Development and validation of a wide band Near Field Scan probe for the investigation of the radiated immunity of Printed Circuit Boards

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FRENCH INSTITUTES OF TECHNOLOGY

CONTENTS

INDUSTRIALS NEEDS

- **The multiplication and the complexification of the electronic functions in the embedded systems dramatically increases the duration of the qualification tests and the EMC non-compliance risk.**

- **For economic reasons, the certified laboratories are obliged to work in 3 shifts and have less and less qualified resources and time for the investigation of the problems during the test.**

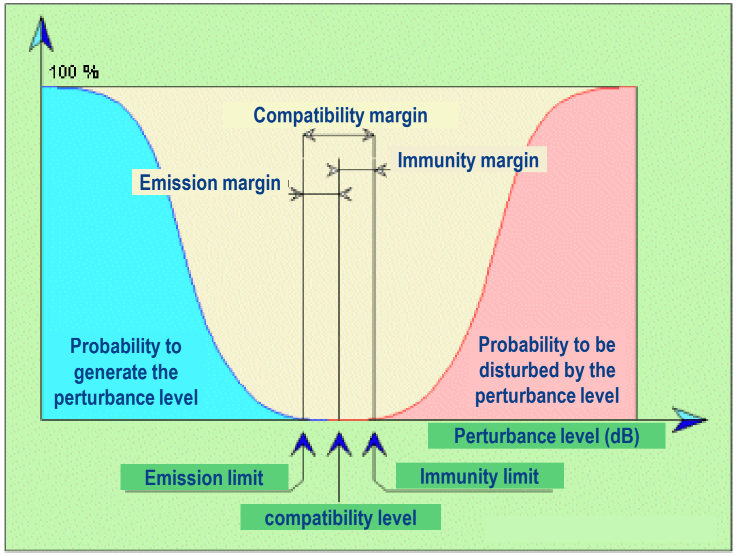


Figure source : A. Perez-Mas

- **The cost of the tests means and the qualified staff for a normative test in radiated immunity is raised and constitutes a bottleneck for the equipment manufacturers.**

To solve their problem, the equipment manufacturers need to have
fast, economic and easily usable investigation tools
allowing quick measurement of the level of susceptibility of their prototypes

OBJECTIVES

The **Near Field Scan Immunity (NFSi)** method allows the **spatial localization** of **functional failures caused by an electric and/or magnetic field** generated by a probe placed nearby the component

- The objective is to propose a **new methodology of investigation of the radiated immunity** of electronic boards based on a **near field scanning** with the aim of detecting any problem before the normative qualification test

- **The main lock lies in the reliable extrapolation of a near-field measurements for the evaluation of a level of immunity in far field.**

