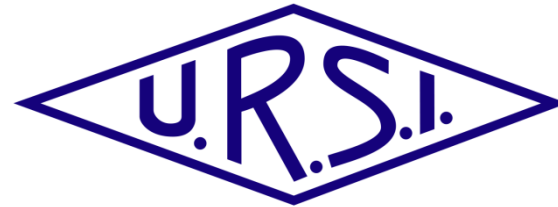




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Proficiency testing in EMC

URSI Commission E

Author

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3rd Int. Workshop on Metrology for Aerospace (June 2016, Firenze)
Special Session on "URSI in Italy"

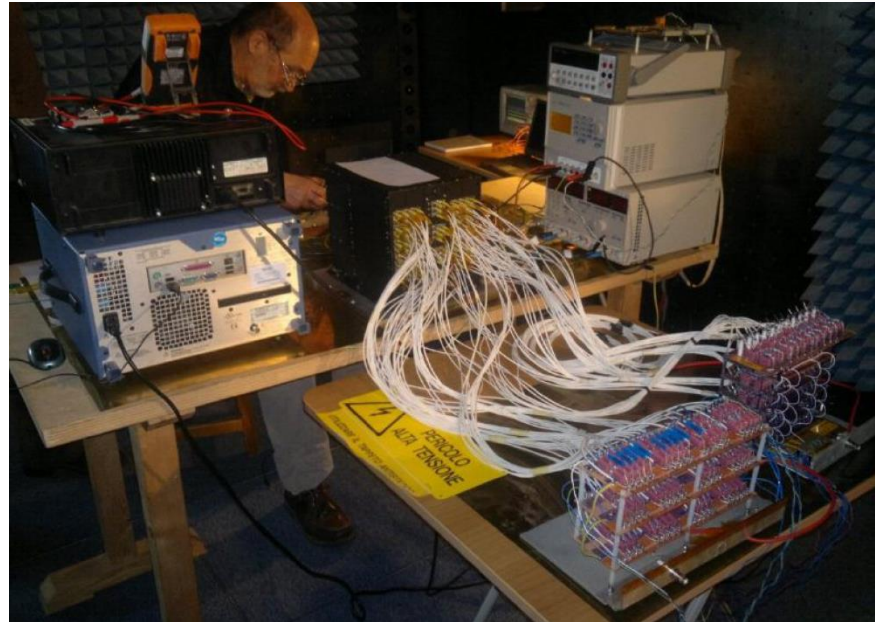
Outline

- 'Quality' issues in EMC testing
- Introduction to Proficiency Testing
- Peculiar aspects of Proficiency Testing in EMC
- Results of Proficiency Test activity in EMC (example)
- Conclusive remarks

'QUALITY' ISSUES IN EMC TESTING

EMC testing of *critical* equipment

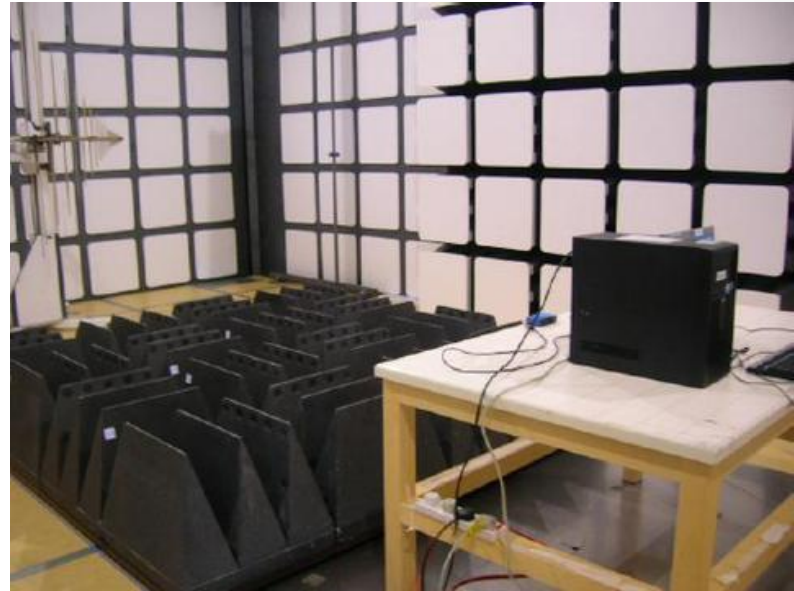
- EMC testing of equipment for military, avionic and space applications must be rigorous due to the safety and economic consequences of a possible failure due to EMI



Conducted susceptibility testing of the high-voltage supply system for the CALET apparatus, for the detection of cosmic rays on-board of the International Space Station (reproduced from IFAC-TSRR vol. 5 (2013) 69-165, authored by Beni et alii)

EMC testing of *uncritical* equipment

- EMC testing of mass produced information technology, household, lighting, automotive ... equipment must be rigorous for the economic consequences of a market withdrawal due to non compliance with EMC requirements set by national and international laws



Radiated immunity testing of a personal computer

Testing has to be rigorous ... ALWAYS!

