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Measurement of non ionizing radiation from a broadcasting station

An Inter-laboratory Comparison
Autumn 2007

METAS-Report Nr 2008-218-658

Publisher	Federal Office of Metrology METAS Section Electricity Lindenweg 50 3003 Bern-Wabern Tel. +41 31 32 33 111 www.metas.ch
Authors	Frédéric Pythoud, Beat Mühlemann (METAS), Jürg Baumann, Andreas Siegenthaler (BAFU)
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Report	2008-218-658. This report is available in PDF format at the following link http://www.metas.ch/2008-218-658.
Bern-Wabern,	April 23, 2008

Measurement of non ionizing radiation from a broadcasting station: an inter-laboratory comparison – autumn 2007

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1 Introduction

1.1 Motivation

In 1999 the Swiss Federal Council enacted the "Ordinance relating to Protection from Non-Ionising Radiation" (ONIR) [1]. This ordinance defines exposure limit values to electromagnetic fields for frequencies from 0 Hz to 300 GHz as well as so called installation limit values. In order to be applied correctly, this ordinance is complemented by measurement recommendations which are technology specific, e.g. GSM [2], UMTS [3], Broadcasting [4]. These measurement recommendations have been written after 2000 with the available know how at that time. The validation of these measurement recommendations is obtained through comparison campaigns with competent laboratories. METAS has already organised measurement comparisons for GSM (2002) and UMTS (2006) [5] radiation. The current report describes a similar inter-laboratory comparison for measurements of broadcasting radiation.

1.2 Scope of the comparison

The scope of the comparison was to measure separately FM (Frequency Modulation), DAB (Digital Audio Broadcasting), DVB (Digital Video Broadcasting), analogue TV signals as specified within the draft of measurement recommendation for broadcasting radiation [4]. This exercise was performed twice: first in a room where the electric field strength was below but not far from the installation limit value of 3 V/m specified in the ONIR and secondly in a room where the levels were significantly lower (about a factor of 4 for the total electric field strength).

1.3 Purpose of the comparison

The purpose of the comparison was to investigate whether the laboratories participating in this exercise are able to measure according to the draft of measurement recommendation and whether the individual results are consistent within the measurement uncertainty estimated by each laboratory. In addition the inter-laboratory standard deviation of the results should give quantitative information about the attainable overall uncertainty for such measurements. This overall uncertainty is made up of two contributions: instrumental uncertainties and uncertainties intrinsic to the measurement method itself. The latter contribution - called sampling uncertainty in the draft of measurement recommendation - can hardly be derived a priori. It mainly originates from different approaches to search for the local maximum of the electric field strength and was estimated to be on the order of 15% (k=1) in the draft of measurement recommendation.

1.4 List of participants

Name	Address	Swiss Accreditation Service Number (if accredited for broadcasting measurements)
BAKOM	2501 Biel	-
em prevent	8304 Walisellen	STS 437
Inventis AG	8050 Zürich	STS 353
Maxwave	8050 Zürich	STS 395
METAS	3003 Bern-Wabern	-
Narda / Emitec	D-72793 Pfullingen / 6343 Rotkreuz	-
RF-IT-Consult GmbH	5415 Nussbaumen	-
Schaffner EMV AG	4542 Luterbach	STS 015
SUPSI	6952 Manno	-
Swisscom Innovations	3050 Bern	-
Prof. Wuschek, FH Deggendorf	D-93049 Regensburg	-

1.5 Schedule

The measurements were performed from September 24 to October 10, 2007, with one participant per day, except for two days where two participants performed their measurements.

1.6 Organisation of the comparison campaign

The comparison campaign was organised by METAS, including the evaluation of the results and the writing of this report. The Swiss Federal Office for the Environment (FOEN) reviewed the report.

2 Measurement task

2.1 Broadcast station

The measurements were performed in the village of Sankt Chrischona (Basel), in the immediate vicinity of a powerful broadcast station equipped with many different transmitters, especially:

Service	Frequency (MHz)
FM SWR 1	87.9
FM SWR 4	89.5
FM DRS 1	90.6
FM SWR 2	92
FM Stiftung Radio X	94.5
FM SWR 3	98.3
FM DRS 2	99
FM Basel 1	101.7
FM DRS 3	103.6
FM Radio Basilisk	107.6
DAB-T SRG channel 12C	227.36
DVB-T SRG channel 31	554
analogue TV SRG channel 46 [1]	671.25
analogue TV SRG channel 49 [1]	695.25

[1] Analogue TV is expected to be set out of service in Switzerland within the next few years

2.2 Measurement sites

The restaurant Waldrain is situated about 200 meters from the tower. In this restaurant, a room (sleeping room, 14 m^2) with line of sight to the tower, and another one at the opposite side of the building (dining room, 30 m^2), were chosen for the measurements.

Dining Room

Sleeping Room

Dining Room Sleeping Room

The windows of the dining room were kept closed during the measurements whereas the window of the sleeping room was open.

2.3 Measurement task

The laboratories were asked to find and measure the spatial maximum of the electric field strength in the volume of the room (with height and wall distance limitations as mentioned in the draft of measurement recommendation) for each service listed in section 2.1 individually.

3 Stability measurements

3.1 Method

In order to guarantee that the electric field strength did not significantly change during the two week measurement period, METAS performed stability measurements before and after each participant's measurements. These stability measurements were carried out in the sleeping room with the following equipment:

- Antenna Rohde & Schwarz HE 200, Module 20 MHz to 200 MHz, for the FM signals
- Antenna Schwarzbeck VUSLP 9111 for all other signals
- Spectrum Analyser Rohde & Schwarz FSMR.

The measurements were performed at a fixed position which had been chosen close to the spatial maximum of the electric field, thus reducing the influence of the exact location of the measurement position. Two fixed measurement points were sufficient to cover all services:

- Location 1: below the ceiling.
- Location 2: behind the window.

The measurement equipment could not be left at the respective locations but rather had to be repositioned prior to each stability measurement. Therefore the stability data contain an unknown contribution due to the limited reproducibility of positioning the equipment.

The following table lists instrumental settings and locations for the stability measurements.

Service	Frequency (MHz)	Location	Polarisation
FM SWR 1	87.9	1	H
FM SWR 4	89.5	1	H
FM DRS 1	90.6	1	H
FM SWR 2	92	1	H
FM Stiftung Radio X	94.5	1	H
FM SWR 3	98.3	1	H
FM DRS 2	99	1	H
FM Basel 1	101.7	1	V
FM DRS 3	103.6	1	H
FM Radio Basilisk	107.6	1	V
DAB-T SRG ch. 12C	227.36	1	V
DVB-T SRG ch. 31	554	2	V
analog TV SRG ch. 46	671.25	2	V
analog TV SRG ch. 49	695.25	2	V

3.2 Results

The stability measurement values are reported in annex A. Neither long term drifts nor a correlation between participant's measurements and the stability measurements were found. It was therefore decided to determine the standard deviation of the stability measurements data and consider it as an additional source of uncertainty to be included in the overall uncertainty calculation. This contribution as well as the difference between maximum and minimum values are summarised in the next table:

Service	Frequency (MHz)	Max-Min (dB)	Standard Deviation (dB)	Standard Deviation (%)[1)]
FM SWR 1	87.9	1.4	0.47	5%
FM SWR 4	89.5	1.4	0.41	5%
FM DRS 1	90.6	2.4	0.82	9%
FM SWR 2	92	1.4	0.45	5%
FM Stiftung Radio X	94.5	0.6	0.18	2%
FM SWR 3	98.3	3.9	1.23	14%
FM DRS 2	99	2.3	0.59	7%
FM Basel 1	101.7	1.2	0.36	4%
FM DRS 3	103.6	2	0.57	7%
FM Radio Basilisk	107.6	1.9	0.49	6%
DAB-T SRG ch. 12C	227.36	3.5	1.07	12%
DVB-T SRG ch. 31	554	2.6	0.63	7%
analog TV SRG ch. 46	671.25	2.9	0.79	9%
analog TV SRG ch. 49	695.25	0.9	0.29	3%

1) % values refer to electric field strength.

