UNIVERSITÀ DEGLI STUDI FIRENZE
DINFO
DIPARTIMENTO DI INGEGNERIA DELL'INFORMAZIONE

Result of the Proficiency Test of Radiated Emission SAR/FAR 30 – 1000 MHz

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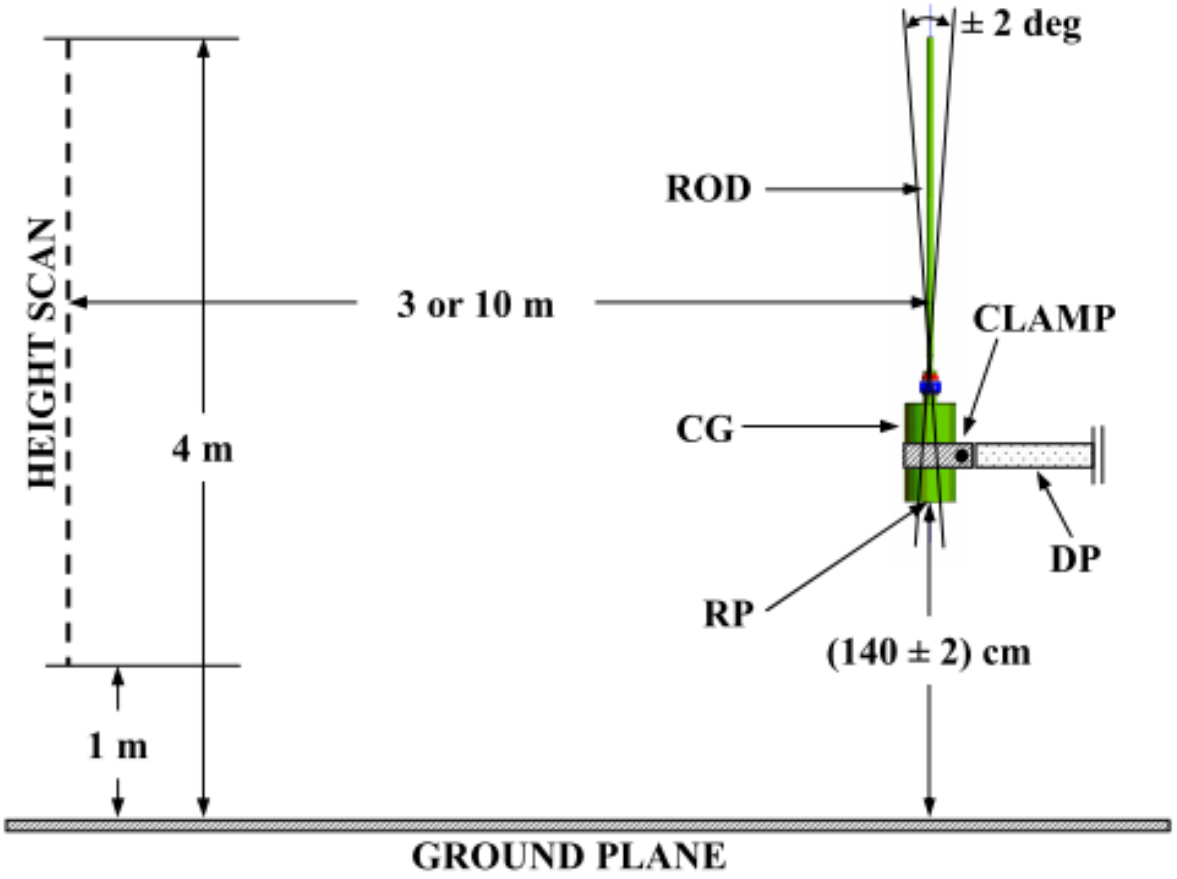
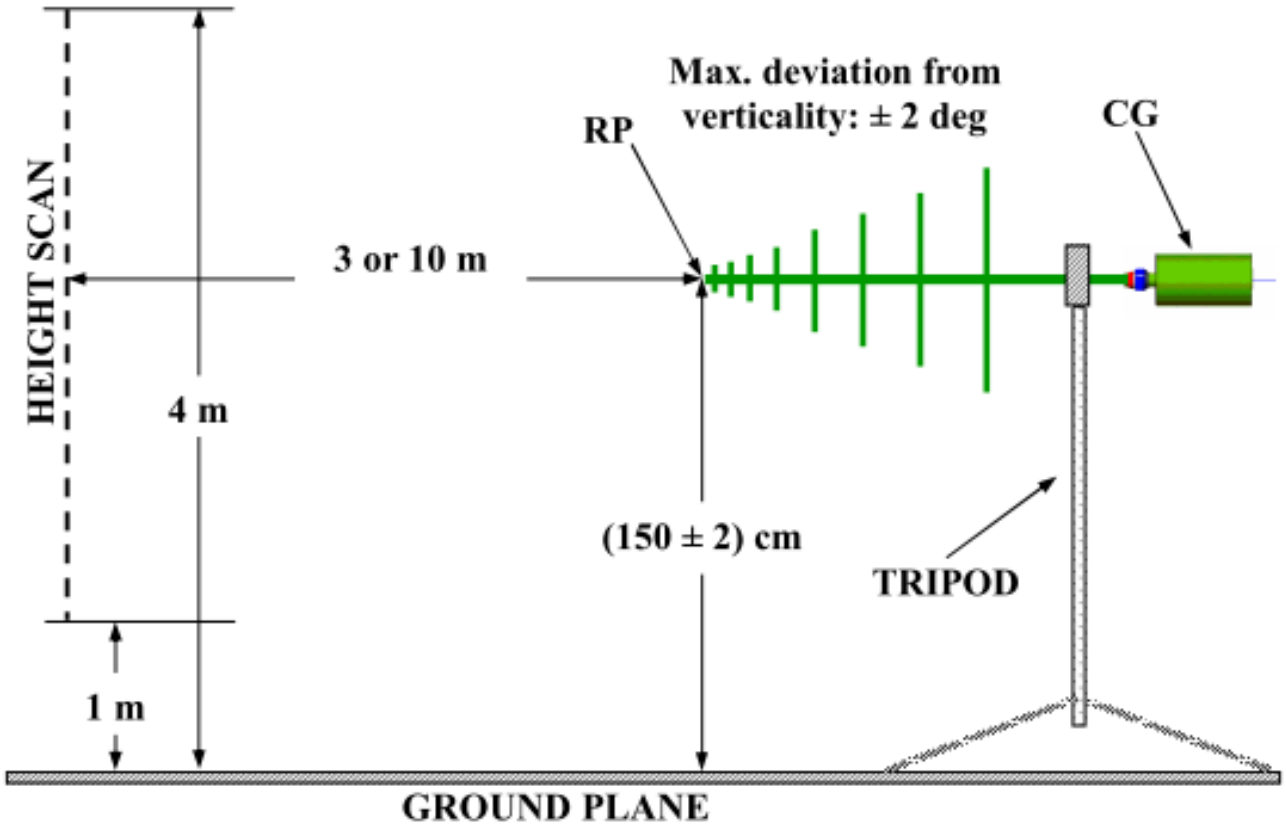
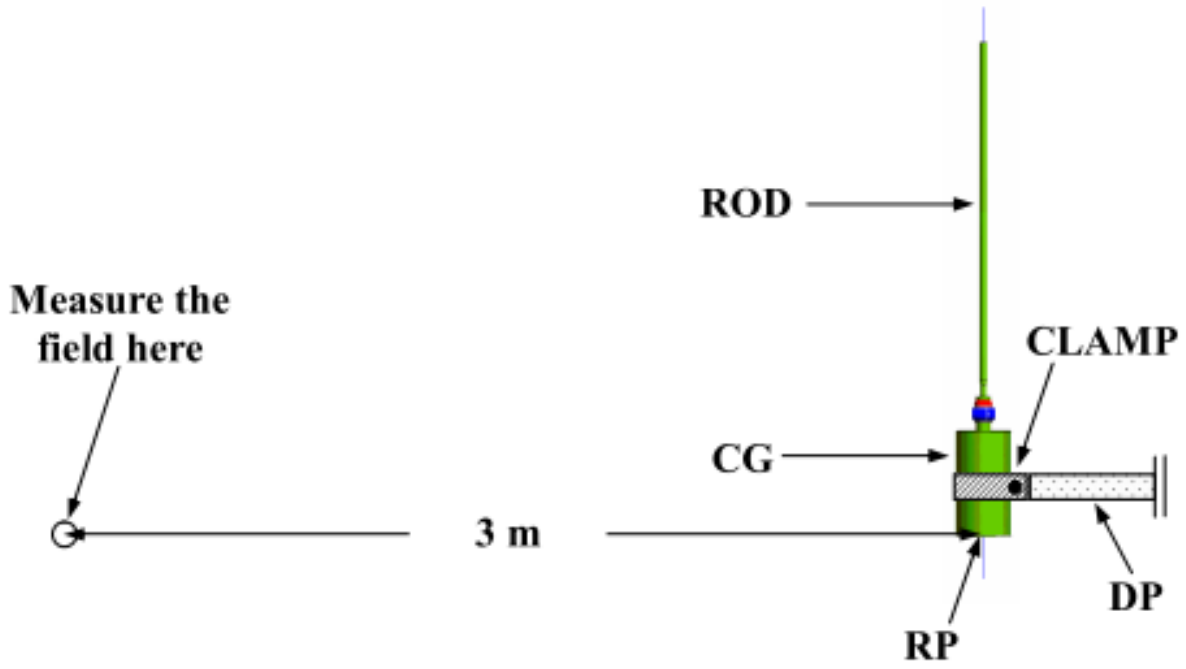
Measurement setup 30-200 MHz, semianechoic room (3 or 10 m)