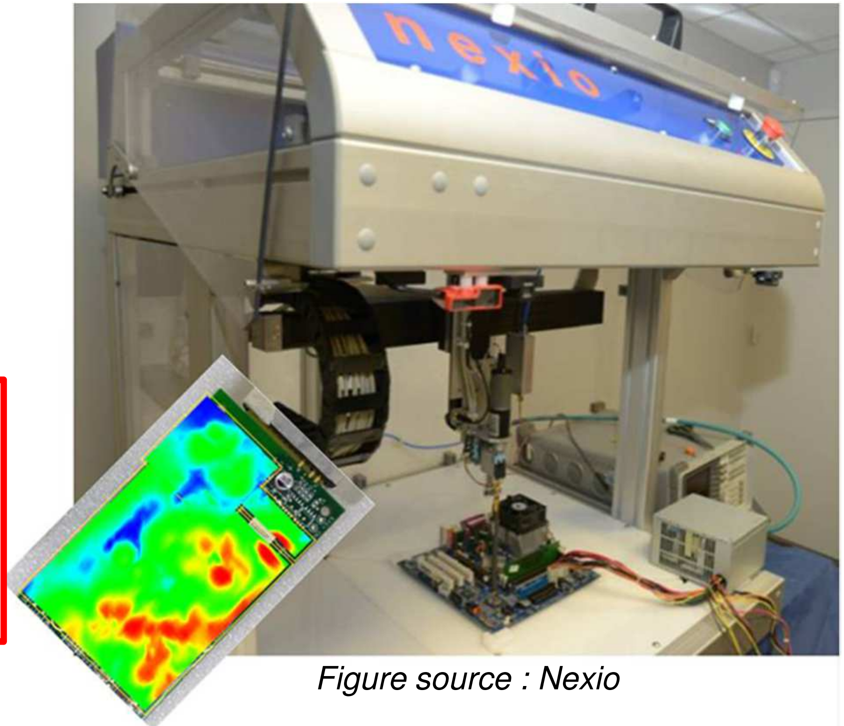


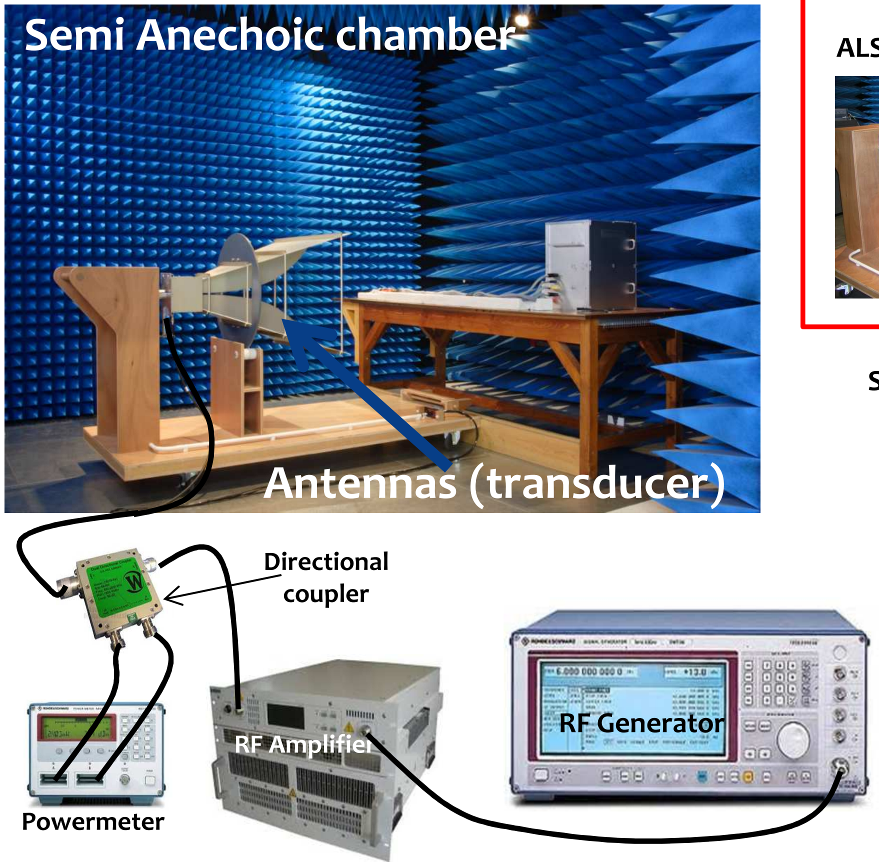
Figure source : Nexio

- **To this end, a modelling of the various normative tests is necessary to make the calculation of the electromagnetic fields and the calculation of inducted currents at the PCB level**

CONTENTS

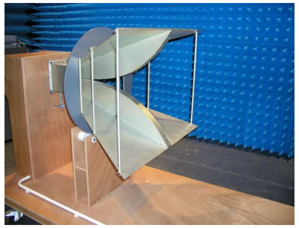
NORMATIVE EMC TEST
ISO 11452-2 (ALSE) Radiated Immunity

Figure source : Continental Automotive



ALSE test

Transducers



Antennas
200 MHz-6 GHz automotive
up to 18 GHz Aeronautics
150 – 200 V/m typically in CW automotive
200 – 490 V/m in CW aeronautics
Up to 600 V/m (PM @2.7- 3.2 GHz automotive)
Up to 7 200 V/m (PM @ 4-6 GHz aeronautics)

Stripline test

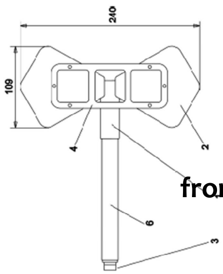
Stripline
100kHz-1GHz
> 200V/m

ISO 11452-5

TEM cell test

TEM cell
100kHz-200MHz
> 200V/m

ISO 11452-3

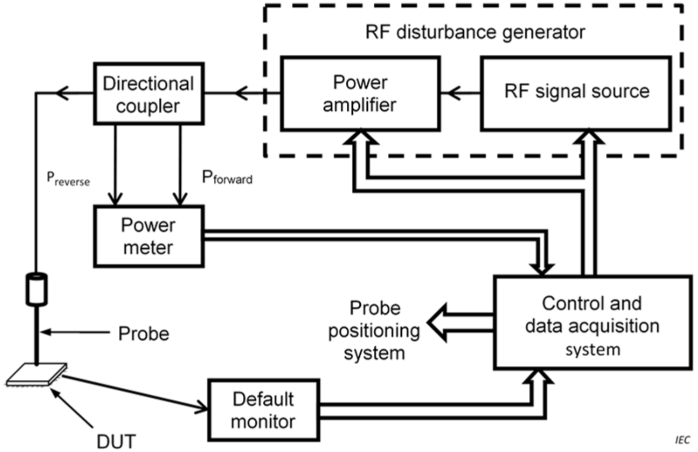


ISO 11452-9

Portable transmitters
Given frequency band
from CB 26 MHz to IEEE 802.11a 5 850MHz
Up to 300V/m @400MHz

NORMATIVE EMC TEST

IEC TS62132-9 Near Field Scan Immunity



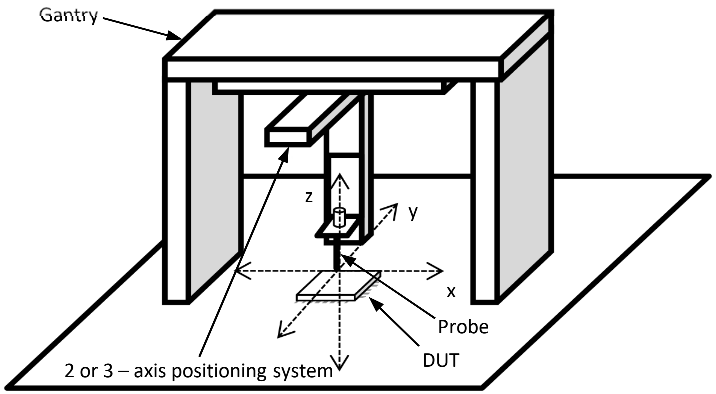


Figure source : IEC

« Radiated Susceptibility Investigation of electronic board from Near Field Scan method »N. Lacrampe, S. Serpaud, A. Boyer, S. Tran APEMC april 2010, Beijin (China)

« Application and limits of IC and PCB scanning methods for immunity analysis » D. Pommerenke, G. Muchaidze, J Koo, Q. Cai, J. Min proc. 18th int Zurich symposium on EMC Munich 2007

Frequency range (MHz)	0,15 to 1	1 to 100	100 to 1 000	1 000 to 6 000
Linear steps (MHz)	≤0,1	≤1	≤10	≤20
Logarithmic steps	≤5 % increment			

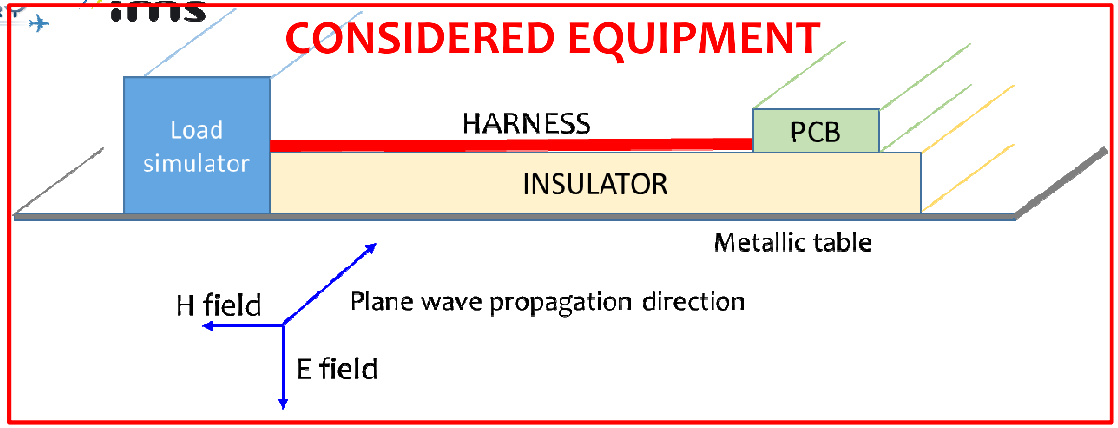
Pros

- **Contactless, no need of specific boards regardless Direct Power Injection**
- Standardized data exchange format (XML)
- More efficient than GTEM ISO 11452-3
- May avoid requalification in case of components obsolescence and second source