4 Measurement equipments and methods

4.1 Measurement apparatus

The following table provides a summary of the measurement equipments used by the participants. Some laboratories brought several equipments and performed more than one measurement (denoted with sub indexes 1, 2 …).

Lab. No.	Receiver or Radiation Meter	Antenna or Field Probe	Type of probe or antenna
1.1	Narda SRM 3000	three axes antenna	E-field, isotropic
1.2	Rohde & Schwarz ESPI	Schwarzbeck UBA 9116	E-field, biconical
2.1	Rohde & Schwarz FSH3	Schwarzbeck VUBA 9117	E-field, biconical
2.2	Rohde & Schwarz FSL	Schwarzbeck VUBA 9117	E-field, biconical
3	Rohde & Schwarz FSP3	Seibersdorf PCD 8250	E-field, biconical
4	Narda SRM 3000	three axes antenna	E-field, isotropic
5.1	Rohde & Schwarz FSH6	Rohde & Schwarz HE 200 (all modules)	H-field, loop antenna E-field, log-periodic
5.2	Rohde & Schwarz FSH6	Seibersdorf 3 axes ADD3D system	E-field, isotropic
5.3	Narda SRM 3000	three axes antenna	E-field, isotropic
6	Rohde & Schwarz FSH3	Schwarzbeck VUBA 9117	E-field, biconical
7	Rohde & Schwarz FSH3	Schwarzbeck UBAA 9114 Schwarzbeck BBUK 9139	E-field, biconical E-field, biconical
8	Rohde & Schwarz FSH3	Rohde & Schwarz HE 200 (all modules)	H-field, loop antenna E-field, log-periodic
9	Rohde & Schwarz FSU	Rohde & Schwarz HE 200 (all modules)	H-field, loop antenna E-field, log-periodic
10.	Rohde & Schwarz ESPI 7	Rohde & Schwarz HE 200 (all modules)	H-field, loop antenna E-field, log-periodic
11	Rohde & Schwarz FSH6	Rohde & Schwarz HE 200 (all modules)	H-field, loop antenna E-field, log-periodic

4.2 Instrument settings and search strategy

Many different instrument settings were used by the participating laboratories. Since we did not find any correlation of the measured values with the instrument settings, we do not report the individual settings but rather summarise them in the following table:

	FM radio	DAB	DVB	TV analog
Resolution Bandwidth	150 kHz to 300 kHz	1.5 MHz to 3 MHz or channel power	5 MHz to 10 MHz or channel power	300 kHz
Sweep time	20 ms to 3 s	20 ms to 290 ms	20 ms to 290 ms	20 ms to 300 ms
Detector	rms	rms	rms	peak – 2.2 dB[1]

[1] According to the measurement recommendation

Note: Channel power is an option offered on some receivers, integrating the power within a defined channel (frequency band), and displaying it as a function of time.

Some laboratories tried to find the spatial maximum for each broadcast service separately, approaching the maximum by continuous observation of the value displayed by their instruments. Other laboratories worked "blindly", by using a large SPAN on their instruments and scanning the volume of the room systematically and at the end reading out the maximum for each service (if possible).

5 Measurement results

Each participating laboratory submitted the electric field strength in V/m for each room and each service to METAS. Since the stability measurements of METAS did not show a significant correlation with the participants data, no corrections have been applied to the participants data.

The submitted measurement values are not listed in this report. The uncertainty (k=2) of the electric field strength (given in V/m) as estimated by the participants varies from 32.6% to 43.9% including the sampling uncertainty set to 15% (k=1) according to the draft of measurement recommendation (see Annex B for detailed values).

6 Calculation of the comparison reference value (CRV)

The comparison reference value (CRV) has been determined as the weighted average of the values submitted by the participants. The weighting of each measurement was chosen to be inversely proportional to the number of measurements provided by a laboratory for each service measured in a room in order to avoid overestimating the weight of a laboratory providing, for example, 6 values for the same service in the same room. This way, every laboratory obtained equal weight, independently of the number of measurements performed. Moreover, we did not consider potential correlations between the measurements performed by the same laboratory, despite the fact that they may have been carried out by the same person (in this case using different measuring equipments) or with the same equipment (in this case by different persons). The weighting was chosen to be independent of the estimated measurement uncertainty taking into account that the uncertainty estimates may lack precision. The detailed mathematics of this evaluation is described in Annex C.

No obvious outliers were identified, so that no results were excluded from the calculations. The standard uncertainty u_{CRV} (k=1) of the CRV was also determined as mentioned in Annex C. The results are presented in the next two tables.

6.1 CRV in the dining room

Service	**Frequency (MHz)**	**CRV (V/m)**	**u_{CRV} (k=1) (V/m)**
FM SWR 1	87.9	0.114	0.006
FM SWR 4	89.5	0.066	0.003
FM DRS 1	90.6	0.093	0.005
FM SWR 2	92	0.067	0.004
FM Stiftung Radio X	94.5	0.092	0.005
FM SWR 3	98.3	0.062	0.004
FM DRS 2	99	0.184	0.010
FM Basel 1	101.7	0.092	0.005
FM DRS 3	103.6	0.242	0.012
FM Radio Basilisk	107.6	0.128	0.007
DAB-T SRG ch. 12C	227.36	0.062	0.004
DVB-T SRG ch. 31	554	0.048	0.003
analog TV SRG ch. 46	671.25	0.066	0.004
analog TV SRG ch. 49	695.25	0.099	0.005
Total Electric Field Strength		**0.43**	**0.02**

6.2 CRV in the sleeping room

Service	Frequency (MHz)	CRV (V/m)	u_{CRV} (k=1) (V/m)
FM SWR 1	87.9	0.23	0.011
FM SWR 4	89.5	0.15	0.007
FM DRS 1	90.6	0.44	0.023
FM SWR 2	92	0.14	0.007
FM Stiftung Radio X	94.5	0.21	0.010
FM SWR 3	98.3	0.19	0.011
FM DRS 2	99	0.75	0.038
FM Basel 1	101.7	0.42	0.021
FM DRS 3	103.6	0.77	0.039
FM Radio Basilisk	107.6	0.54	0.027
DAB-T SRG ch. 12C	227.36	0.17	0.010
DVB-T SRG ch. 31	554	0.26	0.015
analog TV SRG ch. 46	671.25	0.39	0.021
analog TV SRG ch. 49	695.25	0.76	0.040
Total Electric Field Strength		**1.69**	**0.087**

6.3 Dispersion of measurement results

As an estimate of the dispersion of the measurement results, the standard deviation of the measurement values has been computed for each service in each room:

Service	Standard deviation in the dining room	Standard deviation in the sleeping room
FM SWR 1	29%	20%
FM SWR 4	30%	19%
FM DRS 1	28%	20%
FM SWR 2	34%	22%
FM Stiftung Radio X	27%	18%
FM SWR 3	24%	22%
FM DRS 2	31%	19%
FM Basel 1	27%	16%
FM DRS 3	22%	21%
FM Radio Basilisk	31%	18%
DAB-T SRG ch. 12C	26%	17%
DVB-T SRG ch. 31	28%	32%
analog TV SRG ch. 46	32%	20%
analog TV SRG ch. 49	30%	29%
Total Electric Field Strength	**23%**	**14%**

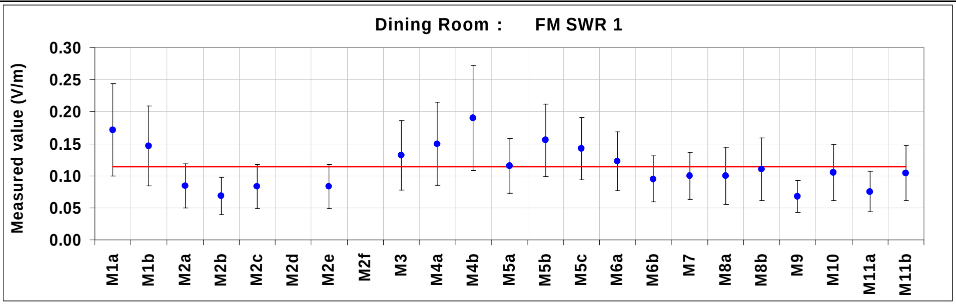
The standard deviation can be considered as an experimentally determined measurement uncertainty and be compared to the measurement uncertainty estimated by each laboratory individually (see annex B):

- If the standard deviation of the measurements is larger than the estimated measurement uncertainty (which is the case for the measurements performed in the dining room), this means that the measurement uncertainty has been underestimated.
- If the standard deviation of the measurements is comparable to the estimated measurement uncertainty, which is the case for the measurements performed in the sleeping room, this means that the measurement uncertainty is realistic.
- If the standard deviation of the measurements is smaller than the estimated measurement uncertainty, which is the case for the "total field strength" measured in the sleeping room, this means that the measurement uncertainty has been overestimated.

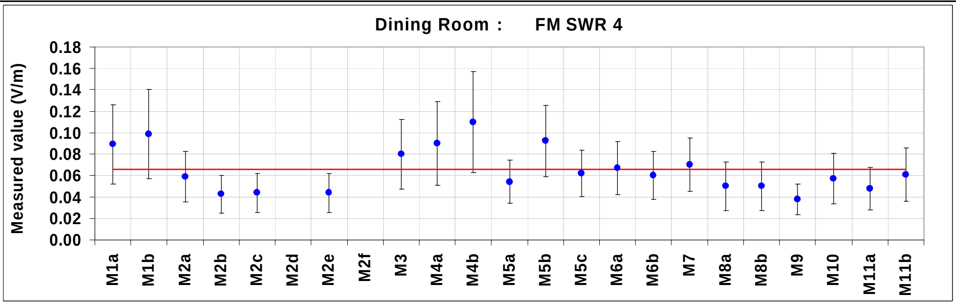
7 Degree of equivalence with respect to the CRV

The degree of equivalence of each individual measurement with respect to the CRV as well as its uncertainty has been determined according to Annex C. The results of these calculations are represented in the next figures. The measurements from laboratory i have been denoted as Mi. If the laboratory provided several measurements, these are denoted as Mia, Mib… The error bars represent the 95% confidence level. A measurement value is considered consistent with the CRV, if it differs by less than the error bars from the CRV. Given the 95% confidence criterion, on average one out of 20 measurements is expected to deviate, for statistical reasons, by more than its error bar from the CRV.