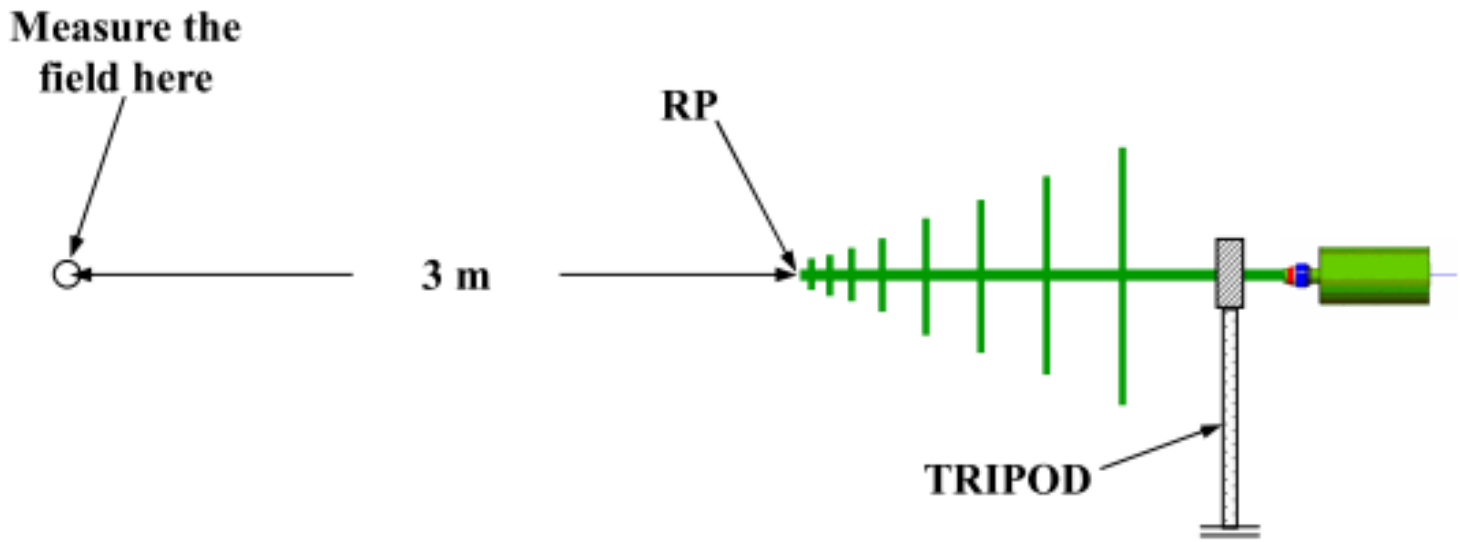
Measurement setup 200-1000 MHz, semianechoic room (3 or 10 m)



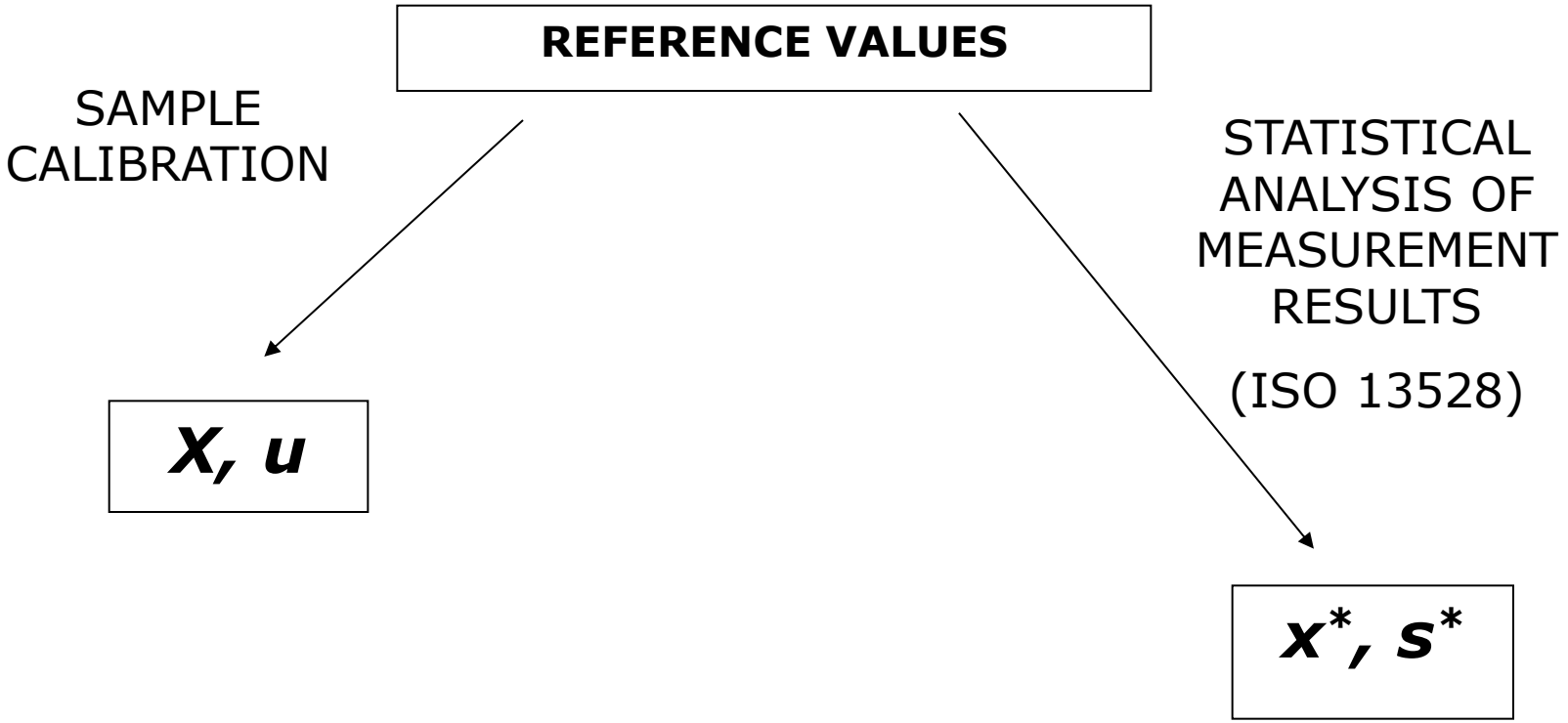
Measurement setup, 30-200 MHz, fully anechoic room (3 m)



Measurement setup, 200-1000 MHz, fully anechoic room (3 m)



Reference Values



Different Test Sites

- Small number of participants having SAR 10 m and FAR test sites:
  - SAR 10 m -> 3 sets of data
  - SAR 3 m -> 12 sets of data
  - FAR -> 4 sets of data
- If we had designed a PT for each type of test site we would not have achieved the minimum number of participants (5) for the validity of the statistics (case of SAR 10 m and FAR).

Analysis of the Deviations between Measurement Results and Reference Values

- Solution:
  - Consider the deviation $\delta_i = x_i - X$ between the measurement result x_i provided by participant i and the a-priori reference value X assigned by the Coordinator for each type of test facility (SAR 3 or 10 m, FAR).
  - Deviation δ_i can be calculated because it is a-priori known the reference value X for each type of test facility.

Example

- Suppose that the measurement result provided by the laboratory at a specific frequency in a FAR is x_i = 73.0 dB(μV/m) and the corresponding reference value is X = 72.7 dB(μV/m)
- The Coordinator calculates the deviation between the result provided by the Laboratory and the reference value, obtaining:

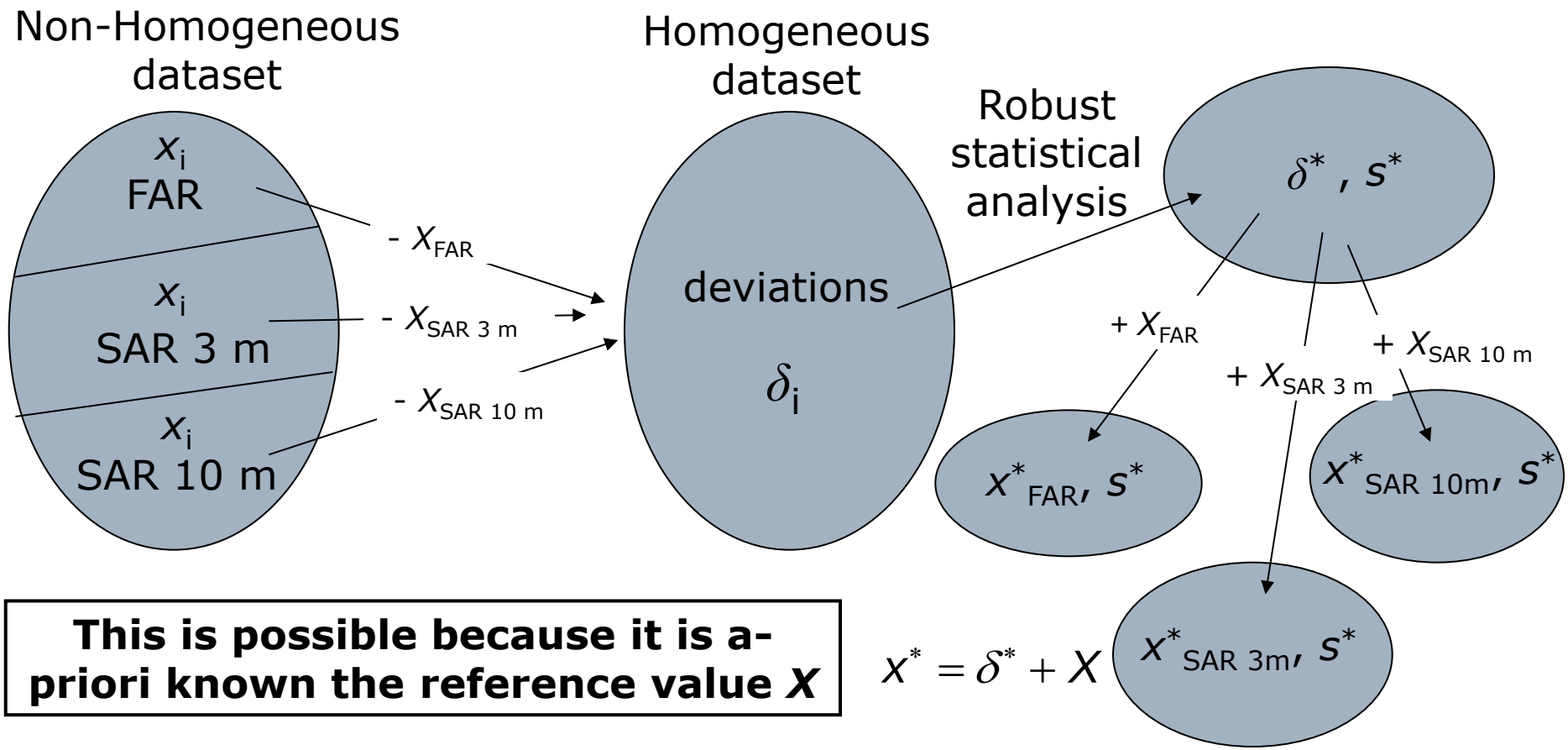
$$\delta_i = x_i - X_{FAR} = 0.3 \text{ dB}$$

Reporting

- In the report issued by the Coordinator to the Lab the measurement result x_i is compared with:
  1. The a-priori reference value X assigned by the Coordinator corresponding to each type of test facility (SAR 3 or 10 m, FAR).
  2. The a-posteriori reference value $x^* = \delta^* + X$ assigned by the Coordinator and corresponding to each type of test facility.

NOTE: δ^* is the robust average of deviations $\delta_i = x_i - X$ between the data provided by the Labs x_i and the a-priori reference value X for each type of test facility.

Data Flow



This is possible because it is a-priori known the reference value *X*

$$x^* = \delta^* + X$$

Results of the Proficiency Test
Reference Values and Their Uncertainty

F MHz	$X_{3\ m\ SAR}$ dB(µV/m)	$X_{10\ m\ SAR}$ dB(µV/m)	$X_{3\ m\ FAR}$ dB(µV/m)	*U* dB
40	40.1	32.7	37.1	1.3
80	52.1	46.0	51.1	1.3
120	60.3	55.4	60.9	1.3
160	71.8	64.1	70.4	1.3
200	74.0	64.7	72.0	1.3
400	75.1	67.4	72.7	0.9
600	74.8	67.8	72.7	0.9
800	75.1	68.2	73.3	0.9
1000	75.7	68.9	73.9	0.9

- Value *X* and uncertainty *U* (2σ) are a-priori known.

Results of the Proficiency Test Aggregate

F MHz	δ^* dB	s^* dB	$\frac{u}{s^*}$	z'
40	2.0	2.3	0.3	**2.1**
80	-1.4	1.3	0.5	-1.9
120	0.4	1.4	0.5	0.5
160	-0.5	0.9	0.7	-0.7
200	-0.5	1.9	0.3	-0.6
400	-1.0	0.7	0.7	-2.0
600	-0.3	0.7	0.7	-0.5
800	-0.7	0.7	0.7	-1.4
1000	-0.6	1.2	0.4	-1.0

Comparison with robust statistic (algorithm A, annex C, ISO 13528)

$$z' = \frac{\delta^*}{\sqrt{\frac{(1{,}25 s^*)^2}{p} + u^2}}$$

- p = 19, number of Labs
- $u = U/2$

Small values of u/s^* indicate that the uncertainty with which the Coordinator assigns the reference value X is small compared with the average measurement capability of the participating Labs.

Results of the Proficiency Test
Warning and Action Signals

FREQUENCY OF WARNING/ACTION SIGNALS (MHz)																			
Lab.		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
ζ	WARNING	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	ACTION	-	-	-	-	-	40	-	-	-	-	-	-	-	-	-	-	-	(*)	-
z	WARNING	-	120 200	-	-	-	120	160	-	400 800	-	200	800	160	800	-	600	-	-	600
	ACTION	400	160	-	-	160	40	-	-	-	-	80	-	-	-	-	-	-	(*)	-

(*) ACTION signals at all frequencies.

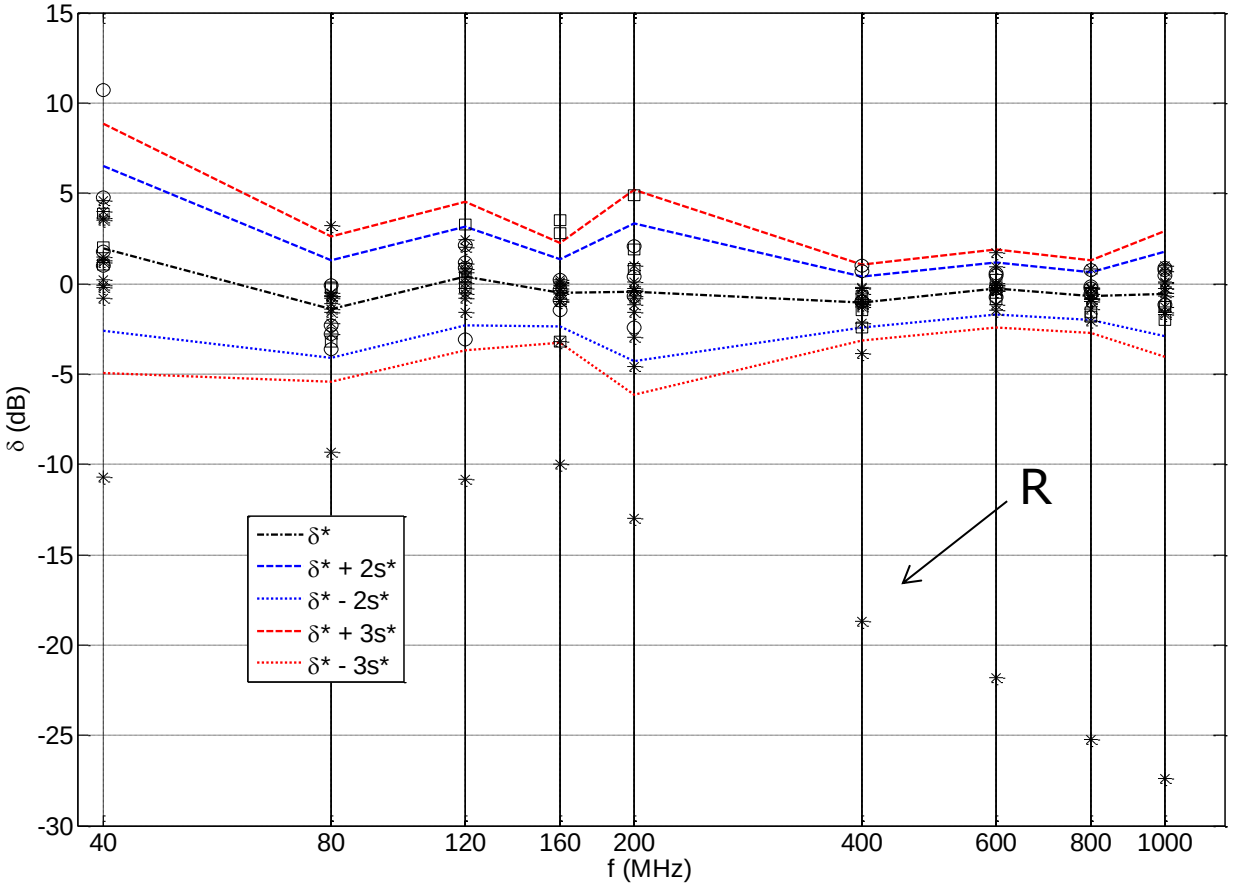
$$\zeta_i = \frac{x_i - X}{\sqrt{u_{xi}^2 + u^2}} = \frac{\delta_i}{\sqrt{u_{xi}^2 + u^2}}$$

$$z_i = \frac{x_i - x^*}{s^*} = \frac{x_i - \left(\delta^* + X\right)}{s^*} = \frac{\delta_i - \delta^*}{s^*}$$

