Two Interlaboratory Comparison Programs on EMF Measurements Performed in Greece

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Abstract – This paper presents two interlaboratory comparison schemes on electromagnetic field measurements. The first scheme involves measurements of the electric field produced by a scale transmission line and of the magnetic field produced by a medium voltage cable, whereas the second scheme involves measurements of the high frequency electromagnetic fields level and calculation of the total exposure ratio in the vicinity of mobile phone base stations and antennas transmitting in the radio and TV frequency bands. The measurements procedure and the calculation of the performance statistics z scores are analyzed for both schemes. Emphasis is given to the evaluation of the results, in order to investigate possible improvements on the overall implementation of the schemes and error factors related to the equipment and the measurement procedures of the participants.

I. Introduction

Proficiency testing schemes have emerged within the growing need for comparable laboratory results as one of the most reliable methods for assessing the adequacy and improving the performance of a laboratory. According to the standard ISO/IEC 17025 [1] every accredited test laboratory should participate in interlaboratory comparison programmes that cover all measurements lying within its scope of accreditation as a prerequisite for demonstrating traceability and proficiency and proving its technical competence.

Interlaboratory comparison programmes (ILCs) are defined as the organization, performance and evaluation of calibration/tests on the same or similar calibration/test items by two or more laboratories under predetermined conditions [2]. The type of ILC that must be applied to Electromagnetic Field Measurements (EMF) is a results comparison programme. In a results comparison programme, all participants measure the same EMF source, usually in normal working conditions [3], [4]. The ILC programmes described in this paper have been set up to comply with the requirements of the ILAC G13: 2000 Guidelines [5], the ILAC Policy [6] and the relevant policy of the Hellenic Accreditation System S.A. (ESYD) for the participation of laboratories in proficiency testing schemes [7].

II. Calculation of the Performance Statistics

The first stage for the statistical analysis of the results is the calculation in each test level of the assigned value $\hat{m}$ and the standard deviation $\hat{\sigma}$, which are used as the best available estimations for the true value of the measurand and the dispersion of the measurements respectively, by applying the iterative robust algorithm described in the standard ISO 13528 (Annex C, Algorithm A) [8] to the measurements of the laboratories.

The main advantage of this algorithm is robustness, the persistence of the method's characteristic behaviour under perturbations or conditions of uncertainty. The robust statistics are resistant to errors in the results, produced by deviations from assumptions (e.g. of normality). If the assumptions are only approximately met, the robust estimator will still have a reasonable efficiency and reasonably small bias. This is of high importance for the present ILC schemes where the measurement conditions are not completely identical for all the participants. The estimators are then used for the calculation of the performance statistic z score from the relationship:

$$z = \frac{x - \hat{m}}{\hat{\sigma}} \tag{1}$$

where: x is the measurement of the laboratory
$\hat{m}$ is the robust mean
$\hat{\sigma}$ is the robust standard deviation

The z scores are evaluated according to the following rules [8]:

- $|z| \leq 2$: the performance of the laboratory is satisfactory.
- $2 < |z| < 3$: the accuracy and correctness of the measurement is questionable and the performance statistic is a "warning signal".
- $|z| \geq 3$: the performance of the laboratory is non-satisfactory and the performance statistic is an "action signal".

Every individual "action signal" requires investigation for the determination of the error factors which affect the measurement quality, whereas a "warning signal" is considered a strong indication of problems in the behaviour of the laboratory, mainly if it is recurrent in various test levels (or various test rounds). The combination of all the evaluation results within a round provides every participant with a simple overview of its performance in all test levels. It must be noted that a measurement is defined as the unique combination of personnel handling the instruments, measuring equipment and measurement procedure. Repetition of the measurement at a specific site with another combination of these factors is considered a different measurement and laboratories that have implemented this practice receive different codes, one for each measurement team.

III. ELF Interlaboratory Comparison Scheme

The reference levels for the exposure of the general population to the field produced by the operational power frequency of 50 Hz set by the ICNIRP [9], the European Union [10] and the Greek legislation are 5 kV / m for the electric field and 100 μT for the magnetic field. Thus, extremely low frequency (ELF) measurements are required in various parts of the power system to ensure the compliance with the above limits.

The lack of available published proficiency testing programmes on ELF EMF measurements organized either by national or by international bodies, as well as the requirement of ESYD for accredited laboratories to participate in proficiency testing programmes at least every four years [7], led us to the attainment of an ELF ILC programme that covers the two types of measurements (electric and magnetic field) described in IEC 61786 [11].

A. Measurement Procedure

The ELF ILC programme was carried out in two stages at the High Voltage Laboratory of the National Technical University of Athens (N.T.U.A.) [12].

During the first phase of the test, a scale transmission line supplied with 5, 10, 15 and 20 kV was properly formed. The high voltage was produced by a testing transformer with transformation ratio of 110V/55kV powered by the low voltage network. A suitable stabilizer was placed at the primary side of the transformer, in order to prevent fluctuations in the network voltage from passing into the produced voltage, as well as a variac for changing the level of the produced high voltage. The measurement of the high voltage level was carried out on the low voltage side (U_1) with an appropriate calibrated voltmeter. The five measurement groups recorded at each voltage level the electric field at a height of 1.80±0.01m at a specific distance from the transmission line with a sensor connected via optical fiber with a fieldmeter. The sensor was placed at a distance of ~ 10m from the fieldmeter so that the measurements would not be affected by the presence of the operators. The experimental layout is displayed in Figure 1.