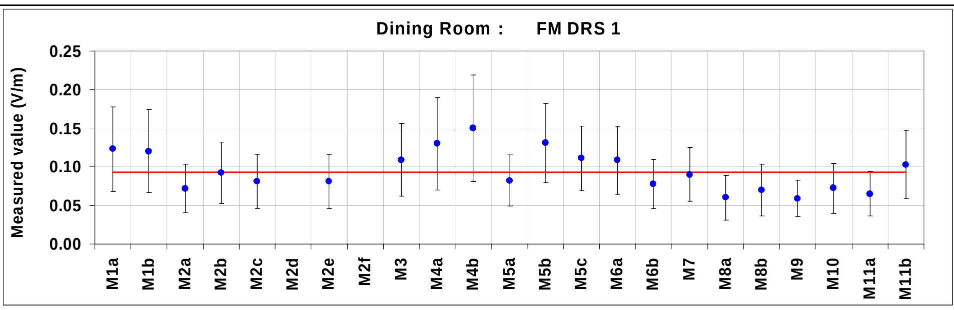
7.1 Dining room



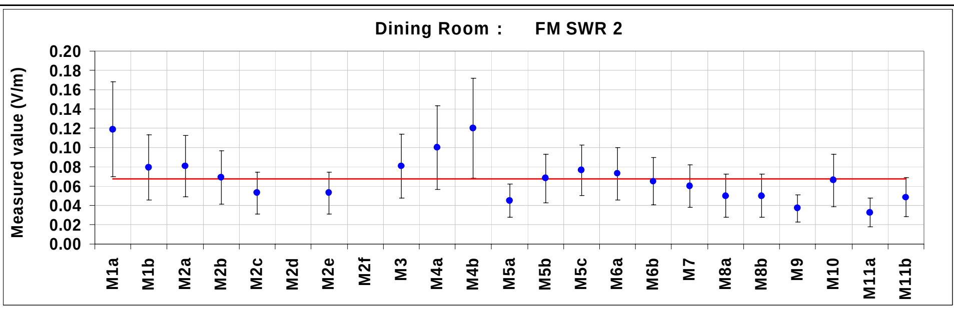
CRV:
0.114 V/m



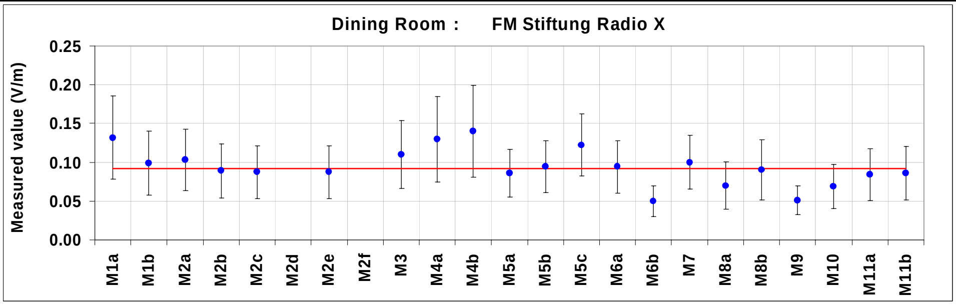
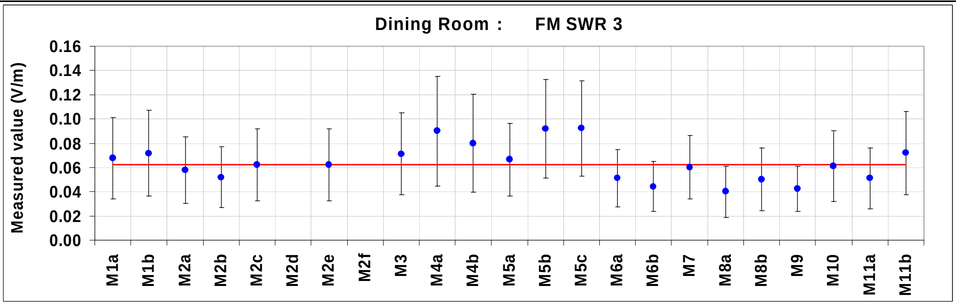
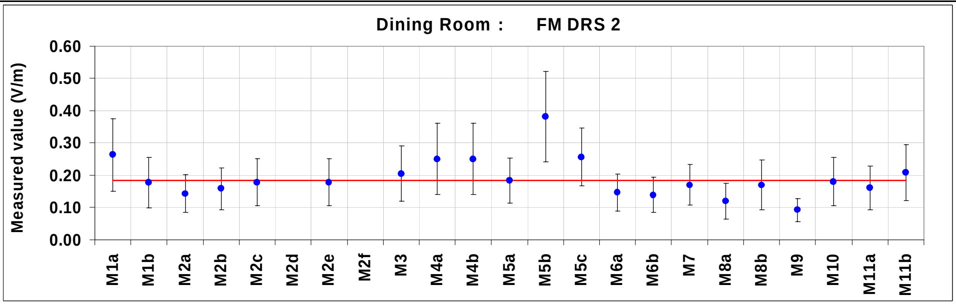
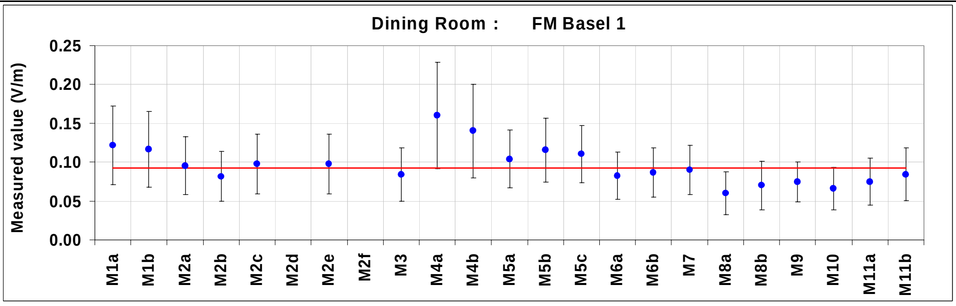
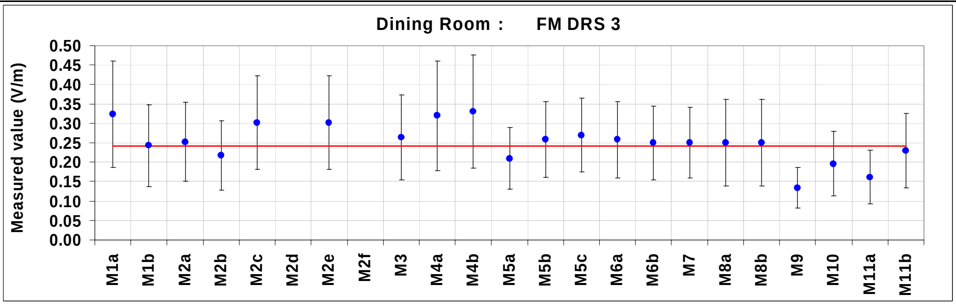
CRV:
0.066 V/m

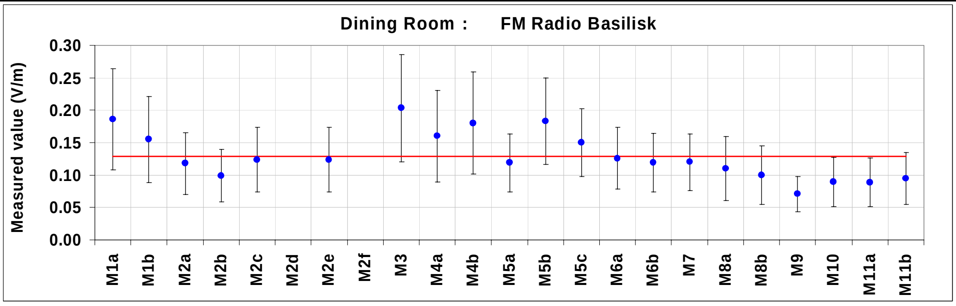


CRV:
0.093 V/m



CRV:
0.067 V/m

	CRV: 0.092 V/m
	CRV: 0.062 V/m
	CRV: 0.184 V/m
	CRV: 0.092 V/m
	CRV: 0.242 V/m



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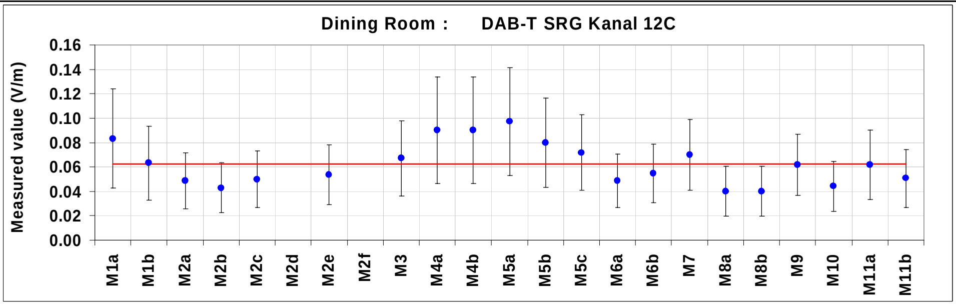

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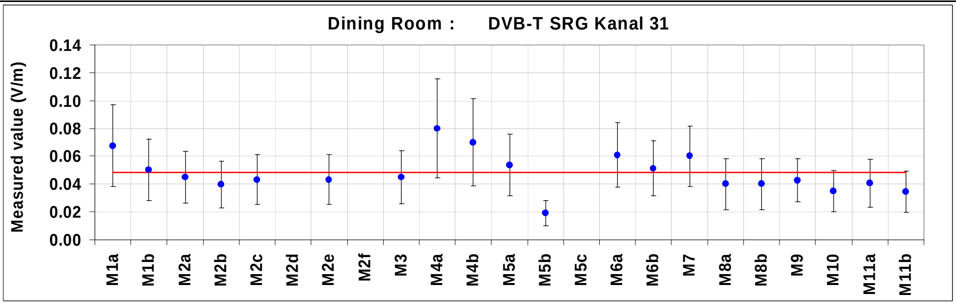

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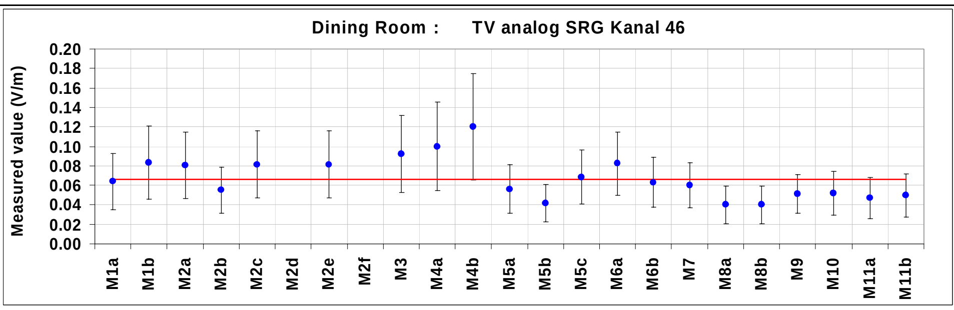