Cons :

- Dedicated and normalized for IC only
- **Test duration** : nb xyz positions x frequencies x dwell time => several hours
- **Probes performances limitations** (in low frequencies especially)
- Probe calibration method
- **Highlights failures not seen at the level system**

APPLIED METHODOLOGY



Far Field

Simulation and **measurement** of the induced currents and voltages when the harness and electronic board are illuminated by a plane wave

Near Field

Design of specific immunity probes

Simulation and **measurement** of the induced currents and voltages when an excitation signal is applied to the probe

Comparison of the current and voltage levels on a load placed on a PCB in far field and near field
Determination of the excitation signal level needed at the input of the probe to induce the same voltage level as in far field

Probe design improvement

Validation on industrial case (Op Amp application)

CONTENTS

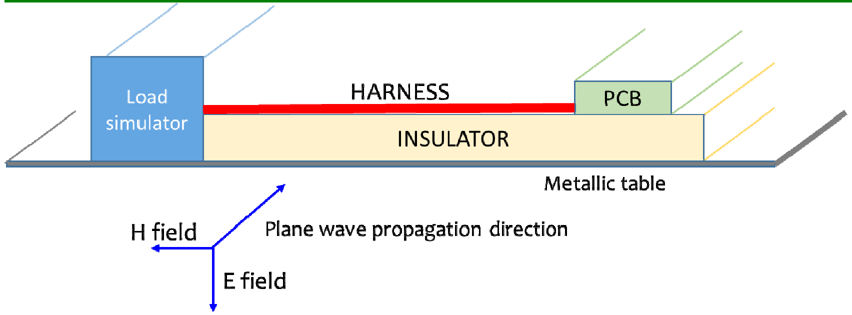
SPECIFIC PROBES DEVELOPMENT
Initial requirements

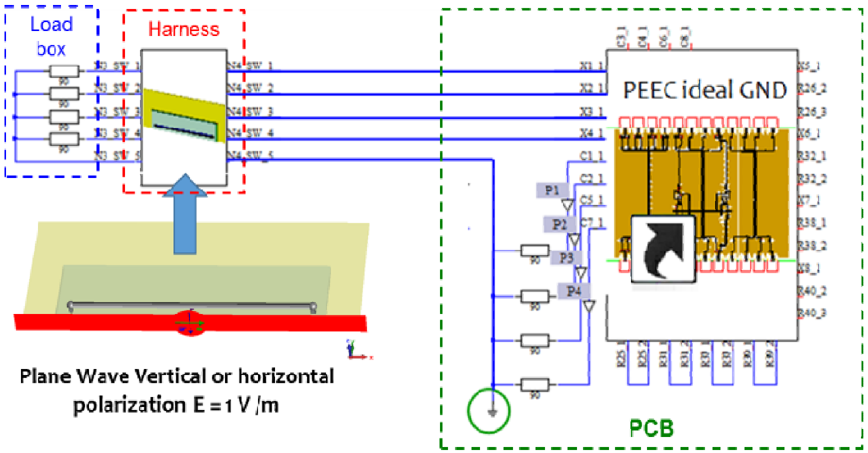
- **Requirement R#1 : Covering Area**
  - Probe must provide a E or H field covering a large area (> 1 cm²)
- **Requirement R#2 : Frequency band**
  - The frequency band covered by the probe must be [100 MHz- 3 GHz[
- **Requirement R#3 : Field**
  - R#3.0 : Field strength : one of the field components (normal or tangential) must be > 500 V/m for E-field and > 1,4 A/m for H-field (RMS value). **These values comes from an analysis of fields generated at PCB level during automotive and aeronautics radiated immunity tests at equipment level**
  - R#3.1 : To avoid spot effect, field uniformity must be < -6 dB. The field uniformity is defined by the ratio standard deviation / median value calculated on the required covering area positioned at 1 mm of the probe. The field uniformity must be calculated for E field and H field in probe's normal and tangential plans @1 GHz.

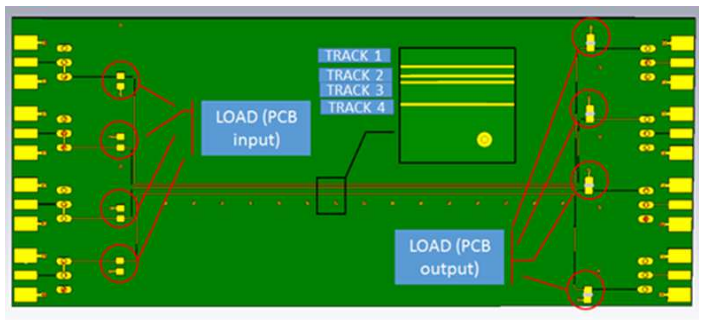
Initial requirements are based on the hypothesis that aiming the same level of E or H-Field at PCB level than during a far field test is satisfying

SPECIFIC PROBES DEVELOPMENT
Requirement on coupling factor (R#4.0)

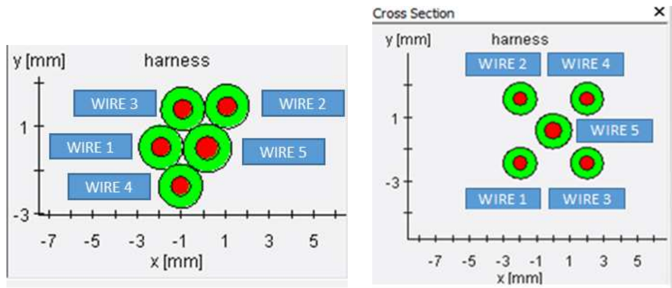
Coupling factor requirement is obtained from the calculation of induced voltages on a PCB load during harness irradiation using a parametric study