During the second phase of the test, the magnetic field generated by a cable carrying 250, 500, 750 and 1000 A was measured. The cable was connected to the secondary side of a current transformer (0-6000A), which provided the required value of the current. A variac placed between the low voltage network and the primary of the transformer enabled varying the level of the produced current. The current of the cable (I_2) was measured at the beginning and at the end of each cycle of measurements with a suitable calibrated clamp meter. For each current value, the five measurement groups recorded the magnetic field at a particular distance at a height of 1.70±0.04m again with a sensor and a fieldmeter. This time the sensor was connected to the fieldmeter either directly or via optical fiber, depending on the type of the fieldmeter. Unlike the electric field, the magnetic field is not affected by the presence of the operator. The experimental layout is displayed in Figure 2.

B. Participants

In this ILC procedure four accredited laboratories (with five groups) have participated. The participants have been randomly named as Laboratories 1-5. Each participating laboratory submitted the measured values of the electric field (E) in V/m for each voltage level and the measured values of the magnetic field (B) in μT for each current level in two types: measurements across the entire frequency range of the fieldmeters (broadband measurements) and measurements in a narrow band around the fundamental frequency of 50Hz (band pass measurements).

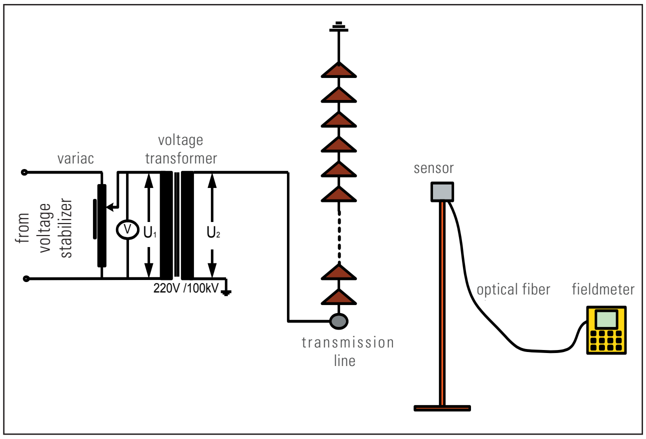


Fig. 1. Test setup for the measurement of the Electric Field (E).

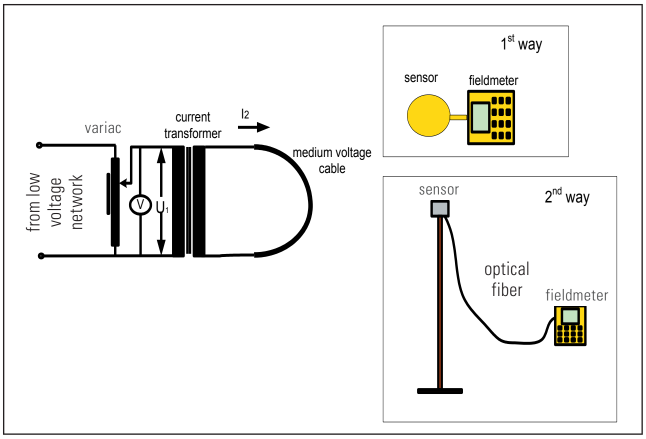


Fig. 2. Test setup for the measurement of the Magnetic Field (B), 1st way: The sensor is directly connected to the fieldmeter, 2nd way: The sensor is connected to the fieldmeter via an optical fiber.

C. Results

The z scores of the five participating teams calculated for each voltage/current level and for all measurement modes provided by the laboratories (broadband/band pass) at each stage of the experiment (E / B measurement) are shown in Tables I and II.

TABLE I
Z SCORES FOR THE ELECTRIC FIELD

Lab code	Z SCORES							
	Band Pass E				Broad Band E			
	5kV	10kV	15kV	20kV	5kV	10kV	15kV	20kV
Lab 1	-1,05	0,04	-0,50	0,47	-0,90	0,48	0,26	0,67
Lab 2	0,06	-1,08	-0,83	-1,35	0,22	-1,13	-1,15	-1,42
Lab 3	-0,60	-0,62	-0,07	-0,45	-0,87	-0,70	-0,18	-0,29
Lab 4	1,22	1,12	1,47	0,71	1,16	1,00	1,28	0,61
Lab 5	0,38	0,54	-0,07	0,61	0,39	0,34	-0,22	0,43

TABLE II
Z SCORES FOR THE MAGNETIC FIELD

Lab code	Z SCORES							
	Band Pass B				Broad Band B			
	250A	500A	750A	1000A	250A	500A	750A	1000A
Lab 1	1,05	0,85	0,69	0,68	1,13	1,14	0,75	1,01
Lab 2	-0,45	-0,60	-0,57	-0,53	-0,30	-0,58	-1,02	-0,54
Lab 3	-1,19	-0,86	-0,71	-0,80	-1,07	-0,82	0,75	-0,82
Lab 4	-0,02	-0,43	-0,61	-0,55	-0,41	-0,50	-0,89	-0,56
Lab 5	0,61	1,05	1,19	1,20	0,65	0,75	0,42	0,90

D. Evaluation-Discussion

The performance of all laboratories is satisfactory, because no laboratory has been rated with a | z |> 2. From Tables I and II it is concluded that the participants have shown more consistent behaviour when measuring the magnetic field, because there are no alternations in the sign of their z scores, with the exception of the broadband magnetic field measurements of Laboratory 2.