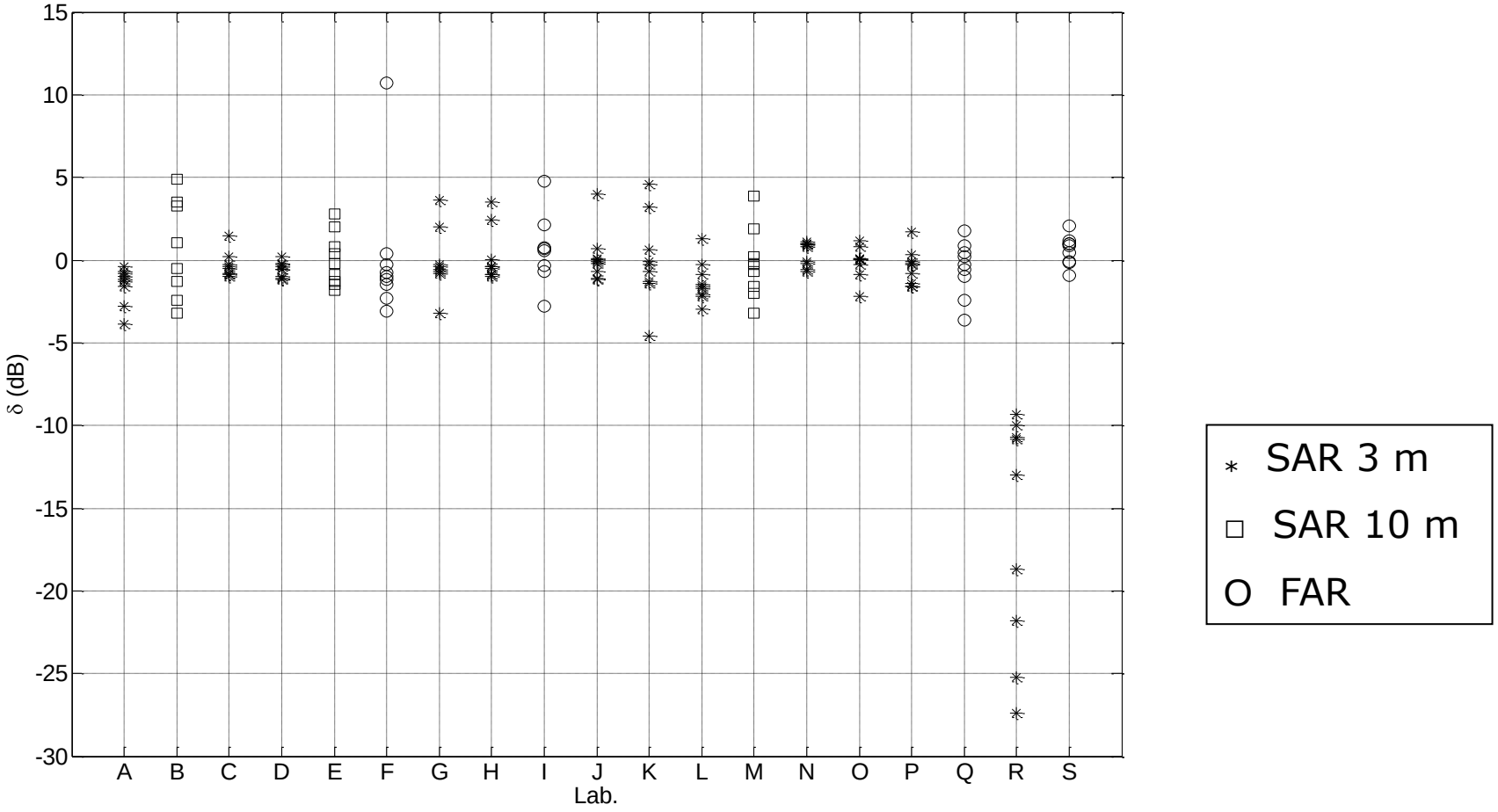
Results of the Proficiency Test Discussion

- 6 out of 19 Laboratories did not exhibit any warning/action signal.
- One Lab (R) exhibited 18 action signals (9 frequencies x 2 statistics). Note: the results provided by Lab R are included in the analysis and processed by using the robust statistical analysis (ISO 13528).
- 171 measurement results:
  - 12 warning signals
  - 24 action signals (including those of Lab. R)
- Most of the measurement results (79 %) did not produce values of $|z|$ or $|\zeta|$ exceeding 2.
- This confirms that the PT was well designed and Laboratories are, on average, able to control their measurement process.

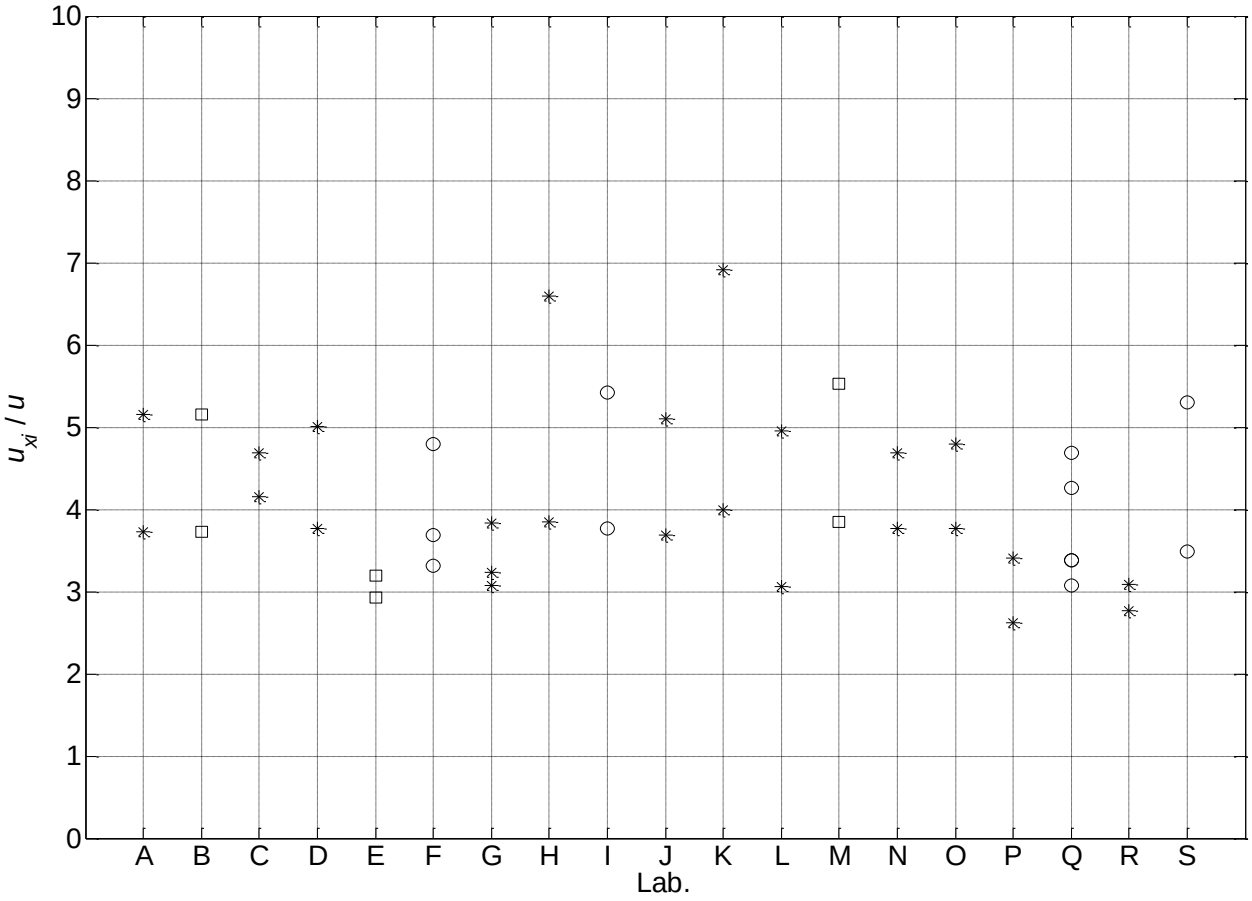
Results of the Proficiency Test
Plot of Deviations δ as a Function of Frequency