What does it mean 'rigorous'?

- Rigorous testing implies reproducible test results
- Reproducibility is achieved through:
 - Training and qualification of testing personnel
 - Correct implementation of test methods
 - Use of adequate test equipment and facilities
 - Adoption of measures for quality assurance of test results
 - Traceability of measurement results
- Robustness of the test method, i.e. insensitivity of test results to the allowable variations of test setup

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INTRODUCTION TO PROFICIENCY TESTING

Motivation for Proficiency Testing

- Proficiency testing (PT) is an experimental activity through which test labs can:
 - Verify the correct operation of measurement systems
 - Confirm the qualification of personnel
 - Verify the correct evaluation of measurement uncertainty
- PT pairs documental analysis in providing evidence of technical competence

Need for an EMC PT provider in Europe

- Accredited test* labs are required to participate in PTs in order to provide evidence of assurance of the quality of test results (clause 5.9.1 of ISO/IEC 17025)
- No accredited** PT provider is available in Europe having EMC tests in the scope

* Accredited to ISO/IEC 17025

** Accredited to ISO/IEC 17043

Contribution of UNIFI-INRIM

- The University of Florence (UNIFI), in collaboration with the Italian National Metrological Institute (INRIM) coordinates proficiency testing activity in EMC since 2012
- 4 EMC proficiency tests were successfully carried out and 2 are running
- All accredited Italian test labs having the IEC-CISPR radiated and conducted test methods in the scope are participating in these PTs
- Scientific aspects of PT activity are described in great detail here (IEEE Trans. on EMC)
 - (2014) C. F. M. Carobbi, A. Bonci, M. Cati, C. Panconi, M. Borsero and G. Vizio, “Design, Preparation, Conduct and Result of a Proficiency Test of Radiated Emission Measurements”, DOI 10.1109/TEMC.2014.2326732
 - (2016) C. F. M. Carobbi, A. Bonci, M. Cati, C. Panconi, M. Borsero and G. Vizio, “Proficiency Testing by Using Traveling Samples With Preassigned Reference Values”, DOI 10.1109/TEMC.2016.2573751
- See also www.emc.unifi.it

PT activity in few words

- The **Coordinator** of the PT **issues** a document (**scheme**) regulating the PT (admission rules, logistics, measurement procedure, reporting, confidentiality, complaints, ...)
- The **Coordinator** provides a **travelling Sample** that is circulated among Participants in the PT
- Each **Participant measures** the **characteristic quantity** generated by the Sample and communicates the measurement result (measured value and uncertainty) to the Coordinator
- The **Coordinator processes measurement results**
- The **Coordinator compares** the **measurement result** of each Participant **with the reference value** in order to assess Participant's performance

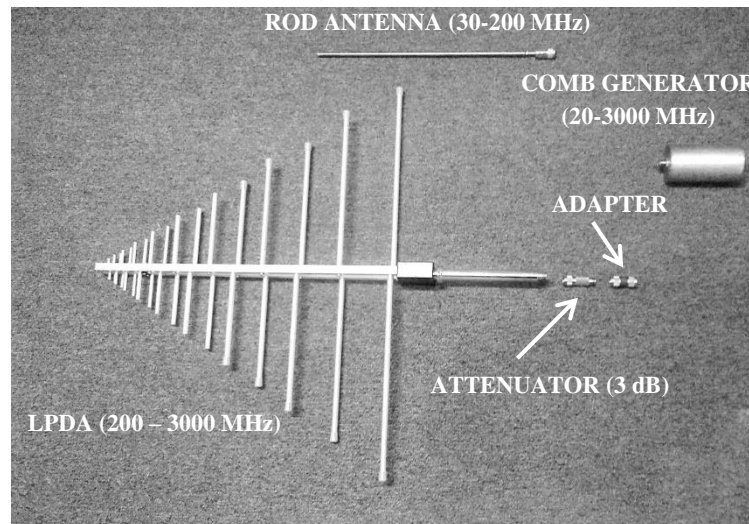
Standards regulating PT activity

- **ISO/IEC 17043:2010**, “Conformity assessment — General requirements for proficiency testing”
 - Part 4 – Technical requirements
 - Part 5 – Management requirements
- **ISO 13528:2015**, “Statistical methods for use in proficiency testing by interlaboratory comparison”
 - Determination of the assigned value and its standard uncertainty
 - Calculation of performance statistics