On the contrary, concerning the electric field measurements only Laboratories 3 and 4 received z scores with the same sign at all voltage levels. Laboratories 2 and 5 display changes in the signs of their z scores, but these are the same for broadband and band pass results. The results of Laboratory 1 show the largest inconsistency as the sign-variations in the band pass measurements differ from those in the broadband measurements.

At this point, the following matter should be clarified: The z scores of a "well-behaving" laboratory are in general expected to fluctuate slightly around zero. Repetitive z scores with the same sign are attributed to the technical characteristics of the instrument (such as its frequency response) or to a systemic factor of the measurement method (such as the calibration parameters of the instrument) [3], [4]. If these z scores exceed the threshold (| z |> 2), they are indicators of a systematic error (bias) caused by the instrument. In this scheme there have been no | z |> 2, so the presence of z scores with the same sign is not perceived as bias and it is positively evaluated as a consistent execution of the measurement method unaffected by the individual test levels.

The existence of band pass measurements that are higher than the corresponding broadband is theoretically impossible under identical testing conditions. Although this phenomenon did not affect the z scores, it indicates either imperfections of the measurement method on behalf of the laboratories or mainly the instability of the voltage/current which causes the production of different fields during the band pass and the broadband measurements. This is expected in the measurements of the magnetic field, where there was instability of the current, due to the absence of a voltage stabilizer.

The order in which the laboratories performed their measurements at each test level affects the results, because the produced fields where unstable. Finally, the different ranges of the frequency filters of the instruments used by the laboratories have an important impact, especially on the broadband measurements.

IV. High Frequency Interlaboratory Comparison Scheme

Measurements of the electromagnetic fields level in the vicinity of mobile phone base stations and broadcast antenna facilities are provisioned in the Greek legislation and are necessary in some cases, due to the large amount of radiated power, for the protection of the general public. The relevant metric as defined in all relevant standards [13], [14], [15] is the exposure ratio. To assess whether the reference levels for human exposure to electromagnetic fields are exceeded, the total exposure ratio is used [13], [14], [15]. This is the sum of the individual exposure ratios concerning the same quantity (electric or magnetic field) and the same effect (thermal or electrical stimulation) at a measurement location at a specific time slot. For frequencies greater than 10 MHz and less than 10 GHz and for measurements in the far or near field of the radiating antenna, the exposure ratio (ER) for a specific frequency (or frequency band) and measurement position, is calculated as follows:

$$ER = \frac{E^2}{{L_E}^2} = \frac{H^2}{{L_H}^2} \qquad (2)$$

Where: E (or H) the average value of the measured electric (or magnetic) field at a certain frequency and measurement position

L_E (or L_H) the corresponding reference level for the electric (or magnetic) field at this frequency

A. Measurement Procedure

The Greek Atomic Energy Commission organised interlaboratory comparison measurements according to the provisions of the Greek legislation in the following test fields:

(1) Field measurements and calculation of the total exposure ratio in the facilities of the National Centre for Scientific Research (N.C.S.R.) "Demokritos" at 3 predefined positions in the vicinity of a van mounted mobile phone base station according to two measurement scenarios (measurement scenario 1: antennas transmitting in the GSM frequency band, measurement scenario 2: antennas transmitting in the DCS & UMTS frequency bands).

(2) Field measurements and calculation of the total exposure ratio in the area of the Antenna Park of mountain Ymittos at 2 predefined sites in the vicinity of many powerful radio and TV antennas (measurement scenario 3).

The purpose of this specific scheme is the evaluation of the overall performance of the participants, taking into account the real conditions and parameters (such as the type and combination of instrumentation and equipment settings) used by each laboratory in everyday practice for in situ measurements. At each measurement point measurements were performed at three heights (1.1m, 1.5m and 1.7m), according to the standards [13], [14], [15], in order to simulate the body of a standing person supposedly exposed to the field.

In each measurement scenario, the participants recorded at each height the time-average intensity of the electric field from which the spatial average value of the electric field strength for each measurement point and