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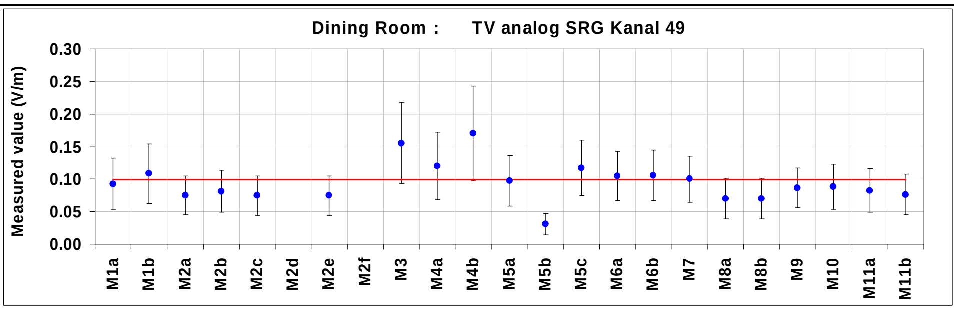

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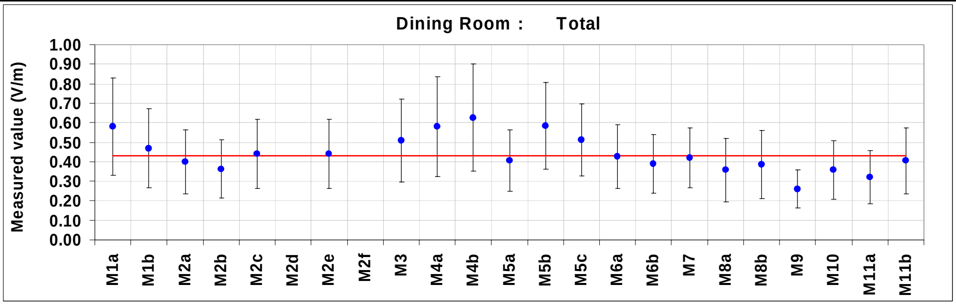
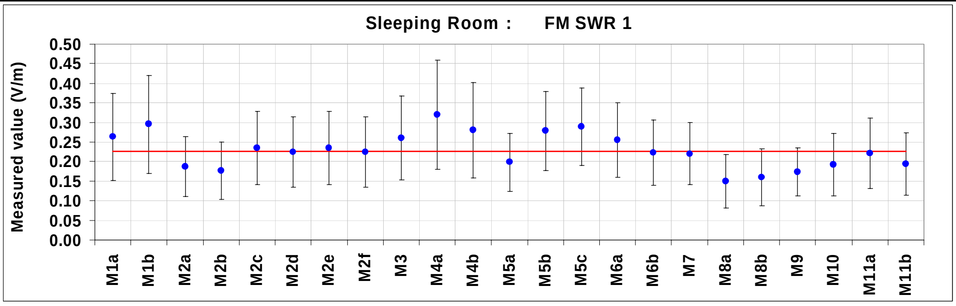


CRV: 0.43 V/m

7.2 Sleeping room



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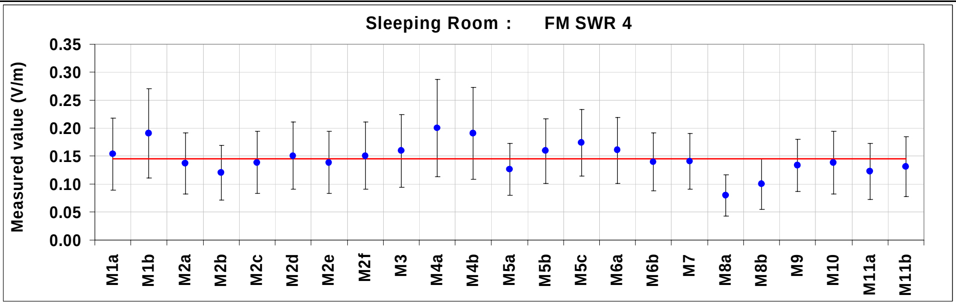

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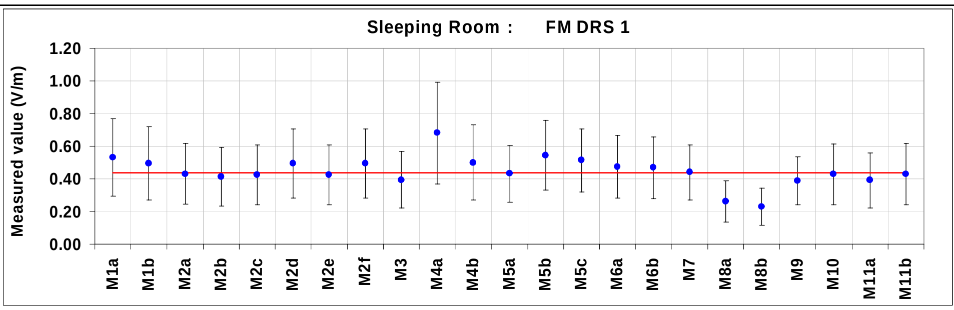

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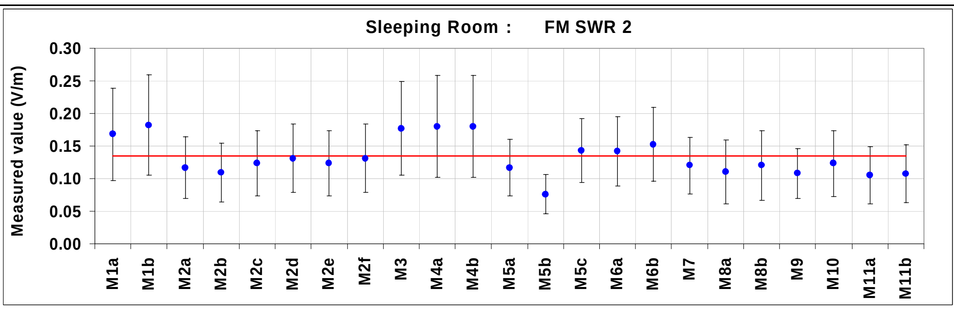

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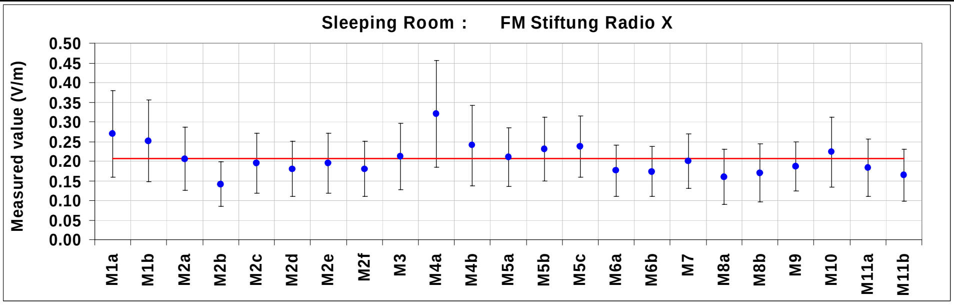