Results of the Proficiency Test
Plot of Deviations δ Produced by Each Laboratory



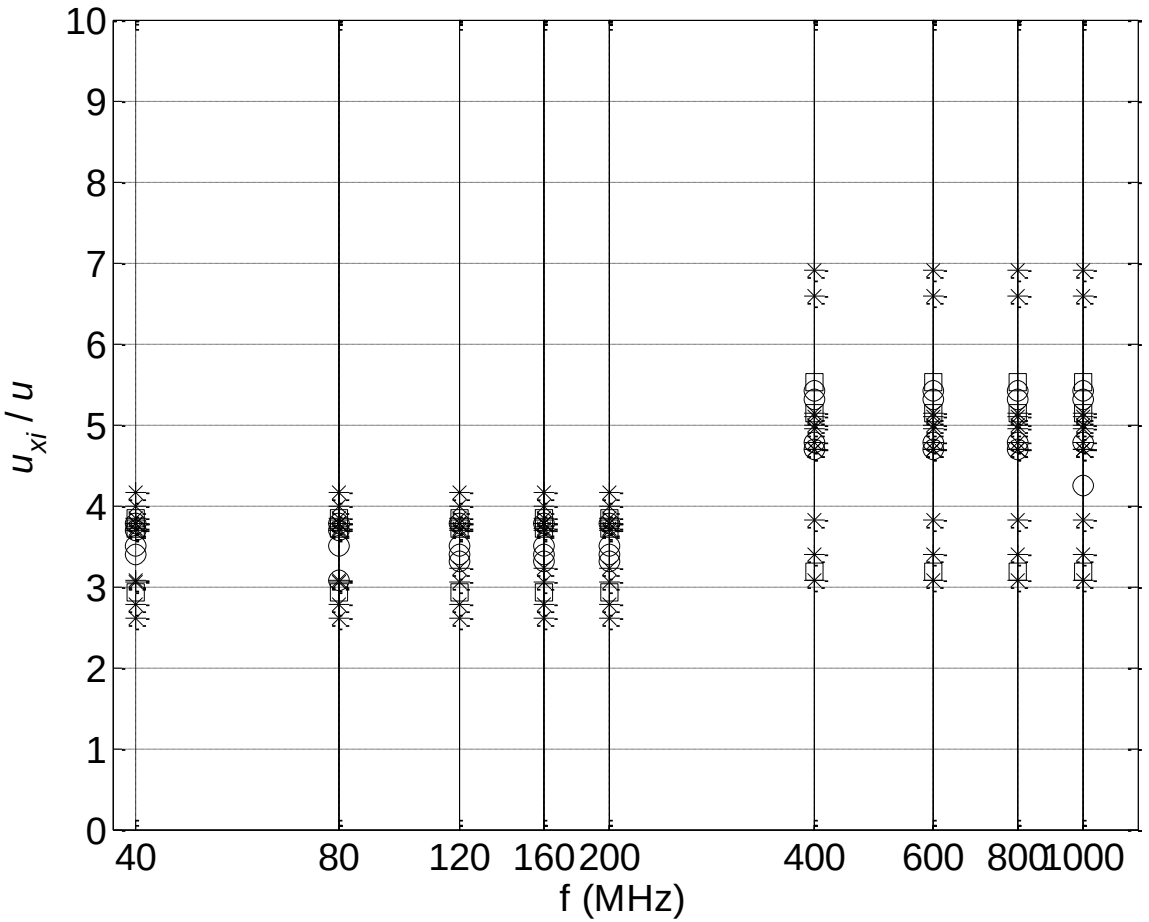
Results of the Proficiency Test
Plot of Ratio u_{xi}/u for Each Laboratory



The standard uncertainty of each Laboratory, u_{xi}, is relatively large compared to the standard uncertainty u of the reference vale X.

* SAR 3 m
□ SAR 10 m
O FAR

Results of the Proficiency Test Plot of Ratio u_{xi}/u as a Function of Frequency



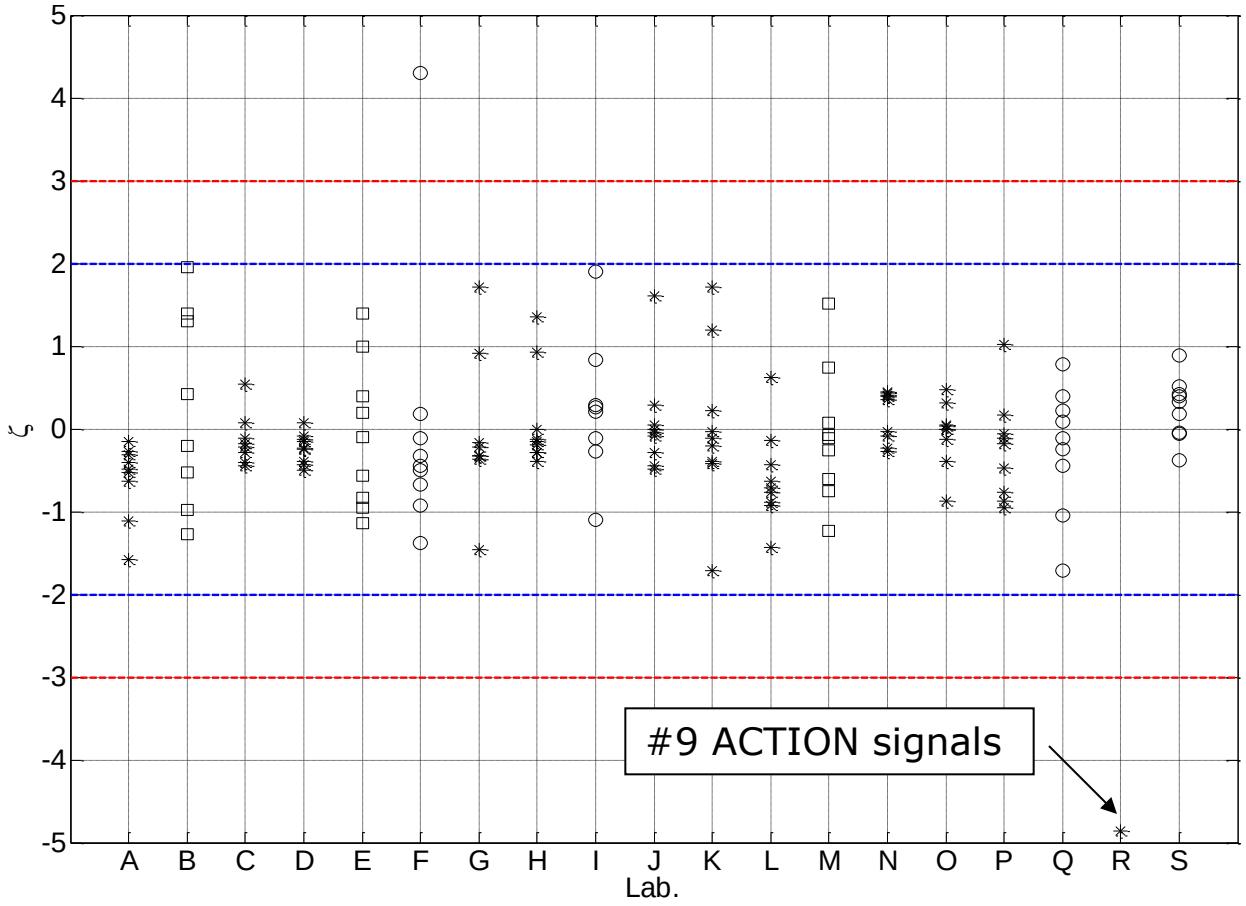
Higher values and spread at higher frequencies.

* SAR 3 m

□ SAR 10 m

O FAR

Results of the Proficiency Test
Values of ζ Produced by Each Lab.