PECULIAR ASPECTS OF PROFICIENCY TESTING IN EMC

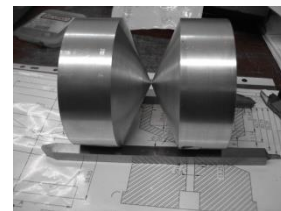
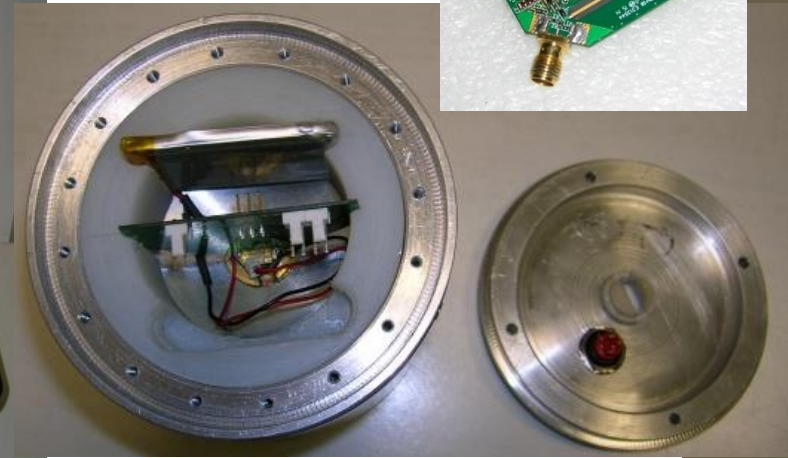
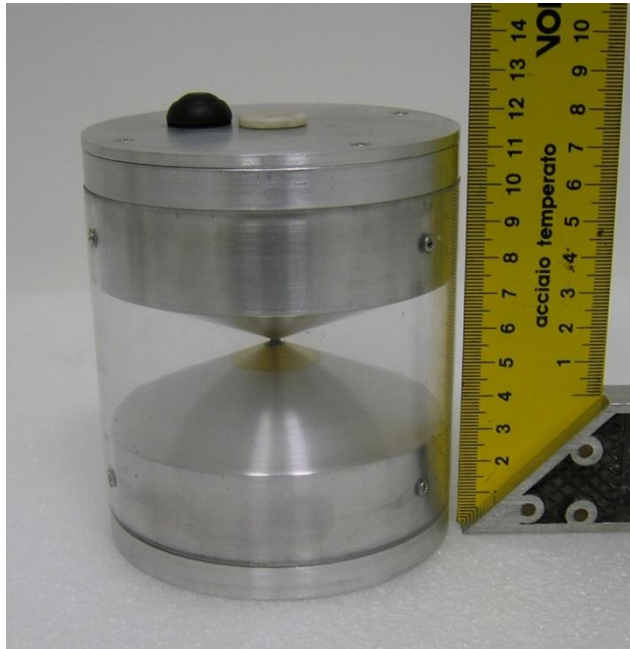
Travelling Sample

- **Stable**
- **Broadband** but with adequate **frequency resolution**
- **Easily transportable** (light and compact)