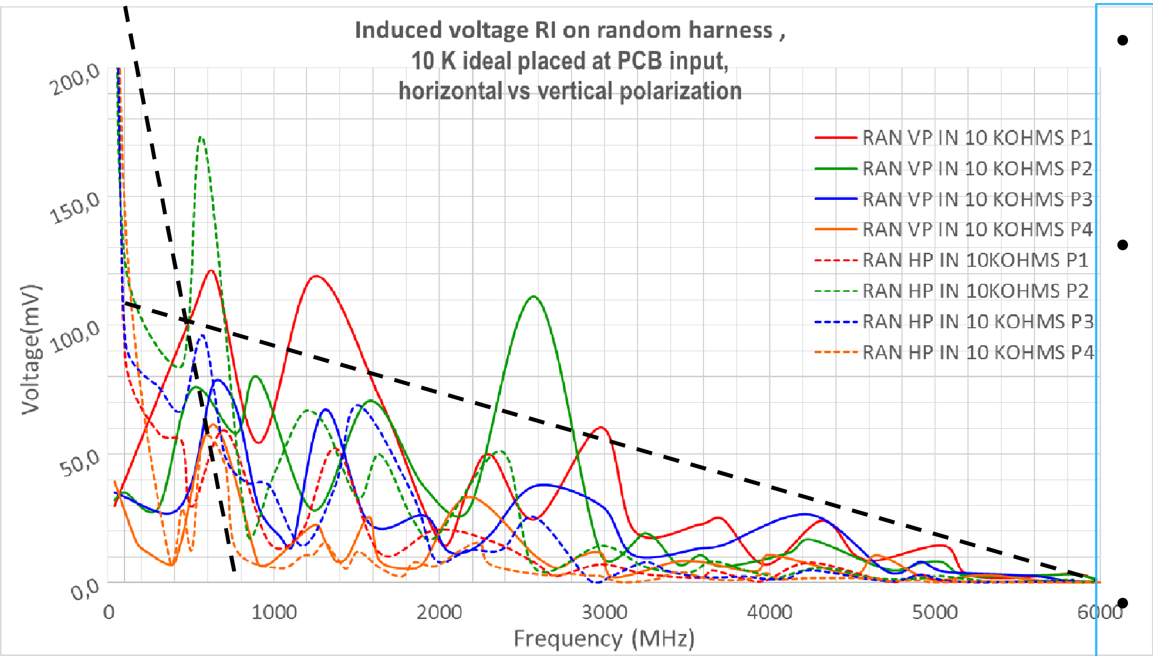




- **Modeling parameters**
- **Harness**
  - Number of wires into the harness : 5, 10, 20
  - Length : 1 500 , 1 800 mm
  - Section and wire rotation : regular without rotation, random with rotation
- **Plane wave**
  - Polarization : vertical, horizontal
- **Load box**
  - Loads : 90 Ω (ideal) fixed on all wires
- **Load PCB**
  - Placement : input, output
  - Values : 90 Ω (ideal) fixed all wires ; 10 kΩ (ideal) fixed all wires ; 10 Ω (ideal) fixed all wires ; Buffer IN, Buffer OUT, 10 pF, 100 pF, 1 nF



SPECIFIC PROBES DEVELOPMENT
Requirement on coupling factor (R#4.0)



- **The value of the load on the PCB has the higher influence :** Higher is load impedance, higher will be the induced voltage
- **Harness resonances** are observable at frequencies corresponding to electric length = (2n +1). λ/4 where λ correspond to the harness length (not seen on the figure because envelop curves are taken)
- The voltages induced by the **direct irradiation of the PCB are negligible** compared to those generated by harness irradiation

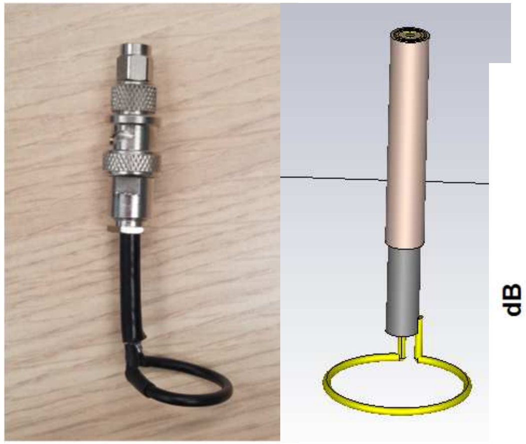
Trend curve equation

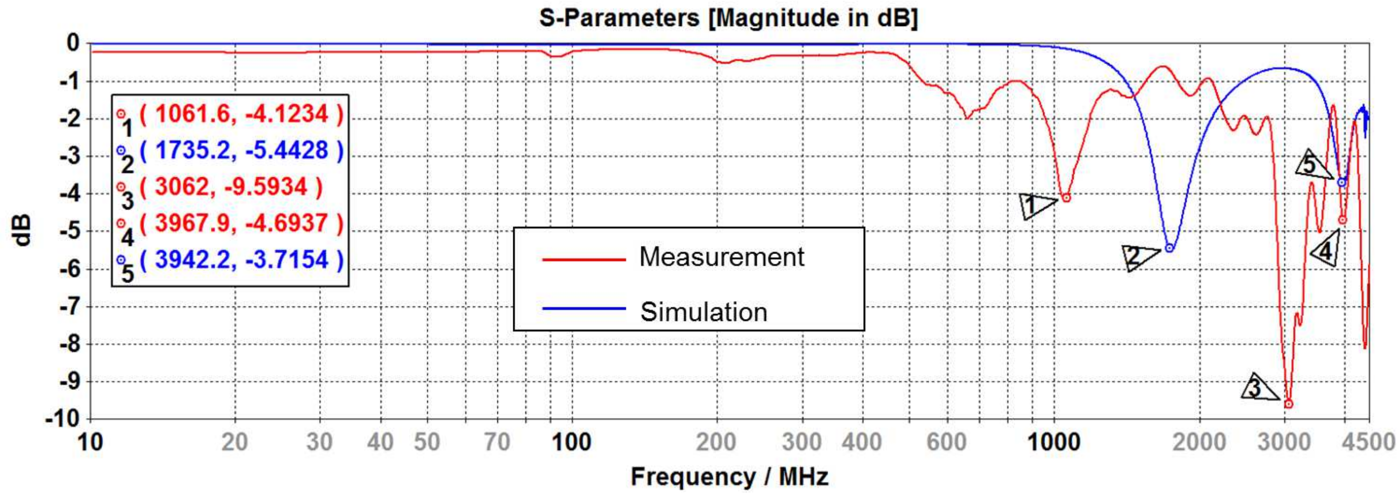
	Frequency	
	100 – 500 MHz	500 – 3000 MHz
Required PCF	$- 2.5\ 10^{-4}$ F(MHz) + 0.225	$- 1.82\ 10^{-5}$ F(MHz) + 0.109