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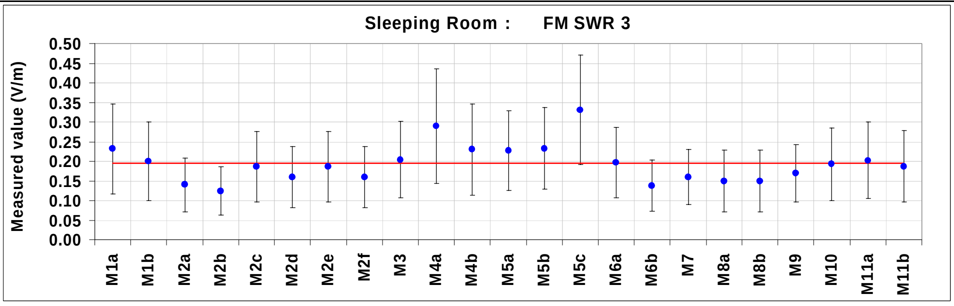

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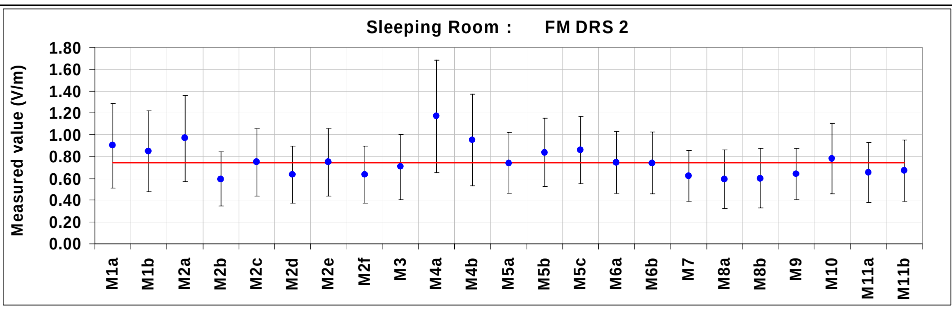

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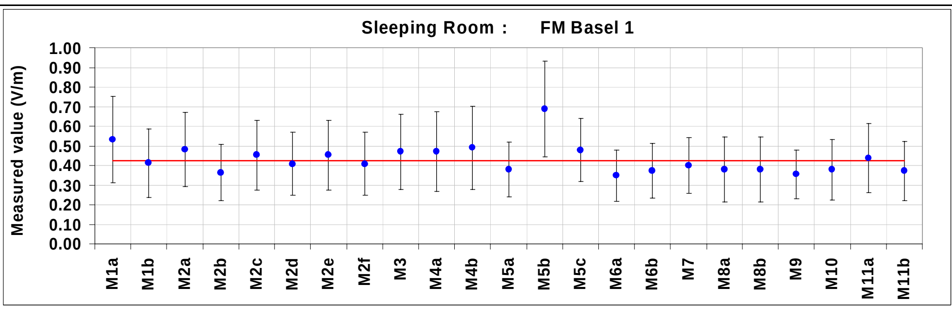
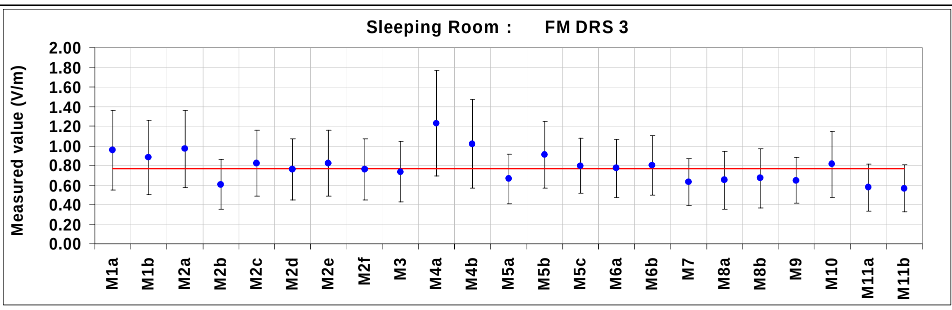


CRV: 0.42 V/m



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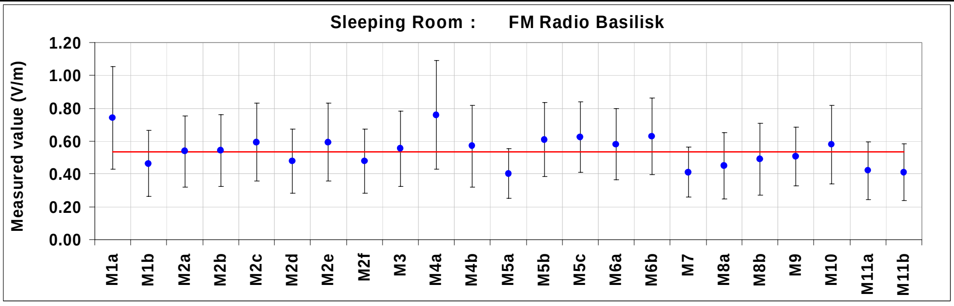

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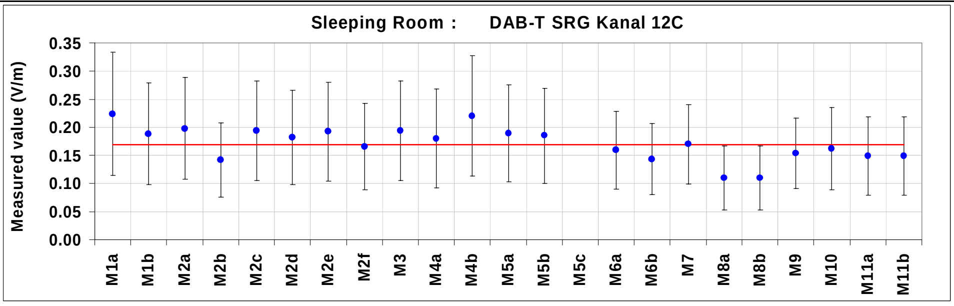

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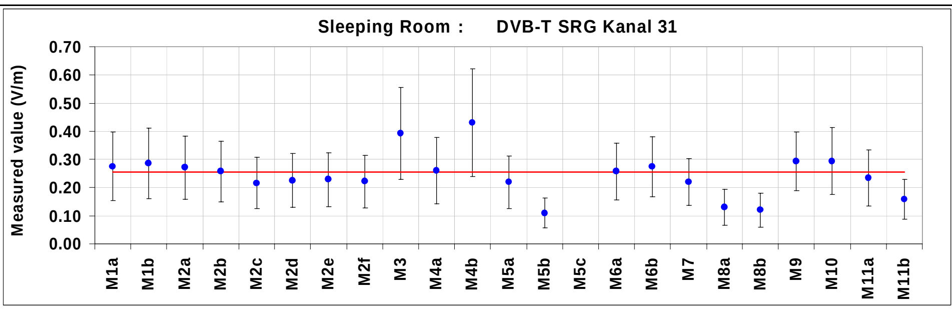