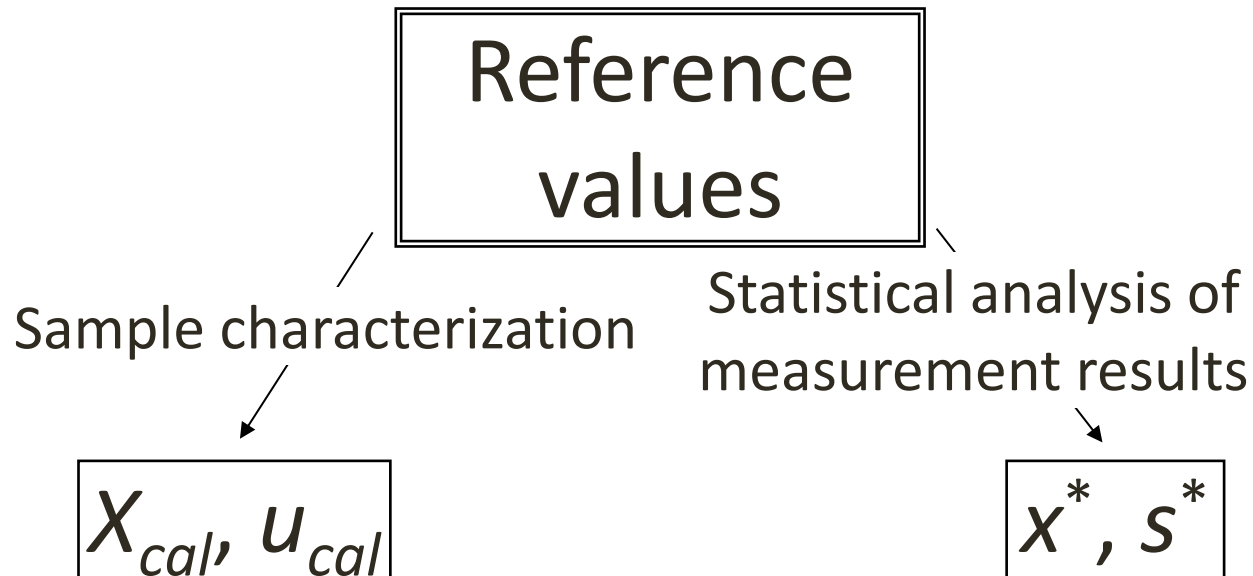


**Travelling Sample for the 30 to 3000 MHz frequency range
(Radiated Emission)**

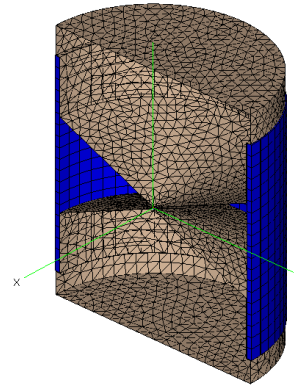
Travelling Sample for the 30 to 6000 MHz frequency range (Radiated Emission)



Reference values

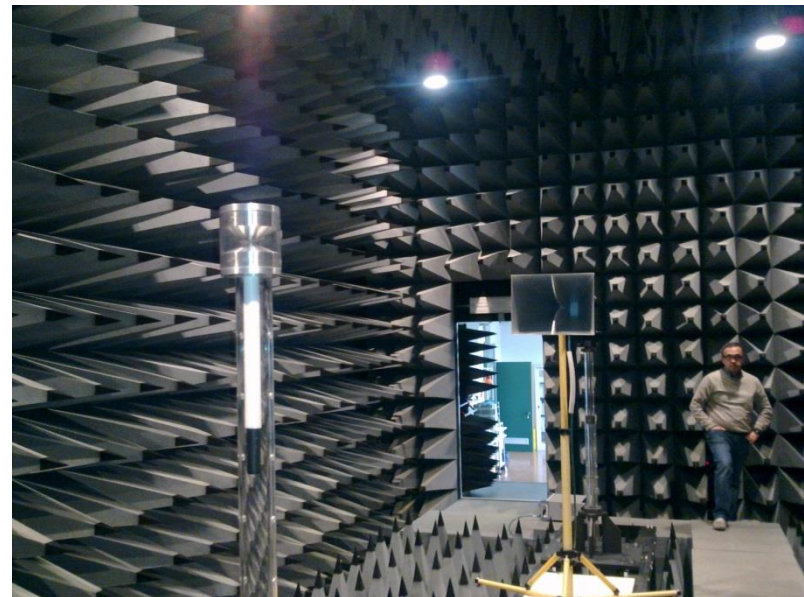
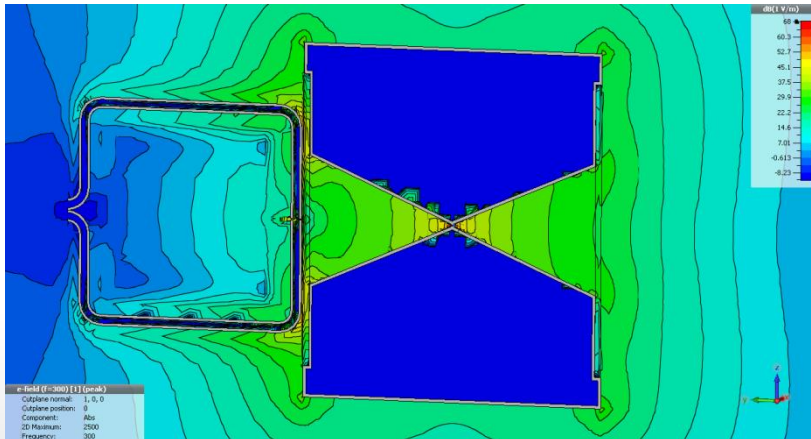


Sample characterization



The **e.m. model of the antenna is validated** through near field (LF) and far field (HF) measurements.