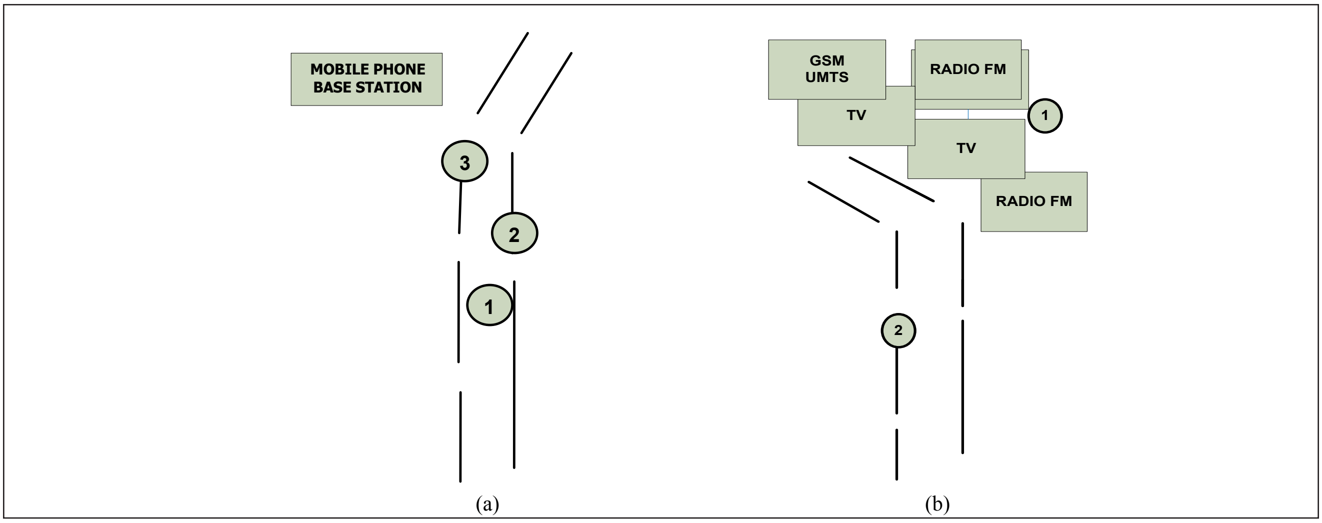


Fig. 3. Diagram of the measurement positions and the nearest antenna stations in the area of (a) the N.C.S.R. "Demokritos" and (b) the Antenna Park of Ymittos.

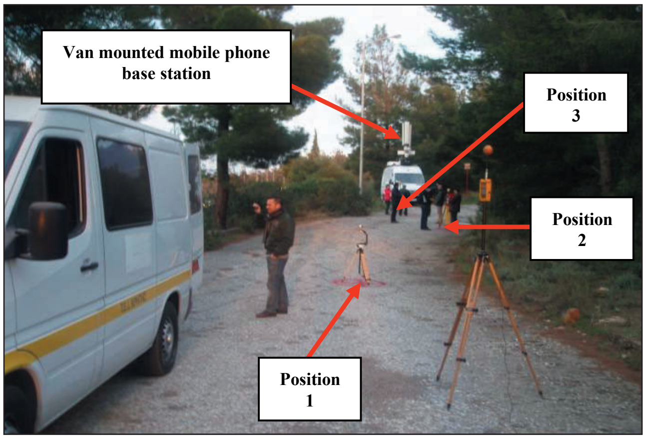


Fig. 4. The mobile phone base station and the measurement positions in the area of the N.C.S.R. "Demokritos" (measurement scenarios 1 and 2).

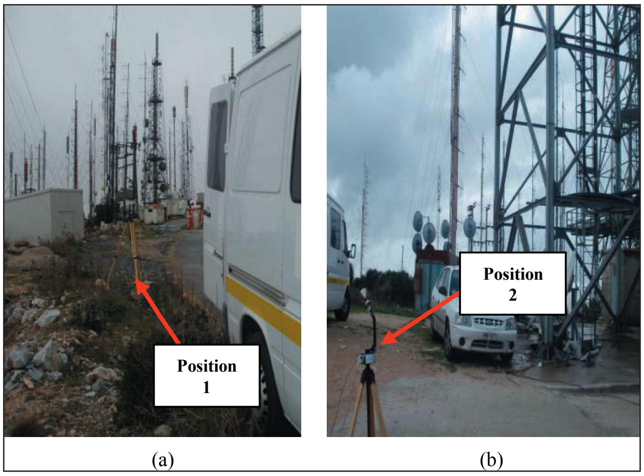


Fig. 5. The measurement positions (a) at the entrance and (b) within the area of the Antenna Park of Ymittos (measurement scenario 3).

frequency band is derived. These averages were used in order to calculate the total exposure ratio. The precise measurement positions and the nearest antenna stations are depicted in Figures 4 and 5.

B. Participants

The participants are not only laboratories accredited in accordance with the requirements of [1], but also non-accredited laboratories, that were selected by the organizer, since they meet some minimum requirements regarding their staff, internal quality controls, instruments and procedures for the measurement of human exposure to electromagnetic fields in the vicinity of antenna stations. 31 measurement teams emerged, designated randomly as Laboratories 1-31.

Due to the heterogeneity of the results delivered by the participants, the comparable measurements must be categorized into individual test levels. The determination of each test level is based on the following parameters:

- delivered quantity (electric field strength E or exposure ratio ER)
- measurement scenario (1, 2 or 3)
- measurement position (1, 2 or 3) and measurement height (1.1m, 1.5m or 1.7m)
- average (AVG) or maximum (MAX) value of the measurand
- measurement across the whole frequency range (TOT) of the equipment used by the laboratories and/or across a specific frequency band corresponding to the mentioned service (e.g. GSM, DCS, UMTS, FM, UHF TV, etc.)

The various limits in the frequency bands adopted by the participants have led us in some cases to the merging of smaller subbands (linear summation of exposure ratios and quadratic summation of field strength values) in order to enable the comparison with results given by other participants in wider frequency bands.

C. Acceptance Criterion Set by the Organizer

If the measurements follow the normal distribution and the values $\hat{m}$ and $\hat{\sigma}$ are good estimators, then the z score is a normally distributed random variable, with mean value 0 and standard deviation 1, regardless of the measurand, the test level and the measurement method. This enables comparing the individual z scores and combining them to create an aggregated score for the whole scheme round. The type of aggregated score, which has been chosen in the present analysis, is the number of individual test levels, where the participant has been evaluated with a |z|>2.

A variable described by the normal distribution N (μ, σ^2) lies with 68% probability in the interval μ±σ, with 95% probability in the interval μ±2σ and with 99,7% probability in the interval μ±3σ. Thus, for a "well behaving" laboratory the z scores - which follow the distribution N(0, 1) - are expected to lie outside the value range ±2 in approximately 5% of the measurements and outside the value range ±3 only for 0,3% of the measurements.