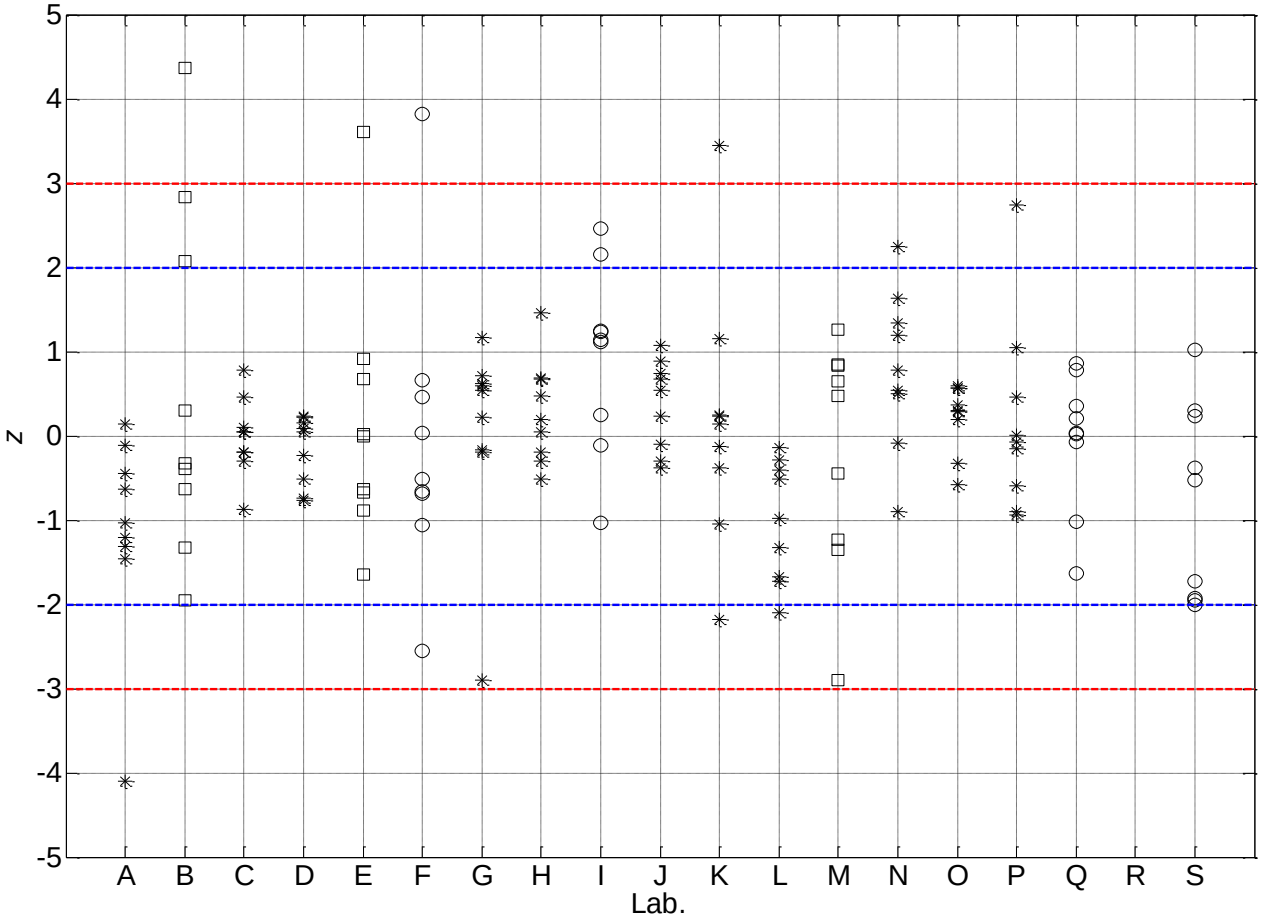
$$\zeta_i = \frac{x_i - X}{\sqrt{u_{xi}^2 + u^2}} = \frac{\delta_i}{\sqrt{u_{xi}^2 + u^2}}$$

if $u_{xi}^2 >> u^2$ then

$$\zeta_i \approx \frac{\delta_i}{u_{xi}}$$

* SAR 3 m
□ SAR 10 m
O FAR

Results of the Proficiency Test
Values of *z* Produced by Each Lab.



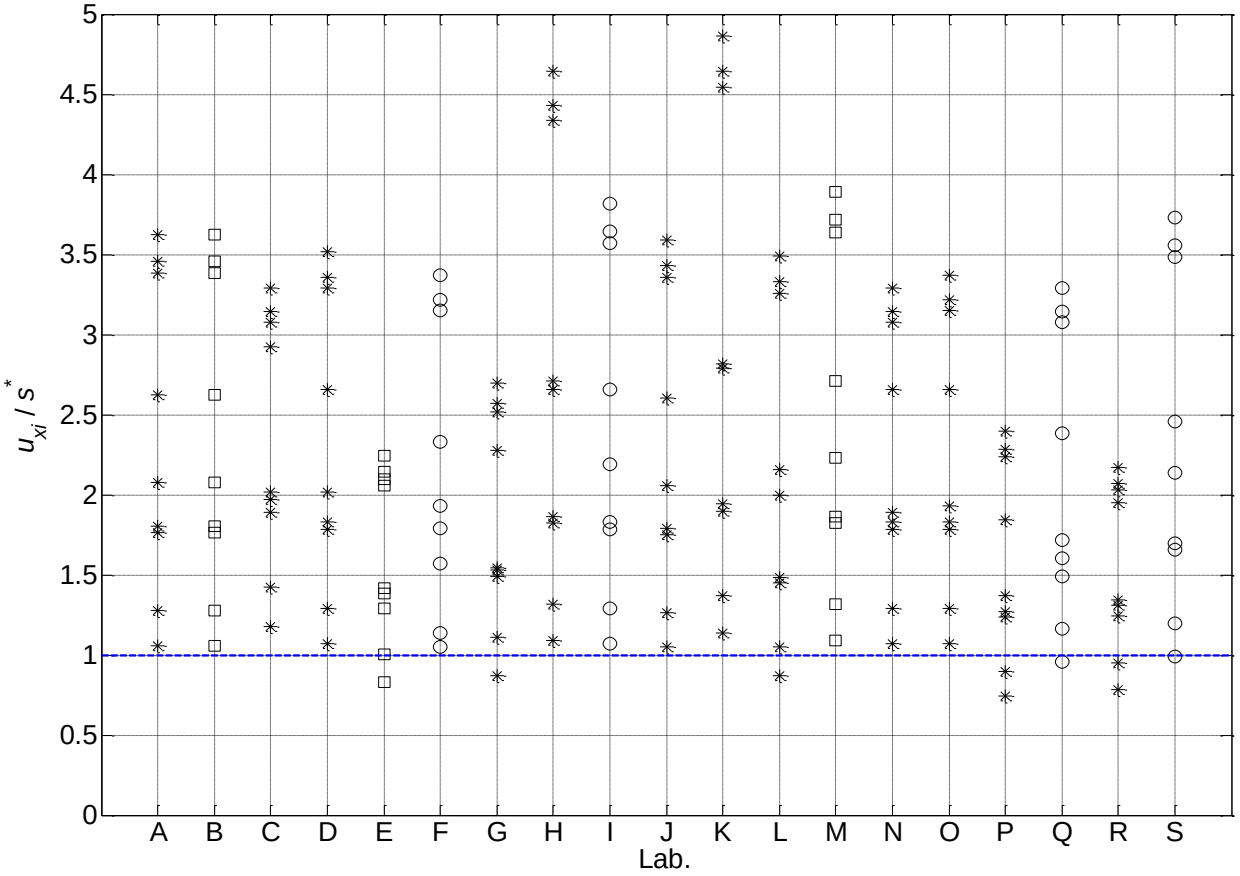
$$z_i = \frac{x_i - x^*}{s^*} = \frac{\delta_i - \delta^*}{s^*}$$