E-field is predicted by using the e.m. model and source calibration.



Statistical (robust) analysis

$x_1, x_2, \dots, x_i, \dots, x_p$ } Raw data (p participants)

$x^* = \text{median of } x_i \quad (i = 1, 2, \dots, p)$

$s^* = 1,483 \text{ median of } |x_i - x^*| \quad (i = 1, 2, \dots, p)$

} Initial reference value

$\delta = 1,5s^*$

$x_i^* = \begin{cases} x^* - \delta, & \text{if } x_i < x^* - \delta \\ x^* + \delta, & \text{if } x_i > x^* + \delta \\ x_i, & \text{otherwise} \end{cases}$

} Transformed set of data

$x^* = \sum x_i^* / p$

$s^* = 1,134 \sqrt{\sum (x_i^* - x^*)^2 / (p - 1)}$

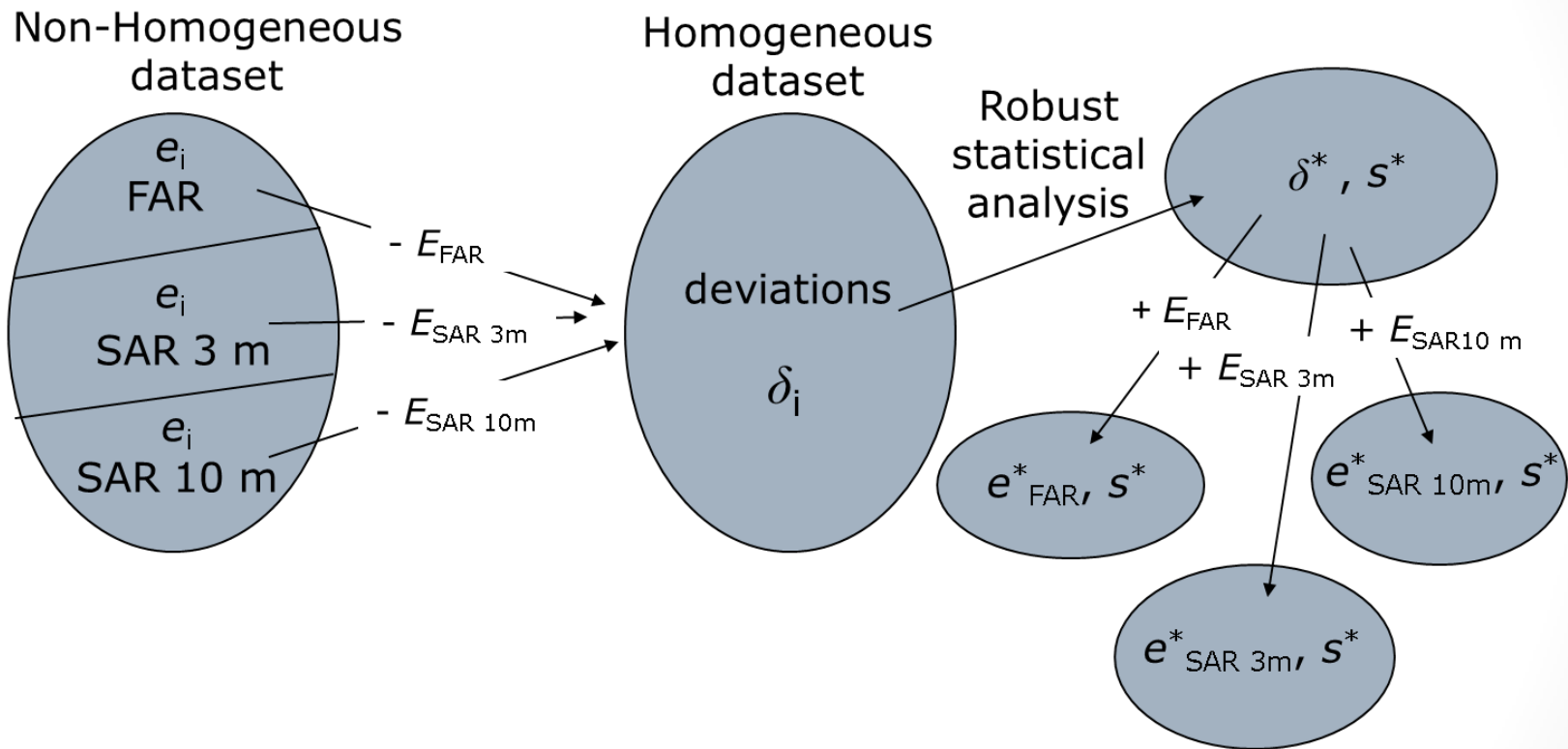
} New reference value
(iterative algorithm)