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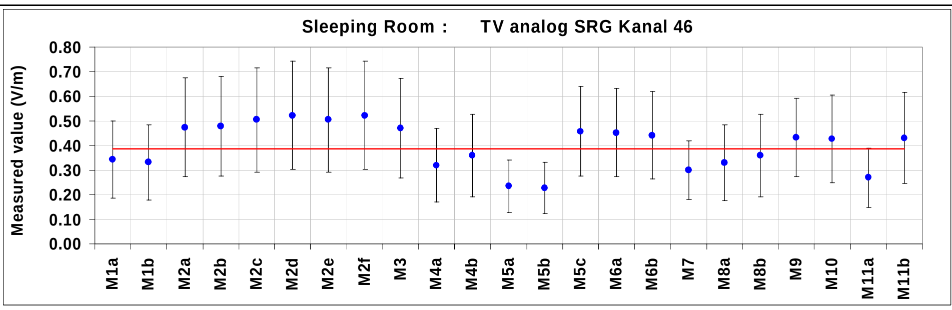

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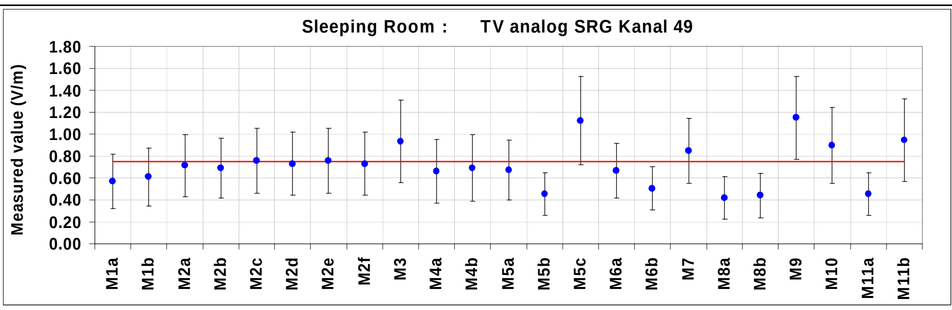
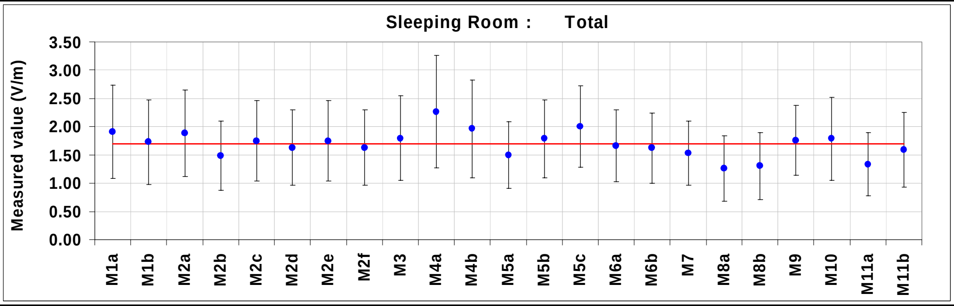


CRV: 0.76 V/m


Sleeping Room : Total
Measured value (V/m)
3.50
3.00
2.50
2.00
1.50
1.00
0.50
0.00
M1a
M1b
M2a
M2b
M2c
M2d
M2e
M2f
M3
M4a
M4b
M5a
M5b
M5c
M6a
M6b
M7
M8a
M8b
M9
M10
M11a
M11b

CRV:
1.69 V/m

8 Observations and conclusion

8.1 Capabilities of the measurement laboratories

The graphs in section 7 show that most of the measurements are consistent with the CRV: 279 measurements out of 314 in the case of the dining room (corresponding to an outlier rate of 11.1%), and 321 measurements out of 343 in the case of the sleeping room (outlier rate 6.4%). Taking into account that the uncertainty bars represent a 95% confidence interval, and provided that this uncertainty has been reasonably estimated by the participants, one expects about 5% of the measured values not to be consistent with the CRV.

A more detailed analysis shows that the measurements M8a, M9 (especially in the dining room) are in many cases very low. We have reason to believe that for these measurements, the search for the spatial maximum may not have been performed with enough care and we consider these deviations from the CRV towards low values to be systematic rather than random.

8.2 Sampling uncertainty

The results presented in section 6.3 show that the sampling uncertainty (15% for k=1 according to the draft of measurement recommendation) is a realistic estimate in case of direct illumination (line-of-sight conditions), a condition which was fulfilled in the sleeping room. In contrast, in case of more diffuse fields (as in the dining room), the overall measurement uncertainty estimated by the laboratories appears to be too low. Assuming that the instrumental uncertainty is independent of the field distribution and of the field strength, this observation suggests that, in cases of diffuse field distributions, the sampling uncertainty may be higher than value of 15% (k=1) which is proposed [4].

Therefore, for each service mentioned in this report, the sampling uncertainty of each laboratory measurement has been modified in order to get a mean uncertainty (among all laboratory measurements) that was equal to the dispersion of the measurements (see section 6.3). These new estimates of the sampling uncertainties are ranging between 13% (k=1) and 30% (k=1) for the dining room, with a median value of 23% (the median value in the sleeping room is 13%). This value of 23% (k=1) sampling uncertainty may therefore be more appropriate to describe the difficulty of reproducibly locating the spatial maximum of the electric field in diffuse fields. However this situation is generally encountered in environments where the field values are significantly lower than the installation limit value, a situation where usually no measurements for compliance testing are performed. A similar behaviour was also observed in the UMTS measurement comparison [5].

Comparing the results for the total field strength with those for the individual frequency bands in section 6.3, it is obvious that the dispersion of the values for the total field becomes narrower. This is a consequence of summing up many independent components. As a general rule it can be concluded that the sampling uncertainty and possibly also the instrumental uncertainty will benefit from aggregating many contributions, at least as long as the total is not dominated by one single band.

8.3 Field probe types

The graphs in section 7 also show that measurements M1a, M4a, M4b and less pronounced also M5c performed in the dining room are higher than the other measurements. These measurements have all been performed with an isotropic probe, which detects by design waves from all different directions while directional antenna respond only to a limited spatial angle. It is indeed known that in a diffuse field (no line of sight to the source) the resulting field at a given point is the sum of waves reflected from many different directions. In these cases, an isotropic probe may provide higher values than a directive antenna. One has to do with this complication mainly in situations where the field values are significantly below the installation limit value, situations where usually no compliance measurements are decreed.

8.4 Conclusion

Based on our observations, we make the following conclusions and recommendations:

- The use of any of the following antenna/probe types is recommended: isotropic, biconical, or directive antennas.

- With respect to the measurement method as outlined in the draft of measurement recommendation [4], no modification except those already mentioned in the report [5], regarding a more precise specification of the measurement volume close to windows is necessary.
- Regarding the sampling uncertainty of 15% (k=1) mentioned in the measurement recommendation, it should be emphasised that this value provides a realistic estimate in cases of line-of-sight. However in case of diffuse fields, higher values should be considered, typically 25% (k=1).

The present report demonstrates the capability of the participating laboratories to measure electric fields generated by broadcast stations within the claimed uncertainty.