Assuming in first approximation required coupling factor = Induced voltage / applied voltage

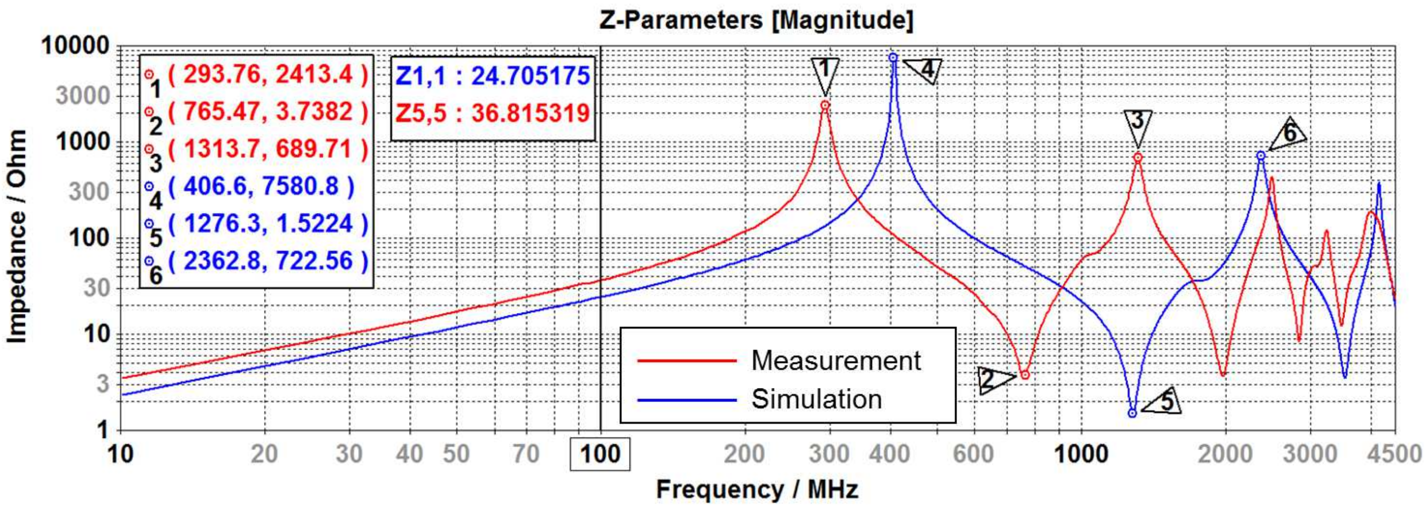
A trend curve could be extracted from worst case saying **whatever the real load, plane wave polarization and harness will be, the induced voltage will not overtake this limit**