Comment on reference values

- Reference value from robust analysis:
 - Easy to obtain (calculation)
 - Need to wait until the end of the PT (or that a sufficiently large amount of data is collected)
- Reference value from sample characterization
 - Requires an important effort from the Coordinator (simulations and traceable measurements by using measuring instrumentation and facilities not significantly better or even worse than that of a good testing lab)
 - Risk that the reference values (from robust analysis and from sample characterization) significantly differ each other !!
 - Available before the start of the PT → immediate response to the participant
 - For radiated emissions: Once that the electromagnetic model is validated it can be used for predicting the E-field generated by the Sample in different facilities and at different distances → inhomogeneous data can be processed together

Inhomogeneous data



$E_{FAR}, E_{SAR\ 3m}, E_{SAR\ 10m}$ = predicted reference values

Performance statistics

- Performance statistics are used to assess participant's performance
- In the PTs organized by UNIFI-INRIM a performance statistic is used to evaluate the compatibility between the two reference values (hence, to assess Coordinator's performance!)
- Performance statistics are essentially a standard (ISO 13528) measure of relative deviation

Performance statistic ζ (Participant)

- Performance statistic ζ (clause 7.7 of ISO 13528) that the Coordinator applies to the Participant providing the measurement result x_i with standard uncertainty u_{xi}

$$\zeta_i = \frac{x_i - X}{\sqrt{u_{xi}^2 + u_X^2}} \quad \left\{ \begin{array}{l} X = X_{cal}, u_X = u_{cal} \\ X = x^*, u_X = \frac{1,25 \cdot s^*}{\sqrt{p}} \end{array} \right.$$

$$\left\{ \begin{array}{l} 2 < |\zeta_i| < 3 \Rightarrow \text{warning} \\ 3 < |\zeta_i| \Rightarrow \text{action} \end{array} \right.$$

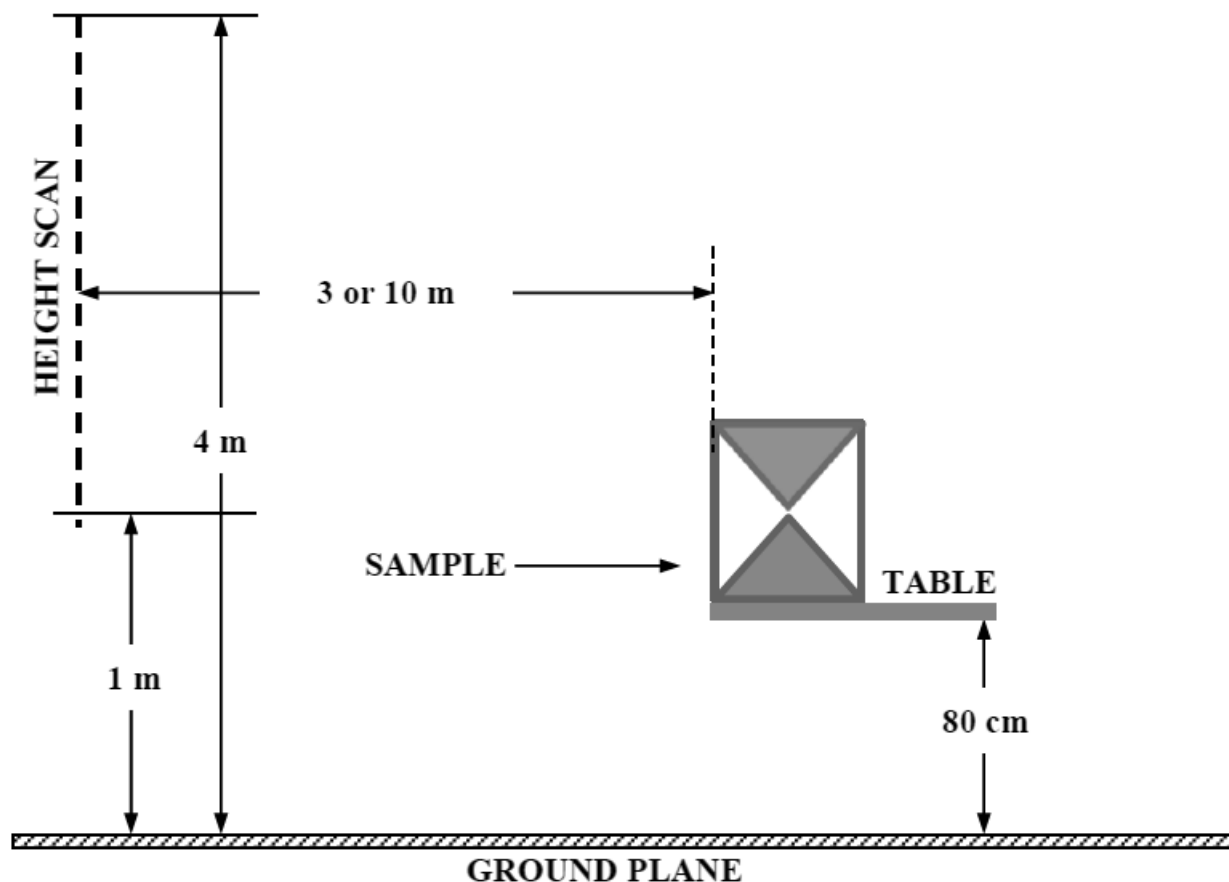
Performance statistic z' (Coordinator)