if $u_{xi}^2 >> u^2$ and δ^* is small, then

$$z_i \approx \frac{u_{xi}}{s^*}\zeta_i$$

*	SAR 3 m
□	SAR 10 m
O	FAR

Results of the Proficiency Test
Plot of Ratio u_{xi}/s^* for Each Laboratory

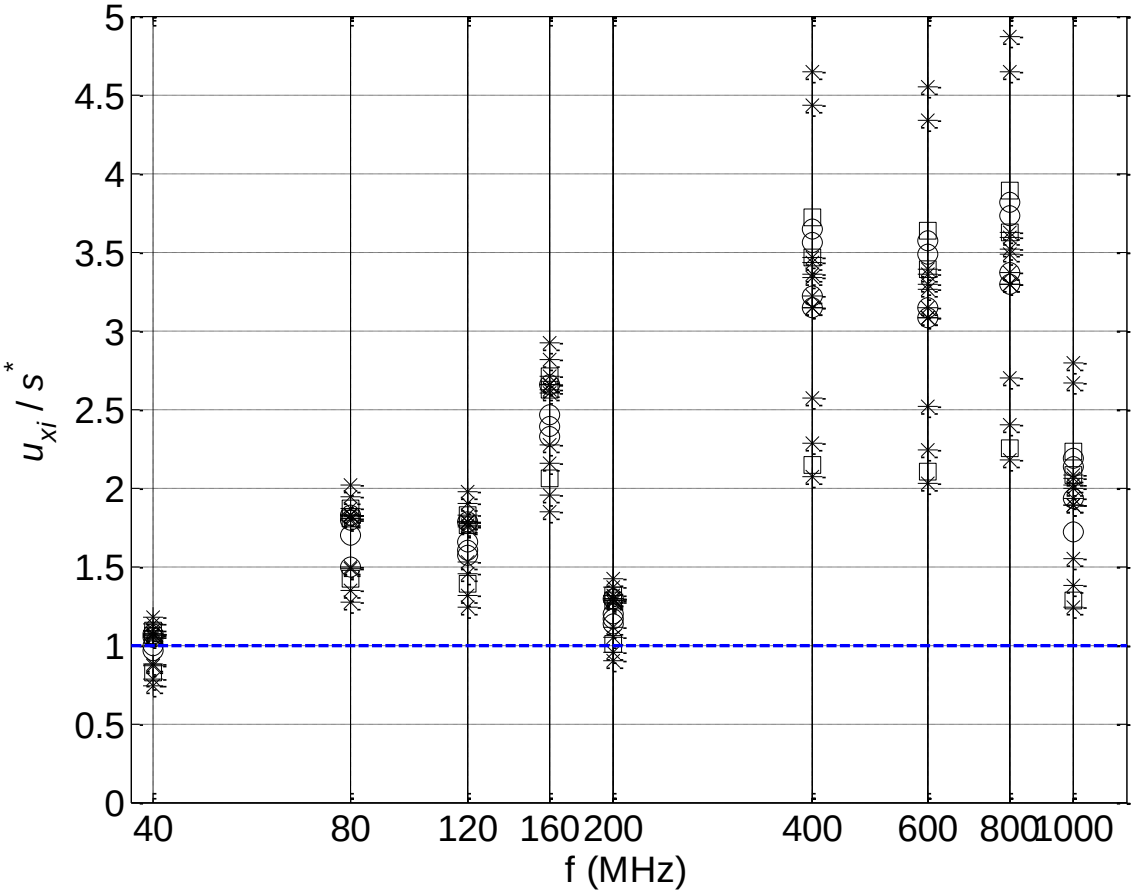


Only for 8 out of 171 measurement results we have

$$\frac{u_{xi}}{s^*} < 1$$

*	SAR 3 m
□	SAR 10 m
O	FAR

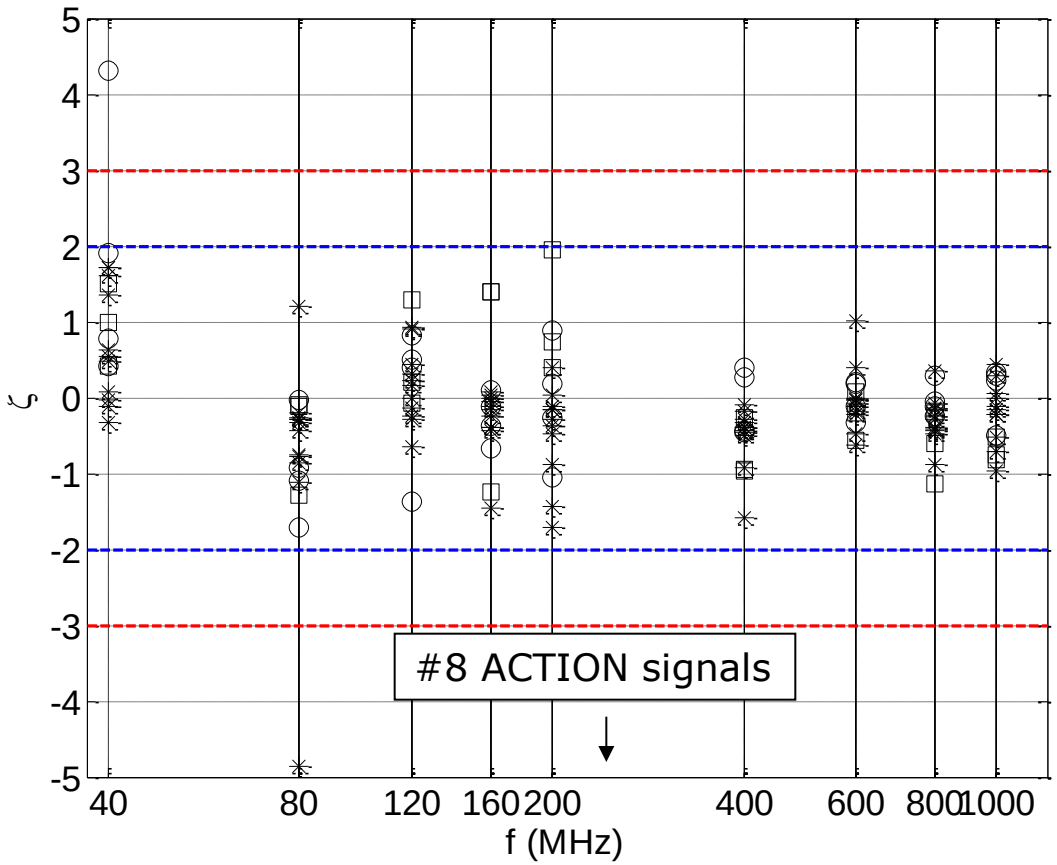
Results of the Proficiency Test Plot of Ratio u_{xi}/s^* as a Function of Frequency



Higher values and spread at higher frequencies.

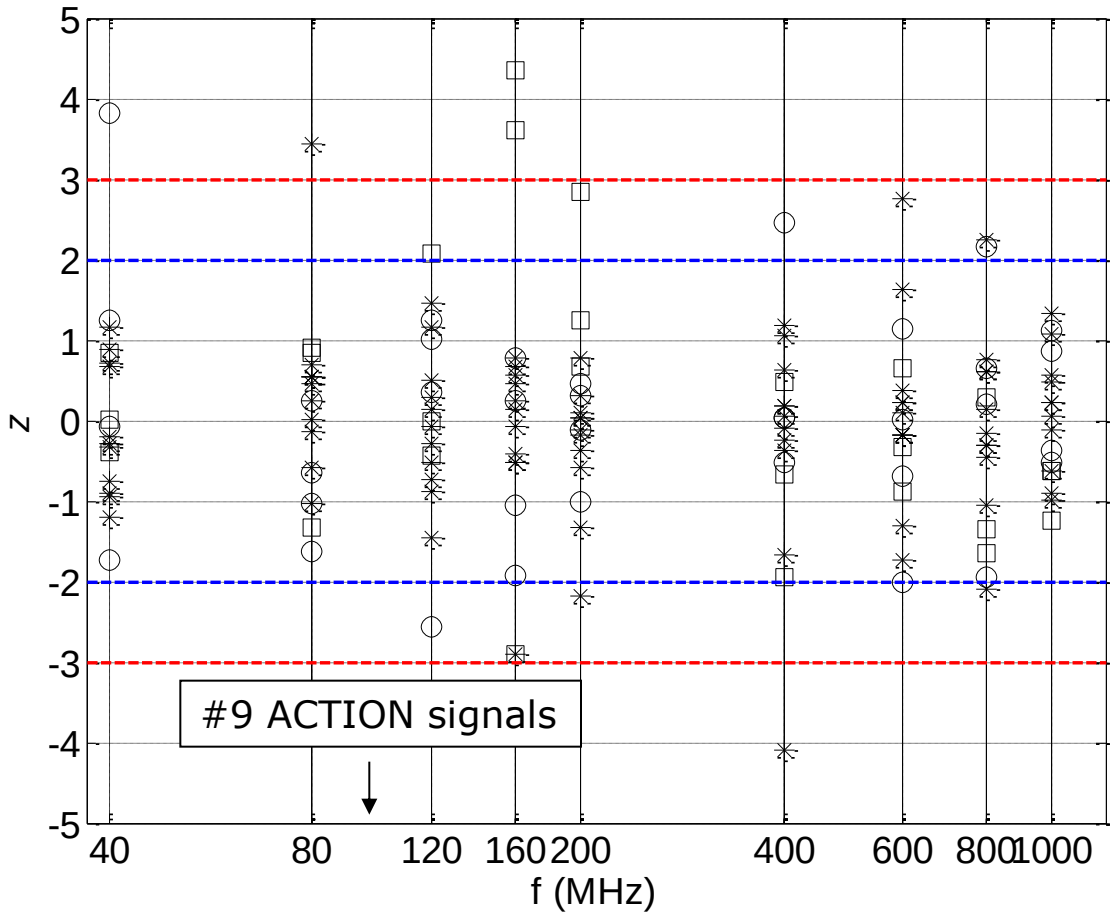
* SAR 3 m
□ SAR 10 m
O FAR

Results of the Proficiency Test
Values of ζ as a Function of Frequency



* SAR 3 m
□ SAR 10 m
O FAR

Results of the Proficiency Test
Values of *z* as a Function of Frequency



* SAR 3 m
□ SAR 10 m
O FAR

Considerations

- Warning signal for the a-priori value X at 40 MHz (statistic $z' = 2.1$). The a-priori value is however confirmed. An unidentified systematic exists (small size of chambers?).
- Statistic z more sensitive than ζ to deviations from reference values.
- It will be not always possible to assign the a-priori reference value in the future (complexity of the travelling sample and measurement setup).

z More Sensitive Than ζ to Deviations

- ACTION signals produced by performance statistic *z* for small deviations (2÷3 dB) from the assigned value *x**, when in combination with small values of the standard deviation *s** (0.7÷1.4 dB).
- The statistic *z* has the purpose to compare the performance of a Laboratory with the average performance

$$z_i = \frac{x_i - X^*}{s^*} = \frac{\delta_i - \delta^*}{s^*} \qquad \zeta_i = \frac{x_i - X}{\sqrt{u_{xi}^2 + u^2}} = \frac{\delta_i}{\sqrt{u_{xi}^2 + u^2}} \approx \frac{\delta_i}{u_{xi}} \qquad z_i \approx \frac{u_{xi}}{s^*}\zeta_i$$

The a-priori Reference Value Cannot be Assigned

- The performance statistic ζ can be replaced by the statistic E_n, (ISO 13528)
- If E_n is adopted and z-statistic is not used for assessment of performance (but for information only), then an additional requirement on Lab. uncertainty can be set:

$$\begin{cases} E_n = \dfrac{x_i - X_{REF}}{\sqrt{U_{LAB}^2 + U_{REF}^2}} = \dfrac{x_i - X^*}{2\sqrt{u_{xi}^2 + \dfrac{\left(1{,}25 s^*\right)^2}{p}}} \\ U_{LAB} \le U_{CISPR} \end{cases}$$

The critical value of 2.0 for the performance statistic ζ is equivalent to the critical value of 1.0 for the statistic E_n.