Therefore, by calculating for each participant the number of individual test levels where it has received a |z|>2 score as % percentage of the total number of its evaluated measurements, the following acceptance criterion arises:

- If this percentage exceeds 5%, the overall performance of the laboratory is non-satisfactory.
- If this percentage does not exceed 5%, the overall performance of the laboratory is satisfactory.

D. Results

Some indicative results are presented in the Appendix in Tables V and VI, which contain the z scores of each laboratory for some of the most important individual test levels. For a future evaluation of laboratories in subsequent scheme cycles some aggregated performance statistics (Sz, S| z |, Sz^2) are calculated. The value | z | shows the "average" behaviour of each laboratory without the influence of opposite z scores, calculated by dividing S| z | with the number of the evaluated test levels. The total evaluation of the participants according to the analysis of the aggregated performance statistics and the performance criterion set by the organizer is shown in Table III.

E. Evaluation-Discussion

The factors that affect the performance statistics of each laboratory can be divided into the following categories:

• Equipment

This category includes all factors associated with the measuring devices and the measuring methods implemented by the participants. A substantial technical characteristic of the equipment is its operating frequency range. In the present ILC scheme, the measurements cover the frequency range 75MHz-3GHz. The large deviation from this bandwidth is a cause for the non-satisfactory behaviour of Laboratories 8 and 19 that used equipment operating in the ranges 100 kHz-3GHz and 400MHz- 2GHz, respectively.

When selecting an instrument, a number of factors should be taken into account, such as its response time, the maximum power limitations of the sensor, its dynamic range, its response to the time and spectral characteristics of the measured signal, its calibration data and of course the polarization of the field. Calibration uncertainty, difference between conditions of measurement, an improper frequency response or deviations from the isotropic response are technical imperfections that affect the precision of the results. The main equipment used for external field measurements are portable instruments with E-field probes and conventional spectrum analyzers with antennas.

Spectrum analyzers provide precise narrowband measurements, but their major limitation is the required fine-tuning of several parameters in order to achieve a proper reading of the desired signal. Also, the type and the large size of antennas used as receivers in conjunction with these instruments enhance the influence of the "human factor" in the measurement process. These limitations justify the unsatisfactory performance of Laboratories 2, 4 and 19 that have used a spectrum analyzer.

Portable instruments are used with broadband probes operating in various frequency ranges. Possible restrictions are the relative spectral "insensitivity" and the slow response time of certain types of this kind of equipment. This type of instruments has been used by the majority of the participants (including all the "well-behaving" laboratories). From the group of laboratories that have performed frequency-selective measurements with the Narda Selective Radiation Meters (SRM), only Laboratories 21 and 31 have a non-satisfactory performance. On the contrary, all the participants that have used other types of portable instruments (Laboratories 6, 8 and 25) have been negatively evaluated. Specifically, Laboratory 6 has used certain resolution bandwidth (RBW) values for the DCS and UMTS bands that might have affected the instrument response, taking into account that the RBW and other parameters should be accordingly set (as defined in the relevant standards [13], [14], [15]) in order to get accurate results. The divergent results of Laboratory 8 are attributed to the spectral response and bandwidth (100 kHz-3GHz) of the broadband probe it has used (and possibly to the subsequent numerical procedure for calculating the exposure ratio).

•Implementation of the measurement process set by the organizer

This category is associated with the partial compliance of the laboratory results with the rules set by the organizer, such as the number and the heights of the individual measurement points at each measurement location. For example, Laboratory 8 has made measurements at heights 1.05m, 1.5m and 2m at each measurement location and not at the proposed by the coordinator heights (1.1m, 1.5m and 1.7m). Also, data from the Laboratory 19 for the measurement scenario 3 are rejected, because the measurements at the Ymittos Antenna Park were not taken at the specified spots.

• Processing of the results

By this term all possible computational steps adopted by the participants to calculate derivative sizes from their initial measurements are stated. Specifically, Laboratory 4 has used a custom made software package to estimate the values of the electric field by extrapolation to the maximum output power of the mobile phone base stations for all frequency bands, in order to provide results with a large safety factor. As expected, the resulting values are overestimated. Laboratory 17 has estimated the total maximum and average values of the electric field by linearly summing the individual frequency components instead of applying quadratic summation.

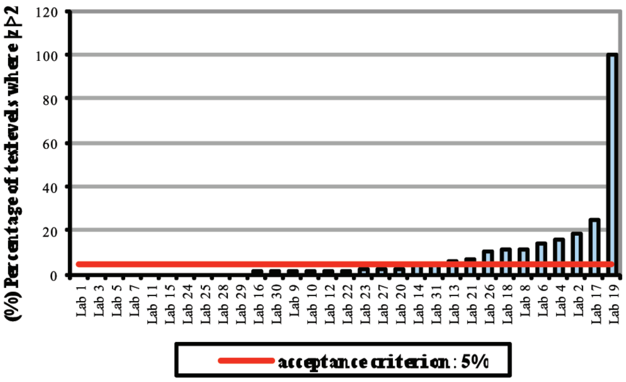
• Presentation of the results

The precision in decimal digits may affect the calculation of the performance statistics, especially when it comes to the exposure ratio, which is a very small number. Laboratories 1, 26, 27 and 29 have kept very few decimals, have presented null results in most frequency bands and thus their total exposure ratio is not identical with the sum of the reported individual exposure ratios.