- Performance statistic z' (clause 5.7 of ISO 13528) that the Coordinator applies as self-check

$$z' = \frac{X_{cal} - x^*}{\sqrt{u_{cal}^2 + \left(\frac{1,25 \cdot s^*}{\sqrt{p}} \right)^2}} \quad \begin{cases} 2 < |z'| < 3 \Rightarrow \text{warning} \\ 3 < |z'| \Rightarrow \text{action} \end{cases}$$

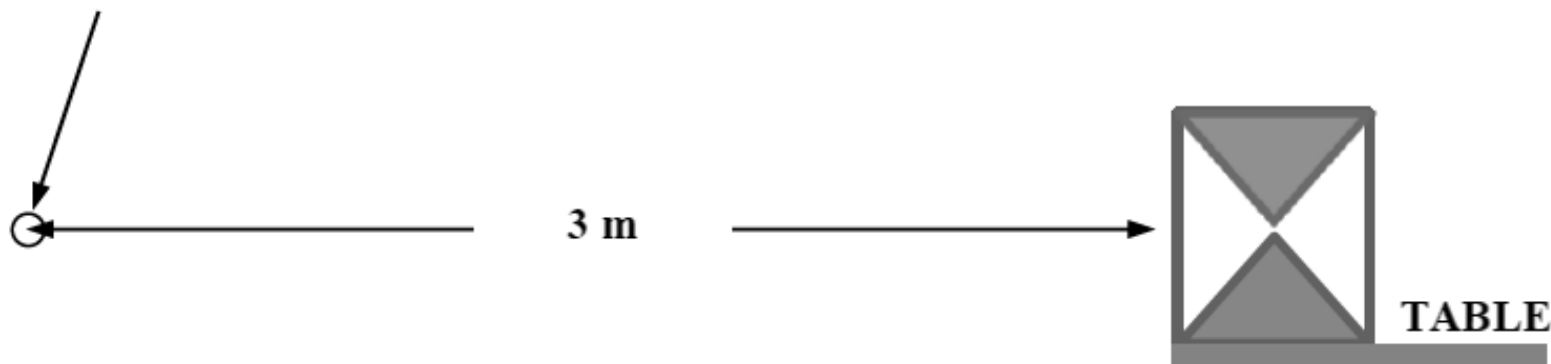
RESULTS OF PROFICIENCY TEST ACTIVITY (EXAMPLE)

Measurement procedure in a SAR (30 MHz to 1000 MHz)



Measurement procedure in a FAR (30 MHz to 6 GHz)