Faced Inconvenient

- Some Labs took a long time (several weeks) to transmit measurement results to the Coordinator.
- Antenna support was broken by a Lab (problem immediately solved by the Lab itself)
- Reported a wrong count of warning/action signals on some reports issued by the Coordinator (problem immediately solved by the Coordinator).

Conclusion

- ILCs should be performed by using a calibrated artifact whose uncertainty is less than or similar to the dispersion of the measurement results provided by the participating Laboratories.
- The dispersion observed in the PT here described ranges from 0.7 to 2.3 dB (in terms of one standard deviation).
- In case of compatibility between measurement and calibration results ($|\zeta|<2$) it is confirmed that the test laboratory is able to produce traceable measurement results.

Conclusion

- Laboratories tend to declare a pretty larger uncertainty than their average dispersion.
- Some Labs performed the PT with much more care than during ordinary test activity (measurement result obtained as the average of several measurements in different positions inside the chamber, with different receiving antennas, receivers, operators …), while other Labs decided to adhere to daily practice. Hence inhomogeneous groups are compared by using the *z* statistic.

Other PT Providers Currently Active

- IFM Quality Services (Australia)
- ACIL, American Council of Independent Laboratory (U.S.A.)
- VLAC, Voluntary EMC Laboratory Accreditation Center (Japan)

None of these organizations use the pre-assigned reference value in their PTs.

IFM Quality Services

- IFM Quality Services (Australia)
  - Accredited to ISO/IEC 17043
  - Radiated Emission (CISPR 22, bands ?) available, starting from June 2014.
  - The reference value is assigned by using robust statistics (see [3]): median (x_M), normalized interquantile range (NIQR).
  - The performance statistic z is in this case:

$$z_i = \frac{x_i - x_M}{NIQR}$$

$$|z_i| \le 1 \text{ excellent}$$

$$2 < |z_i| \le 3 \text{ acceptable}$$

$$|z_i| > 3 \text{ action}$$

ACIL

- ACIL (U.S.A.)
  - Accredited to ISO/IEC 17043
  - Radiated Emission 150 kHz – 6 GHz.
  - Conducted Emission 150 kHz – 30 MHz.
  - Statistical treatment of data (see [2]):
    - The reference value is assigned by using robust statistics x^* and s^* as defined by ISO 13528 (annex C, alg. A).

(follows)

ACIL

The participants' performance is evaluated as:

$$LCL \leq x_i \leq UCL \quad \Rightarrow \text{PASS}$$

$$LCL = x^* - \left(U_{NORM} + \frac{1{,}25s^*}{\sqrt{p}} \right) \qquad UCL = x^* + \left(U_{NORM} + \frac{1{,}25s^*}{\sqrt{p}} \right)$$

- $\boldsymbol{U_{NORM}}$ is the reference expanded uncertainty that appears in the CISPR and ANSI standards.
- $\boldsymbol{p}$ is the number of participating Labs.

(follows)

ACIL

Rewriting:

$$-\left(U_{NORM}+\frac{1{,}25}{\sqrt{p}}s^*\right)\le x_i-X^*\le\left(U_{NORM}+\frac{1{,}25}{\sqrt{p}}s^*\right)$$

Thus in terms of *z*-score we have:

$$-\left(\frac{U_{NORM}}{s^*}+\frac{1{,}25}{\sqrt{p}}\right)\le z\le\left(\frac{U_{NORM}}{s^*}+\frac{1{,}25}{\sqrt{p}}\right)$$

Hence a pass result is obtained if:

$$\left|z_i\right|\le z_{LIM}\qquad\text{where}\qquad z_{LIM}=\frac{U_{NORM}}{s^*}+\frac{1{,}25}{\sqrt{p}}$$

(follows)

ACIL

Example:

p = 19 laboratories

U_{NORM} = 5 dB

$$z_{LIM} = \frac{U_{NORM}}{s^*} + \frac{1{,}25}{\sqrt{p}} \approx \frac{U_{NORM}}{s^*}$$

F MHz	***s**** dB	z_{LIM}
40	2.3	**2.5**
80	1.3	**4.1**
120	1.4	**3.9**
160	0.9	**5.8**
200	1.9	**2.9**
400	0.7	**7.4**
600	0.7	**7.4**
800	0.7	**7.4**
1000	1.2	**4.5**

The ACTION threshold signal (z_{LIM}), in general, takes values much higher than 3.0.

VLAC

- VLAC (Japan)
  - VLAC is an accreditation body (ISO/IEC 17011).
  - Radiated Emission, annually from 2005.
  - The reference value is assigned by using robust statistics [4]: median (x_M), normalized interquantile range ($NIQR$).
  - VLAC uses the performance statistic z combined with an evaluation of the deviation [4]:

$$z_i = \frac{x_i - x_M}{NIQR}$$

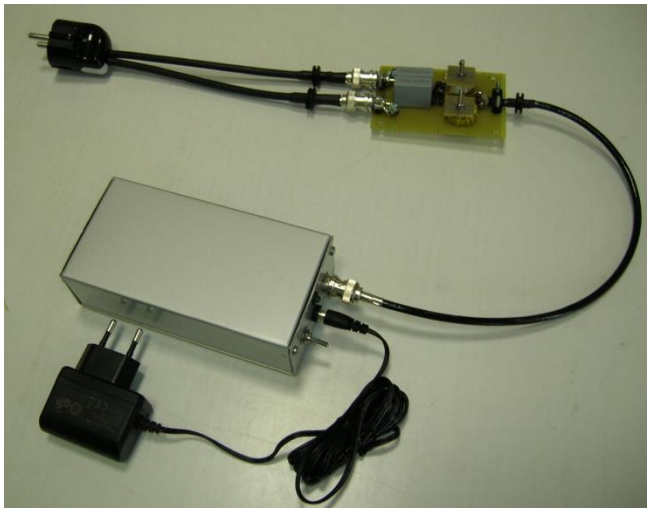
$$\begin{cases} |z_i| > 3 \\ |x_i - x_M| > 6\,\mathrm{dB} \end{cases}$$

=> ACTION

Future PTs

- Conducted Emission 9 kHz – 30 MHz (October 2014).
- Radiated Emission 30 MHz – 6 GHz (October 2014).

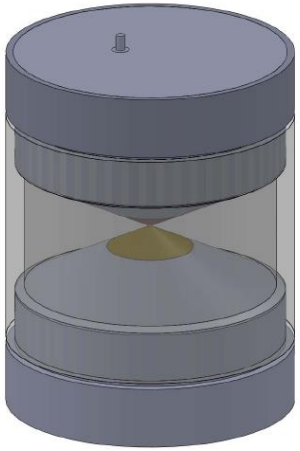
Conducted Emission 9 kHz – 30 MHz

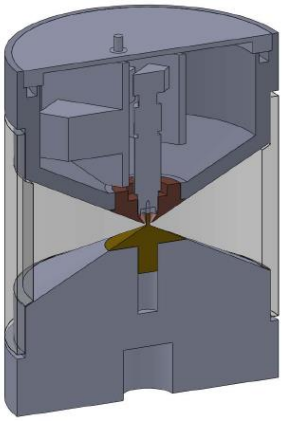


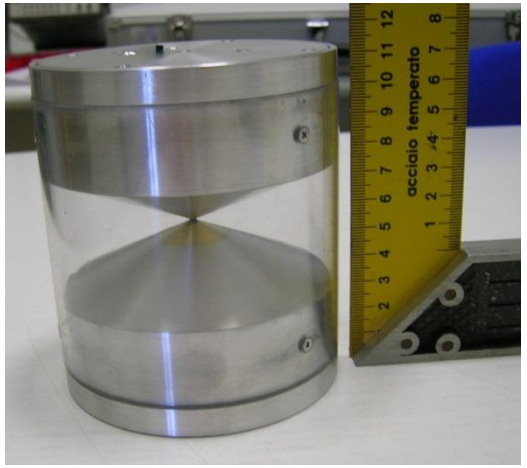
- Measurements according to EN 55016-2-1.
- Progress:
  - Realization of comb generators: completed.
  - Realization of coupling network: completed.
  - Calibration and tests: in progress.

Radiated Emission 30 MHz – 6 GHz

- Use of a broadband antenna, "simple", almost calculable, compact (about 100 x 100 mm), generator is inside the antenna, rechargeable batteries.







- Progress:
  - Mechanical realization of the antenna: completed.
  - Realization of the generator: completed.
  - Calibration and tests: in progress.

Bibliography

[1] *Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparison*, ISO 13528:2005.

[2] *Tutorial on the Statistical Basis of ACE-PT Inc.'s EMC Proficiency Testing Schemes, http://www.acil.org*, consulted 19/06/2014.

[3] *Information about Statistical Methods Used, http://www.ifmqs.com.au/Information%20about%20statistical%20methods%20used.htm,* consulted 19/06/2014.

[4] K. Osabe, T. Kato, *Consideration of Data Evaluation Criteria for Radiated Emission Test in the PT Program,* Symposium EMC EUROPE, 17-21 Sept. 2012, IEEE.

[5] C. F. M. Carobbi, A. Bonci, M. Cati, C. Panconi, M. Borsero, G. Vizio, *Design, Preparation, Conduct, and Result of a Proficiency Test of Radiated Emission Measurements*, IEEE TRANSACTIONS EMC, in print.