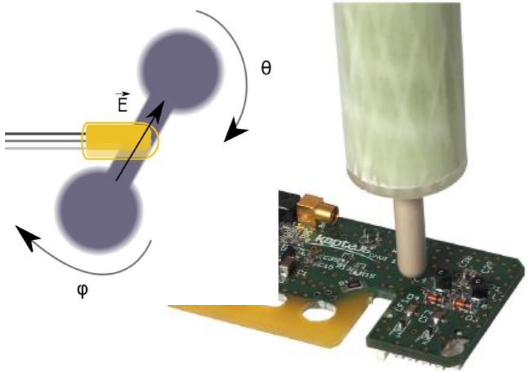
- Broadband Network modeling of coupled probes

- Multi-path Near-Field to Far-Field interactions [e.g., MIMO]

- Evaluation of Optical Near-Field Probing (Kapteos solutions): [seems suited only for high power applications: e.g., >30dBm]







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- Sidina Wane, Damienne Bajon, Dominique Lesénéchal, Johannes Russer, Peter Russer, Jean-Marc Moschetta, David Thomas and Gregor Tanner, «**Near-Field Measurement and Analysis of Noisy Electromagnetic Emissions: Towards Stochastic Energy-Oriented Approaches**», presented at URSI-France Workshop JS2016 on Energy & RADIO-SCIENCES, 15 ET 16 MARS 2016, RENNES.
- Sidina Wane, Damienne Bajon, Dominique Lesénéchal, Johannes A. Russer, Mohd H. Baharuddin, David Thomas, and Peter Russer, «**Multi-Probe Near-Field Measurement of Stochastic Noisy Radiations: Perspectives for Chip-Package LNA-Probe Co-Design**», accepted for European Microwave Week 2016, London.
- Sidina Wane, Damienne Bajon, Johannes Russer, Peter Russer, Jean Baptiste Gros,Jean-Marc Moschetta, David Thomas, Yury Kuznetsov, «**Measurement and Analysis of Radiated Emissions from Coupled UAV and Smart RFIC Objects**», accepted for European Microwave Week 2016, London.
- Sidina Wane, Damienne Bajon, Dominique Lesénéchal, Johannes Russer, Peter Russer, David Thomas, Gregor Tanner Gabriele Gradoni, and Yury Kuznetsov, «**Near-Field Measurement of Connected Smart RFIC Objects accounting for Environmental Uncertainties** », accepted for European Microwave Week 2016, London.

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Ackowledgment

This work was supported in part by COST ACTION IC1407, and by the European Union’s Horizon 2020 research and innovation programme under grant no. 664828 (NEMF21).