SPECIFIC PROBES DEVELOPMENT
Wire loop H-field probe design

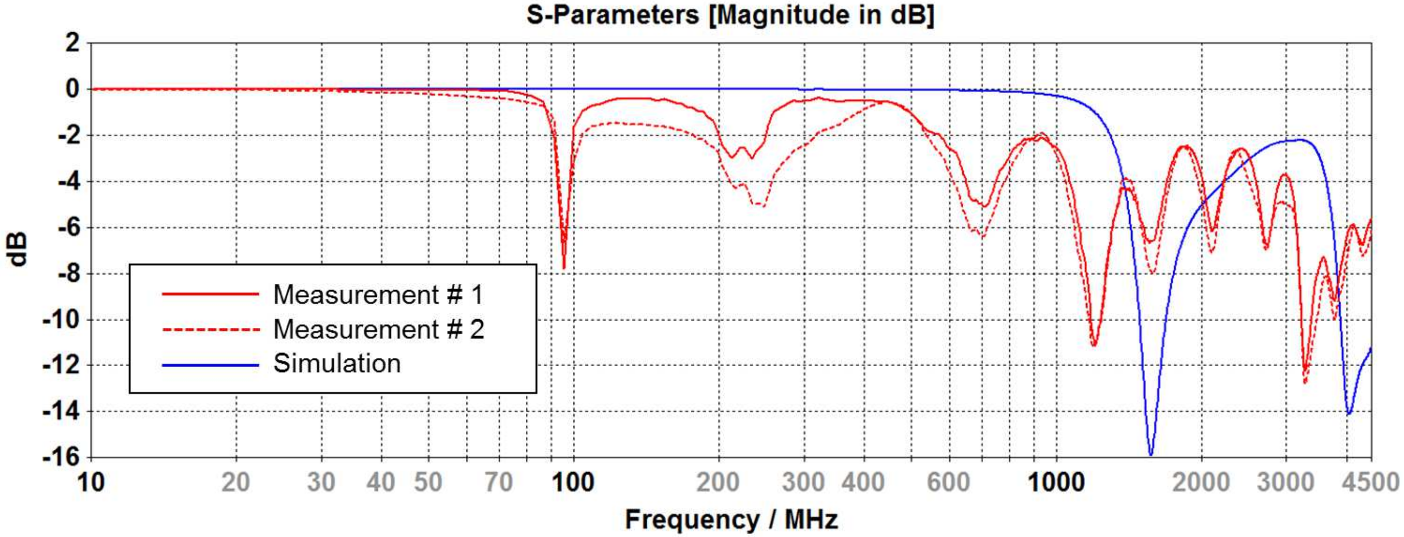




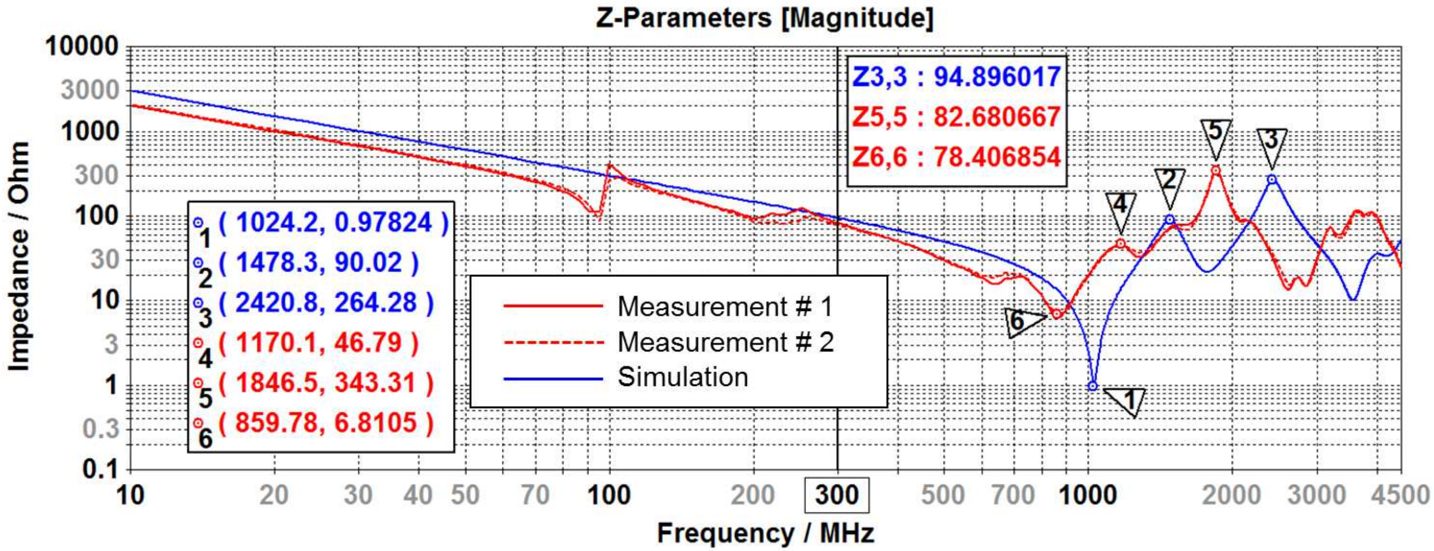
INDUCTIVE COUPLING



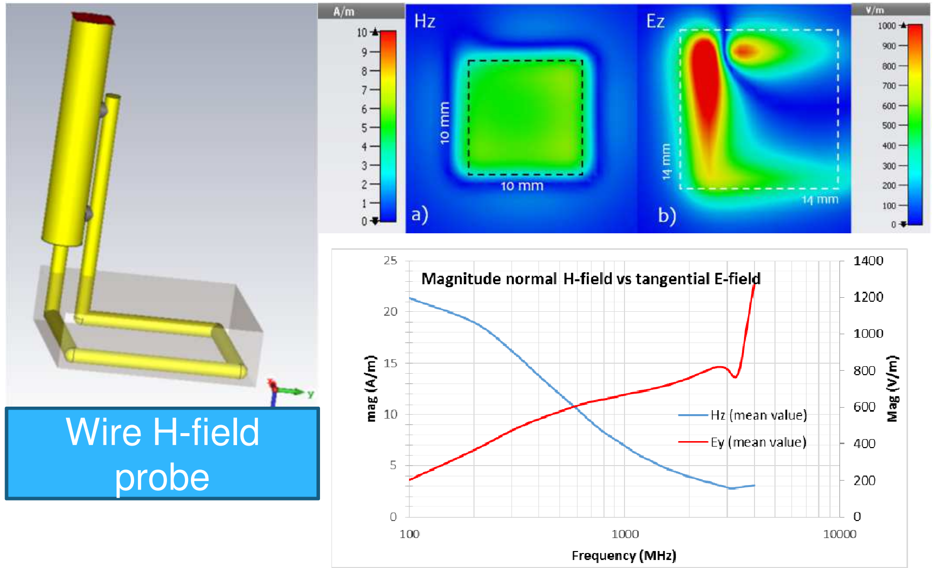
SPECIFIC PROBES DEVELOPMENT
conical E-field probe design



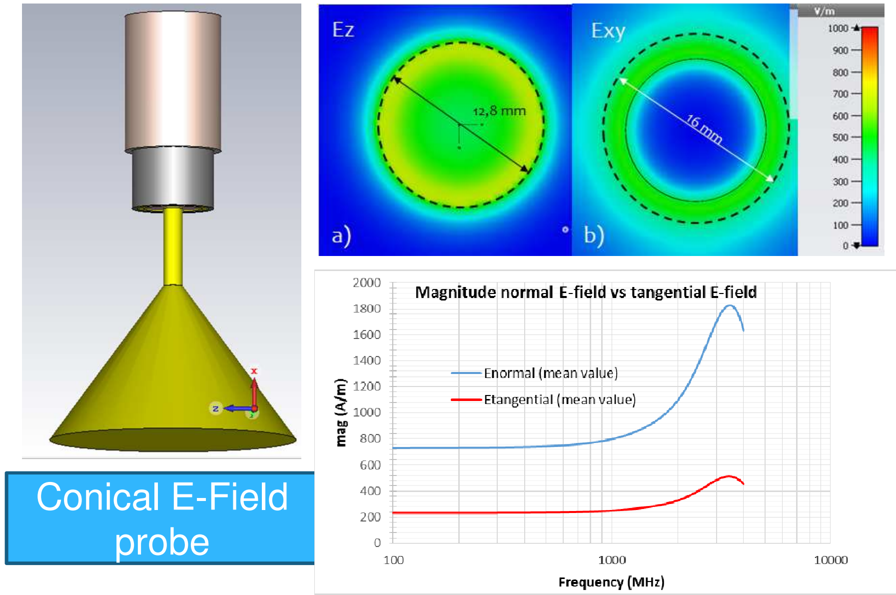
CAPACITIVE COUPLING



SPECIFIC PROBES DEVELOPMENT
Initial requirements validation



Wire H-field probe



Conical E-Field probe

Wire H-field Probe

Pros

- High Hz field strength 7.38 A/m@1 GHz
- Homogeneity of Hz field

Cons

- Inhomogeneity of Ez and Exy fields (spot effect)