Measure the field
here

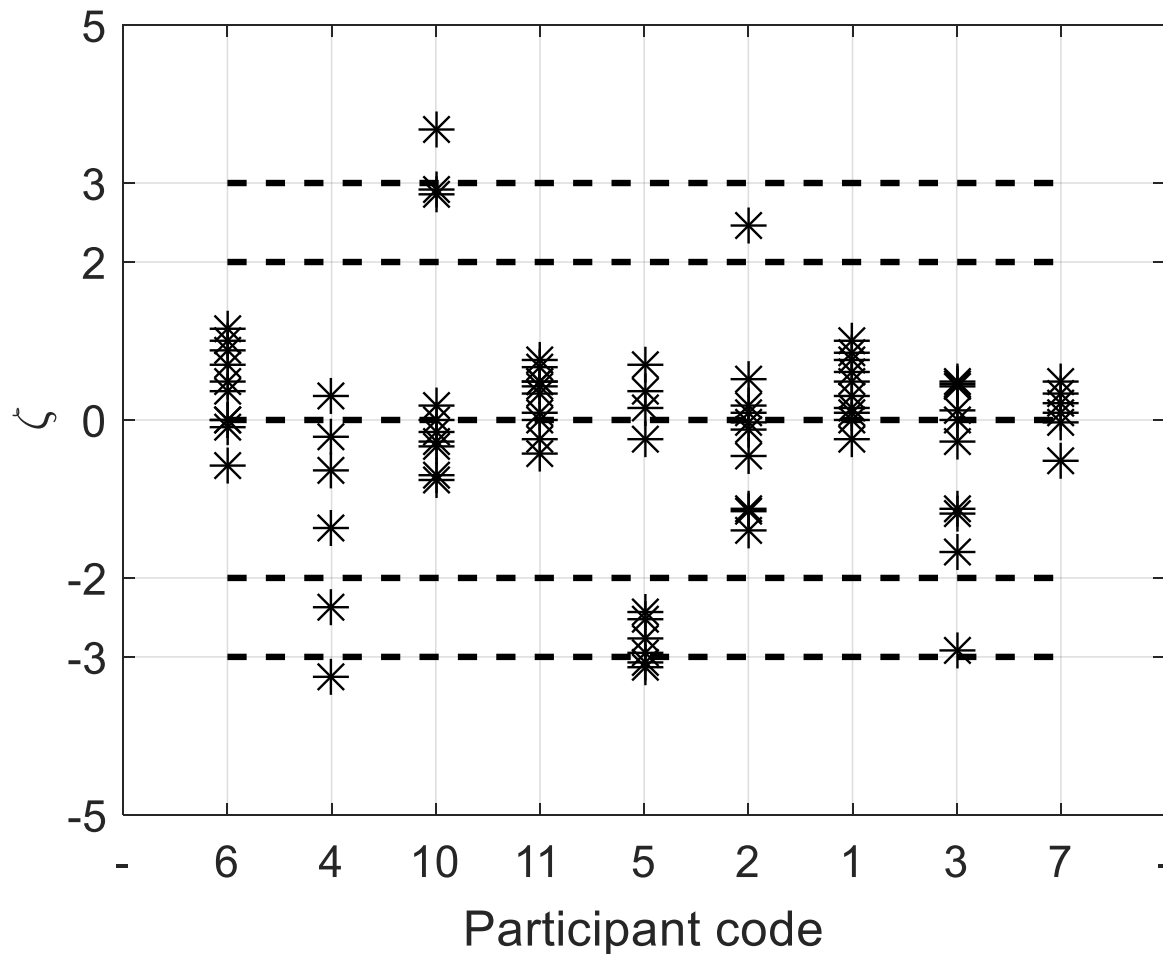


Ref. vales – comparison

f [MHz]	δ^* [dB]	s^* [dB]	u [dB]	z'
50	0.1	1.9	1.1	-0.1
150	-0.5	2.0	1.1	0.4
250	-0.9	1.2	1.1	0.7
500	-0.5	1.2	1.9	0.3
750	-1.1	0.7	1.9	0.6
950	-2.2	1.9	1.9	1.1
2000	0.0	1.0	1.4	0.0
3000	-0.7	2.4	1.4	0.4
5000	-1.1	2.2	1.4	0.7
6000	-1.0	2.1	1.4	0.6

$p = 9$ participants

Performance statistic ζ



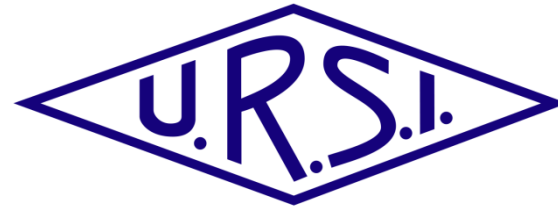
Conclusive remarks

- Organization and management of a EMC PT is a multidisciplinary activity, involving measurement, simulations, statistics and which is tightly connected with standards development and accreditation of test labs
- Important issues such as confidentiality, logistics, management of complaints, relation between Coordinator and Participants and economical aspects were not dealt with during this presentation but need careful analysis
- Important point: only 'robust' test methods can be submitted to PT activity, otherwise reproducibility issues caused by the test method affect participants' performance
- Test methods whose result is assessed through a qualitative criterion (e.g., immunity test methods) do not easily lend themselves to PT



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Thank you for your kind attention

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