- **Operator errors / report author errors**

This category includes cases of incorrect copying/ transferring of measurement data, delivering thus measurements with missing decimal digits. Such an omission probably explains some values reported by Laboratory 13, which are up to two orders of magnitude greater than those of other laboratories and cannot be attributed to a temporal variation of the levels of the measured field. The above categorization should not be considered obligatory, since there are error sources that were either not pointed out during the measurements or detected in the measurement reports. Moreover, the "human factor", i.e. the dependence of the result from the presence of the operator or from the exact manner in which the measurement is performed by the operator, is an important aspect of the procedure. Further investigation of factors that introduce inaccuracy in the results and selection of the appropriate corrective actions is a matter of internal quality control of each laboratory.

TABLE III
EVALUATION OF THE PARTICIPANTS:
PERCENTAGE OF TEST LEVELS WHERE |Z|>2 FOR EACH LABORATORY



The measurement conditions are not completely predefined, because of remote sources that emit in other frequency bands beyond these used in the measurement scenarios. Furthermore, the transmission power of the mobile communications base stations varies according to the telecommunication traffic. Therefore, the measured electric field shows temporal variability, especially in the mobile telephony spectrum (but to a much lesser extent in other spectrum areas such as the FM, VHF TV and TV UHF services). Under these circumstances the rejection of distant values with the statistical test of Grubbs [16] would theoretically not be reliable, which justifies the choice of the robust algorithm for calculating the z scores.

The change of the parameters of the EMF sources during the measurements may affect some z scores in individual test levels. However, it is a factor that all laboratories face throughout the measurements. So, we can assume that these deviations are balanced in the total results. Besides, the organizer conducted broadband measurements of the electric field throughout the scheme and it was found that the variation of the field strength was not significant.

The fact that obvious technical reasons for the unsatisfactory performance of laboratories were detected in all cases proves the effectiveness and proper function of the test scheme. The calculated performance statistics have verified the effect of all the factors that are in advance expected to degrade the measurement quality. Finally, taking into consideration that the 5% limit is stricter than other corresponding limits used in practice, its suitability as a threshold evaluation and its reliable theoretical basis are demonstrated, since error sources have been detected in all laboratories that exceed it.

V. Conclusions

The purpose of the presented analysis was to describe the organisation and execution of two EMF ILC schemes and to assess their overall function by detecting weaknesses in the predetermined measurement procedures and inaccuracy factors within the laboratories.

Based on the experience gained by the newly introduced ELF ILC scheme, some suggestions for improving its future rounds arise: The instability of the current during the magnetic field measurements should be minimized by adding a voltage stabilizer between the low voltage network and the variac. An alternative solution that does not require extra equipment would be the continuous monitoring of the current so that the measurements can be compared on a common basis. The duration of the measurements and hence the number of the participating teams is significantly limited by the maximum operating time of the current transformer, which is just one hour. Since there are no other spectral components in the measurement area apart from the frequency of 50Hz and the broadband results are very close to the corresponding band pass, the number of participants can be doubled in a subsequent test cycle by selecting only one of the two measurement modes (broadband or band pass).

The use or not of an optical fibre between fieldmeter and sensor (see Fig. 2) does not seem to affect the measurements of the magnetic field, where the participants have demonstrated a more consistent behaviour compared to the electric field measurements, where the z scores show more sign alternations. The satisfactory behaviour of all participants provides us with no specific remarks on the instruments or the procedures of the laboratories for the ELF measurements.

On the contrary, various factors that strongly influence the high frequency measurements are detected in the second ILC scheme, where 10 out of 31 participants had a non-satisfactory performance. Instrumentation in general and inappropriate technical parameters/settings of the equipment in particular, are the major causes of inaccurate results. Other error sources are the used computational steps for the analysis of the results and the calculation of derivative values, as well as deviation from the measurement procedure set by the organizer. The omission of decimal digits in the delivered results - attributed either to an author's error or to the level of precision adopted by the participant for the presentation of the exposure ratio - should not be underestimated, as it can also lead to a negative evaluation.

For the improvement of the high frequency ILC scheme in future events, a stricter compliance of the participants with the instructions of the organizer is required, especially concerning the way the results are delivered. Furthermore, it would be desirable that the participants use the same total measurement bandwidth and the same ranges on the used frequency bands, in order to achieve data uniformity and decrease the assumptions made during the classification and processing of the measurements by the organizer. A future round of the scheme could be organised in a controllable environment with a stable reference signal source and specific requirements for instrumentation and equipment settings, aiming at a further reduction of all the factors that minimize the comparability of the measurements.

VI. Appendix

The total results of the aggregated performance statistics of the high frequency ILC scheme are analytically presented in Table IV. Table V contains z scores referring to the calculation of the exposure ratios and Table VI contains z scores concerning the calculation of the average and maximum electric field strength values. Cells with non-satisfactory results are highlighted. The symbolization "x.y" is used for each test level, where "x" stands for the measurement scenario (1, 2 or 3) and "y" for the measurement point (1, 2 or 3).