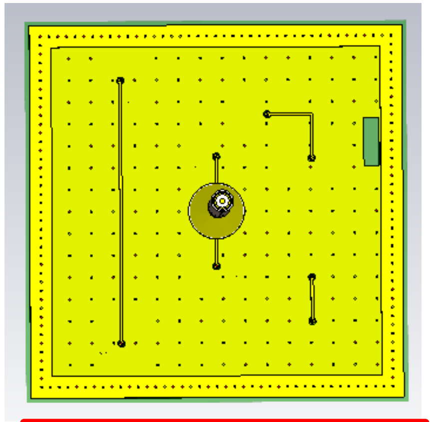
Conical E-field Probe

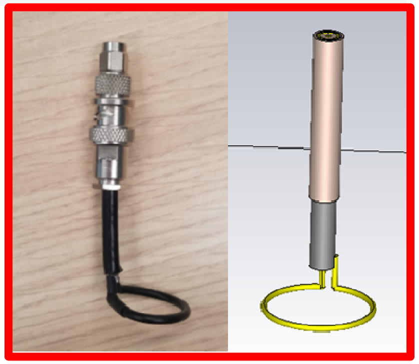
Pros

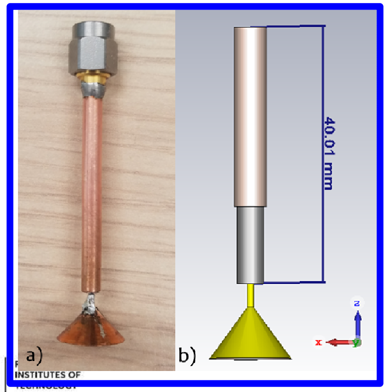
- High Ez-field strength 800 V/m@1 GHz
- Homogeneity of Ez-Field
- Negligible H-Field

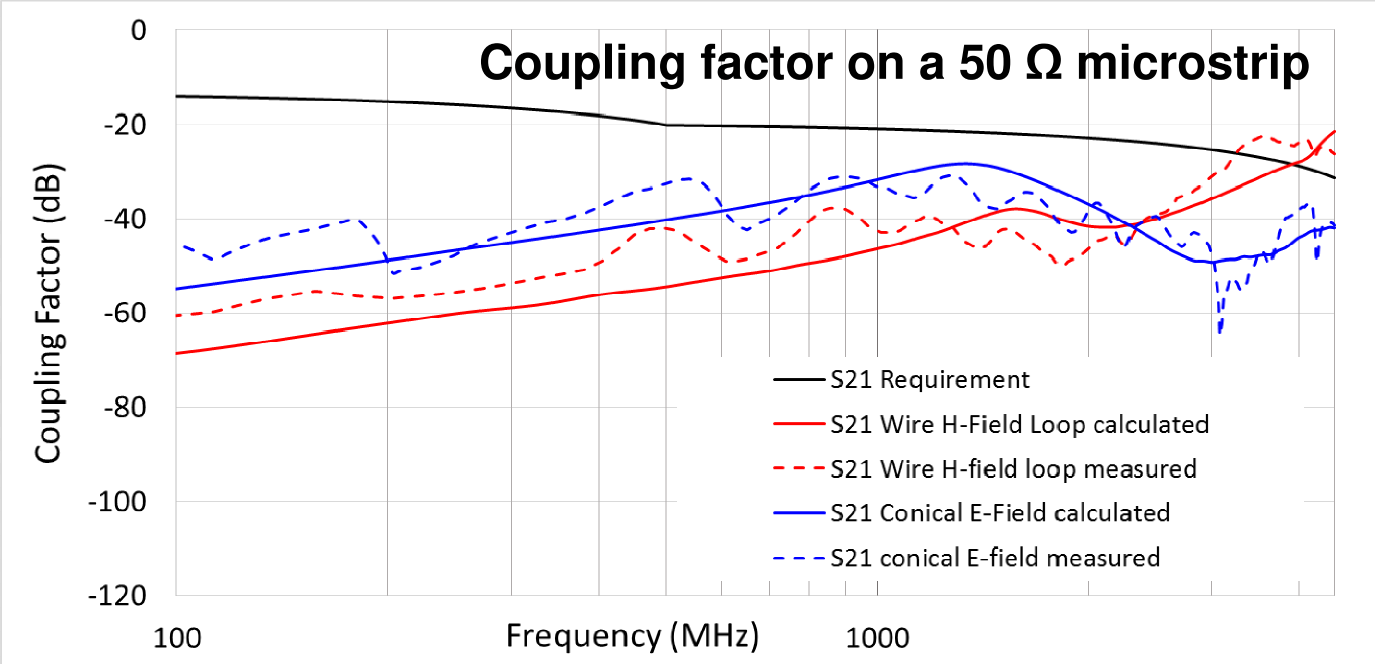
No Cons

SPECIFIC PROBES DEVELOPMENT
coupling factor validation









Conical E probe shows the best coupling factor from 100 MHz up to 2 GHz.
Wire H-Field probe shows the best coupling factor above 2 GHz

Coupling factor between 100- 800 MHz is low (< - 40 dB)

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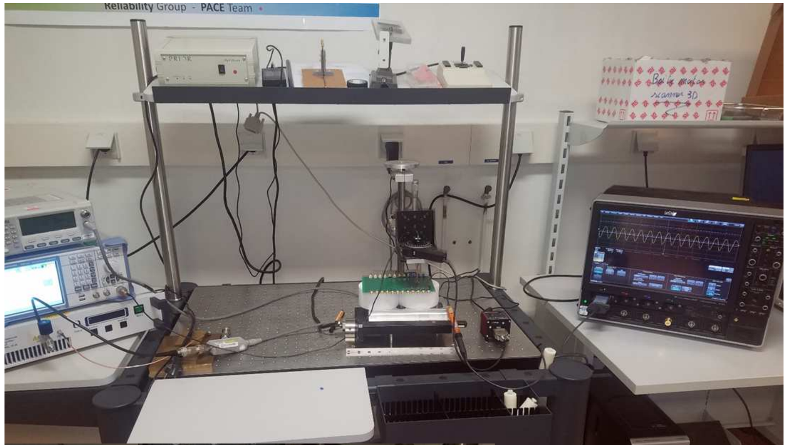
CONCLUSION