TABLE IV
AGGREGATED PERFORMANCE STATISTICS FOR THE HIGH FREQUENCY ILC SCHEME

LABORATORY CODE	TOTAL NUMBER OF EVALUATED TEST LEVELS (Z SCORES)	NUMBER OF TEST LEVELS WHERE |Z|>2	PERCENTAGE OF TEST LEVELS WHERE |Z|>2 (%)	Sz	S|z|	AVG |Z|	Sz^2
Lab 1	12	0	0.0	-1.15	3.35	0.28	1.79
Lab 2	98	18	18.4	-79.31	135.43	1.38	278.60
Lab 3	33	0	0.0	-13.02	22.99	0.70	19.44
Lab 4	133	21	15.8	114.04	152.64	1.15	382.90
Lab 5	13	0	0.0	-8.62	11.88	0.91	12.81
Lab 6	49	7	14.3	55.07	63.73	1.30	240.05
Lab 7	100	0	0.0	1.83	48.54	0.49	34.21
Lab 8	34	4	11.8	20.01	29.25	0.86	80.64
Lab 9	71	1	1.4	-0.07	51.88	0.73	534.83
Lab 10	120	2	1.7	5.67	54.25	0.45	47.64
Lab 11	96	0	0.0	-35.51	54.32	0.57	43.57
Lab 12	58	1	1.7	-9.98	38.65	0.67	39.86
Lab 13	178	10	5.6	140.85	210.39	1.18	1034.45
Lab 14	25	1	4.0	3.22	21.19	0.85	23.21
Lab 15	25	0	0.0	-7.20	20.15	0.81	20.54
Lab 16	72	1	1.4	1.34	28.99	0.40	22.28
Lab 17	49	12	24.5	88.01	119.77	2.44	1074.99
Lab 18	87	10	11.5	-53.24	127.51	1.47	359.89
Lab 19	3	3	100.0	16.79	16.79	5.60	96.65
Lab 20	104	3	2.9	45.61	71.95	0.69	78.04
Lab 21	104	7	6.7	49.22	70.71	0.68	92.12
Lab 22	102	2	2.0	20.02	65.02	0.64	70.09
Lab 23	47	1	2.1	-33.65	37.75	0.80	45.08
Lab 24	70	0	0.0	-14.12	21.34	0.30	10.74
Lab 25	10	0	0.0	-12.33	12.33	1.23	15.74
Lab 26	46	5	10.9	-21.17	48.93	1.06	79.60
Lab 27	38	1	2.6	-7.41	27.83	0.73	36.46
Lab 28	43	0	0.0	-4.37	19.49	0.45	13.67
Lab 29	18	0	0.0	-11.50	14.41	0.80	18.97
Lab 30	72	1	1.4	-26.39	40.15	0.56	32.95
Lab 31	21	1	4.8	18.88	25.08	1.19	69.91

Table V

Z Scores For Individual Test Levels That Refer To The Calculation Of The Exposure Ratios **(ER)** In The Whole Measurement Range Of The Equipment Used By The Laboratories **(TOT)** And In Certain Frequency Bands-Services **(FM, GSM, DCS, UMTS, TV UHF)**

	ER TOT 1.1	ER TOT 1.2	ER TOT 1.3	ER TOT 2.1	ER TOT 2.2	ER TOT 2.3	ER TOT 3.1	ER TOT 3.2	ER GSM 1.1	ER GSM 1.2	ER GSM 1.3	ER DCS 2.1	ER DCS 2.2	ER DCS 2.3	ER UMTS 2.1	ER UMTS 2.2	ER UMTS 2.3	ER FM 3.1	ER FM 3.2	ER TV UHF 3.1	ER TV UHF 3.2
Lab 1																					
Lab 2	-0.96	-0.87	-1.21	-0.90	-1.20	-1.08	1.96	2.17	-1.41	-0.94	-2.63							1.51	0.94	3.28	2.95
Lab 3	-0.45	-0.56	0.51						-0.69	-0.68	0.95										
Lab 4	0.81	2.88	1.67	-0.01	0.43	1.09	1.32	-0.03													
Lab 5																					
Lab 6	-0.19	0.68	0.25	0.35	4.10	3.46			-0.05	0.93	0.54	2.54	5.34	9.85	1.30	1.67	-0.17				
Lab 7	0.82	1.04	-0.21	-0.22	0.61	-0.30	-0.34	0.05													
Lab 8	2.35	1.23	1.25	2.17	3.64	6.90	-0.33	0.27													
Lab 9	-0.37	-0.55	0.12	-0.54	-0.72	0.22	-0.91		-0.47	-0.64	0.12	-0.41	-0.41	0.83	0.13	-0.76	-0.46	-0.95		-1.24	
Lab 10	-0.37	0.10	0.11	-0.35	-0.27	-0.43			-0.50	0.14	-0.05	-0.14	-0.34	-0.81	0.63	0.09	-1.08				
Lab 11	-1.22	-0.37	-1.03	-0.79	-1.12	-1.08															
Lab 12	0.42	-1.04	0.21	-0.59	-0.28	-0.53			0.88	3.06	0.32	-0.54	-0.50	-0.77	-0.13	0.71	-1.03				
Lab 13	0.49	1.09	0.01	0.28	1.16	1.84	1.27	-0.95	0.81	1.25	-0.19	1.72	0.63	0.55	1.71	1.24	6.29	1.01	-1.02	-0.25	0.41
Lab 14	-1.22	-0.58	-1.36	-0.79	0.84																
Lab 15	-1.56	-0.89	-1.50	-0.91	-0.14																
Lab 16	0.06	-0.27	0.54	-0.33	-0.19	-0.20			0.26	-0.29	1.04	0.35	0.13	-0.61	0.25	-0.27	-0.09				
Lab 17	0.10	-0.87	-1.71						0.35	-0.99	-0.42										
Lab 18	-0.86	-0.57		-1.13	-1.99	-2.65			-1.26	-0.59		-1.81	-1.62		-1.31	-1.46					
Lab 19	5.52	4.49	6.79																		
Lab 20	1.42	1.20	0.94	2.60	-0.68	0.51	-0.51	0.08	2.50	1.36	1.84							-0.66	-0.26	0.25	-0.20
Lab 21	0.95	-0.03	0.01	1.35	0.68	-0.45	0.42	-0.09	1.69	-0.06	-0.10							0.24	-0.56	0.26	-0.07
Lab 22	0.12	-0.07	0.53	2.04	-0.28	-1.00	-0.51	-0.42	0.25	-0.13	0.95							-0.61		-0.53	-0.55
Lab 23	-0.44	-1.31	-0.51	0.65	-1.15				-0.47	-1.42	-1.10	-0.68	-0.67		-0.76	-0.74					
Lab 24	0.00	-0.87	0.01	1.35	-0.73	-0.05	-0.55		0.16	-0.24	-0.11	-0.25	-0.51	-0.35	-0.20	-0.60	0.18	-0.64		-0.77	
Lab 25							-1.10	-1.38													
Lab 26				-0.47	0.84	0.22						0.13	1.43	1.04	-0.01	-0.43	-0.17				
Lab 27				-0.41	0.51	-0.27						0.61	0.56	-0.73	-1.33	0.62	-0.17				
Lab 28				-0.29	0.58	0.16	-0.60	-0.50													
Lab 29		0.57	0.01							0.81	-1.49										
Lab 30	-0.61	-0.05	-0.17	-0.73	-0.39	0.20			-0.85	-0.02	-0.46	-0.56	-0.31	-0.65	-0.06	0.10	1.92				
Lab 31							0.34	1.60										0.11	0.90	0.79	-1.07