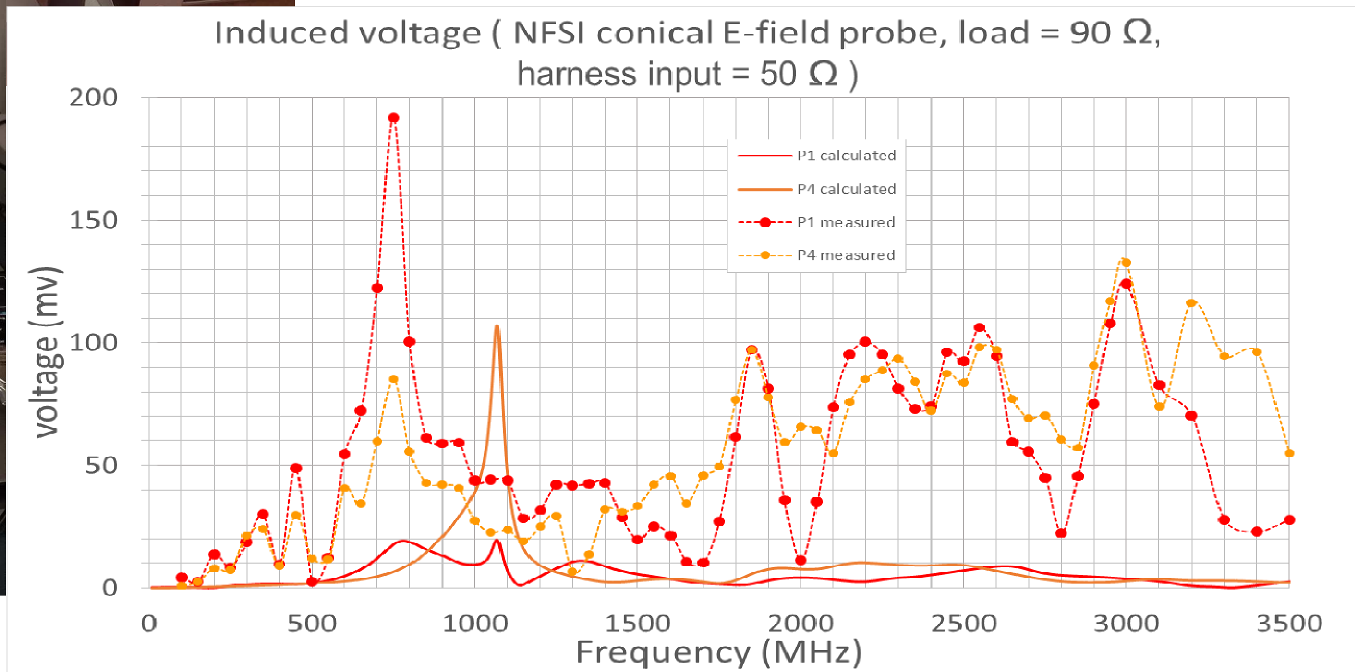
Calculation of the induced voltages



Voltages measured with a differential probe on a 90 Ω load placed on PCB demonstrator

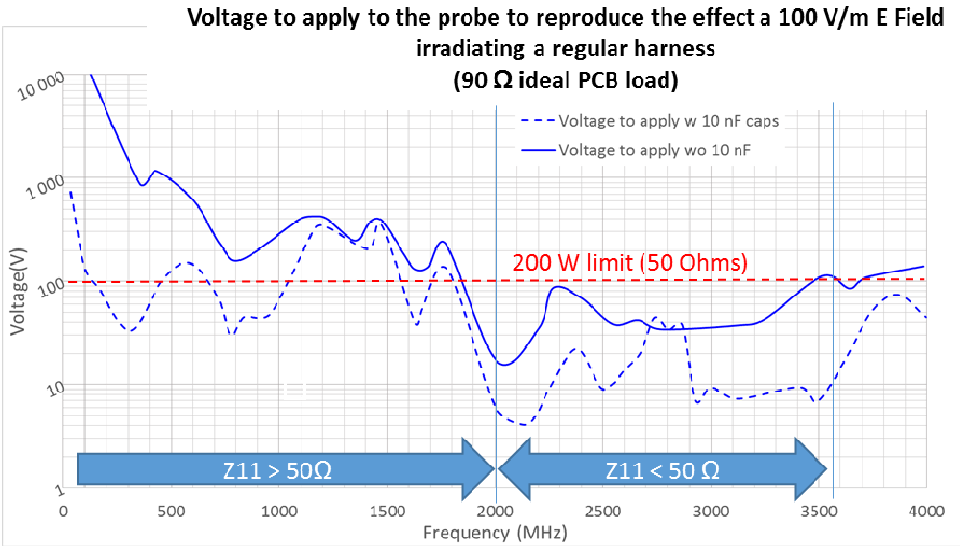
- The measurements are higher than the calculation seems indicating a better coupling than expected ?

High discrepancies between the calculation and the measurements



CONCLUSION & PERSPECTIVES

- A Probe Coupling Factor requirement has been originally determined from Far Field simulation at equipment level
- Some probe design have been compared in term of radiated field strength and homogeneity and in term of coupling factor on 50 Ω microstrip



ISSUES TO SOLVE

- Measured and modeled **probe coupling factor are far away from the requirement**
- Consequently, **the necessary power** to be applied on the probe to reproduce the effect of a 100 V/m E-field **is practically not reachable** in an **affordable** way : adding filtering capacitors at connector level will be helpful but **PCF must be improved for F < 1 GHz**
- **Discrepancies between measurements and simulation must be solved**


Thanks for your attention
« Shayma by Duriera »