TABLE VI
Z SCORES FOR INDIVIDUAL TEST LEVELS THAT REFER TO THE CALCULATION OF THE AVERAGE **(AVG)** AND MAXIMUM **(MAX)** ELECTRIC FIELD STRENGTH **(E)** IN THE WHOLE MEASUREMENT RANGE **(TOT)**

	E TOT AVG 1.1	E TOT AVG 1.2	E TOT AVG 1.3	E TOT AVG 2.1	E TOT AVG 2.2	E TOT AVG 2.3	E TOT AVG 3.1	E TOT AVG 3.2	E TOT MAX 1.1	E TOT MAX 1.2	E TOT MAX 1.3	E TOT MAX 2.1	E TOT MAX 2.2	E TOT MAX 2.3	E TOT MAX 3.1	E TOT MAX 3.2
Lab 1									-0.83	0.01	-0.04					
Lab 2							1.38	1.29	-1.97	-1.76	-4.09	-1.87	-2.24	-0.84	-2.88	-5.32
Lab 3	-0.84	-1.10	-0.18						-0.79	-0.74	0.83					
Lab 4	0.57	1.92	0.79	1.19	0.18	0.81	0.89	-0.29	2.29	5.49	6.05	3.56	4.88	4.42	1.30	0.13
Lab 5	-0.77	-0.64	-0.74	-0.49	1.43	-1.46			-1.34	-0.58	-1.39	-0.94	0.20	-1.09		
Lab 6																
Lab 7	0.33	0.45	-0.73	0.22	0.16	-0.42	-0.51	-0.26	0.16	0.90	-0.79	-0.05	0.61	-0.15	0.22	0.27
Lab 8	-0.13	-0.47	-0.69	0.35	-0.43	-0.13	-0.20	0.27	0.47	0.43	0.64	0.70	0.38	0.44	-0.28	0.53
Lab 9																
Lab 10	-0.64	-0.29	-0.41	0.11	-0.31	-0.39			-0.03	0.44	-0.39	0.66	0.28	0.08		
Lab 11																
Lab 12																
Lab 13									0.91	1.45	0.88	1.32	0.08	1.47	2.81	-0.41
Lab 14									1.16	0.54	-0.24	-0.87	0.94			
Lab 15									0.69	0.18	-0.71	-1.05	0.45			
Lab 16	1.27	-0.04	1.09	1.10	1.16	2.29			-1.00	-1.14	-0.68	-0.49	-0.96	-0.35		
Lab 17	9.24	6.55	2.46						0.24	-1.38	-0.66					
Lab 18	-0.37	-0.43		-5.47	-2.63				-0.20	-0.60	-0.29	-2.41	-3.18	-1.97		
Lab 19																
Lab 20									0.46	0.47	2.62	0.20	-1.03	0.41	0.16	0.34
Lab 21									0.79	0.23	0.57	0.45	0.41	-0.13	0.31	0.99
Lab 22									0.15	-0.51	0.86	0.21	-0.71	-0.27	-0.13	-0.21
Lab 23																
Lab 24																
Lab 25							-1.04	-1.23							-1.09	-1.40
Lab 26												0.28	1.19			
Lab 27												0.35	0.30			
Lab 28				-0.01	-0.34	-0.10	-0.74	-0.68				0.56	0.13		-0.40	-0.12
Lab 29											-0.26					
Lab 30	-0.92	-0.46	-0.63	-0.97	-0.35	0.20			-0.84	0.30	0.17	0.17	-0.76	0.44		
Lab 31							0.22	0.90							-0.08	1.38

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