9 Literature

1. "Ordinance relating to Protection from Non-Ionising Radiation (ONIR)" (document No. 814.710), December 1999. Available in German, French, Italian, and in English.
2. Measurement recommendation for GSM: "Nichtionisierende Strahlung: Mobilfunk-Basisstationen (GSM) - Messempfehlung", 2002. Available at www.bafu.admin.ch/elektrosmog.
3. Measurement recommendation for UMTS: " Nichtionisierende Strahlung: Mobilfunk-Basisstatinonen (UMTS – FDD), Entwurf vom 17.9.2003", September 2003. Available at www.bafu.admin.ch/elektrosmog.
4. Draft of measurement recommendation for broadcasting: "Nichtionisierende Strahlung: Runkfunk- und Funkrufsendeanlagen, Vollzugsempfehlung zur NISV, Entwurf vom 6.7.2005", July 2005. Available at www.bafu.admin.ch/elektrosmog.
5. UMTS comparison "UMTS Vergleichsmessungen, Sommer 2006", January 2007. Available at www.metas.ch/2006-218-598.
6. W. Bich, M. Cox, T. Estler, L. Nielsen, W. Woeger, "Proposed guidelines for the evaluation of comparison data", April 2002.
7. G. Ratel, "Evaluation of the uncertainty of the degree of equivalence", Metrologia 42, 140–144, 2005.

Annex A: Stability measurements

The stability measurement values in dBm are reported in the following tables. They do not include the antenna factor, and therefore should only be used for stability considerations.

Service	24 Sept.	25 Sept.	25 Sept	26 Sept.	26 Sept.	27 Sept.	27. Sept.	28 Sept.	28 Sept.
	17:15	10:10	14:00	09:40	13:20	09:30	17:30	09:15	13:30
	sunny	cloudy dry	cloudy dry	cloudy wet	cloudy wet	cloudy wet	cloudy dry	cloudy dry	cloudy dry
FM SWR 1	-26.0	-26.3	-26.4	-25.4	-25.8	-26.1	-25.9	-25.4	-25.1
FM SWR 4	-30.3	-30.2	-30.7	-29.4	-30.4	-30.7	-30.7	-29.8	-29.7
FM DRS 1	-24.3	-23.8	-24.8	-23.1	-25.4	-23.0	-23.3	-23.4	-24.0
FM SWR 2	-29.6	-29.9	-29.9	-29.7	-30.5	-30.9	-31.0	-30.8	-30.6
FM S. Radio X	-26.1	-26.3	-26.2	-26.2	-26.3	-26.0	-26.1	-26.5	-26.5
FM SWR 3	-27.0	-27.0	-26.4	-26.2	-26.1	-23.4	-23.3	-24.5	-26.8
FM DRS 2	-15.2	-15.3	-15.1	-16.1	-15.2	-13.8	-13.8	-14.7	-14.9
FM Basel 1	-20.0	-20.2	-19.5	-19.2	-19.9	-19.9	-19.9	-19.9	-19.7
FM DRS 3	-13.8	-14.4	-14.4	-14.3	-14.4	-15.4	-15.5	-15.8	-14.5
FM Radio B.	-17.8	-18.8	-18.3	-17.4	-18.1	-18.9	-18.7	-18.9	-18.0
DAB-T SRG (12)	-20.3	-20.3	-21.3	-19.1	-18.7	-18.3	-18.3	-19.9	-20.2
DVB-T SRG (31)	-25.5	-25.6	-25.9	-25.1	-25.7	-25.9	-25.9	-26.7	-26.3
a. TV SRG (46)	-17.4	-17.1	-16.3	-15.6	-16.4	-16.5	-16.5	-16.3	-16.2
a. TV SRG (49)	-11.4	-11.6	-11.3	-11.1	-11.8	-11.7	-11.7	-11.6	-11.5

Service	02 Oct.	02 Oct.	03 Oct.	03 Oct.	04 Oct.	04 Oct.	05 Oct.	05 Oct.
	09:30	11:30	11:50	16:00	08:30	11:30	09:30	13:30
	slightly cloudy	slightly cloudy	sunny	sunny	light rain	slightly cloudy	in fog	in fog
FM SWR 1	-26.5	-26.5	-25.8	-26.0	-25.1	-26.0	-25.4	-26.4
FM SWR 4	-30.8	-30.5	-30.1	-30.7	-30.2	-30.1	-29.8	-30.5
FM DRS 1	-25.1	-24.8	-24.8	-25.1	-23.2	-24.4	-23.0	-24.2
FM SWR 2	-30.2	-30.2	-30.4	-30.0	-29.6	-30.4	-30.3	-29.8
FM S. Radio X	-26.3	-26.5	-26.3	-26.3	-25.9	-26.5	-26.2	-26.1
FM SWR 3	-26.7	-26.9	-27.0	-26.4	-26.5	-27.0	-27.2	-26.6
FM DRS 2	-15.2	-15.5	-15.3	-15.6	-15.0	-15.5	-15.6	-15.4
FM Basel 1	-19.9	-19.9	-19.0	-19.3	-19.1	-19.6	-19.3	-19.4
FM DRS 3	-14.2	-14.5	-14.6	-15.5	-15.5	-14.8	-14.4	-14.8
FM Radio B.	-18.2	-18.2	-18.3	-17.9	-19.3	-18.2	-18.3	-17.7
DAB-T SRG (12)	-19.1	-20.7	-20.0	-21.4	-21.2	-19.6	-20.3	-21.8
DVB-T SRG (31)	-25.7	-25.4	-25.5	-26.1	-26.0	-25.2	-25.0	-27.6
a. TV SRG (46)	-17.0	-18.5	-17.9	-15.7	-15.7	-16.2	-16.2	-16.0
a. TV SRG (49)	-11.2	-11.1	-11.0	-11.2	-11.6	-11.0	-10.9	-11.7

Annex B: Measurement uncertainties of the participating laboratories

Measurement Number	**Measurement uncertainty (k=1) including sampling uncertainty**
M1a	21.0% to 22.0%
M1b	21.2%
M2a	19.0%
M2b	19.0%
M2c	19.0%
M2d	19.0%
M2e	19.0%
M2f	19.0%
M3	21.5%
M4a	21.8%
M4b	21.8%
M5a	17.5% to 19.7%
M5b	17.5% to 19.7%
M5c	16.3% to 17.9%
M6a	18.2%
M6b	18.2%
M7	18.3%
M8a	21.9%
M8b	21.9%
M9	17.5%
M10	20.6% to 21.3%
M11a	20.0%
M11b	20.0%

The measurement uncertainties reported in this table are the measurement uncertainties communicated by each participating laboratory. The values are expressed in percent of the measured electric field strength values (V/m).

Annex C: Comparison reference value mathematics

C.1 Weighting factor

Let $x_{i,j}$ be the measurement result of laboratory i for a given frequency band and measurement site. Associated with this value is a total uncertainty (k=1) of $u_{i,j}$. The index j distinguishes repetitive measurements of the same situation by the same laboratory. With n participating laboratories and k_i repetitions by laboratory i the weighting factor w_i for any measurement $x_{i,j}$ provided by laboratory i is given by

$$w_i = \frac{1}{n \cdot k_i}$$

C.2 Comparison reference value (CRV)

The CRV is obtained as the weighted average of all measurement values $x_{i,j}$ as follows:

$$CRV = \sum_{i,j} w_i \cdot x_{i,j}$$

and its uncertainty (k=1) as:

$$u_{CRV} = \sqrt{\sum_{i,j} w_i^{\,2} \cdot u_{i,j}^{\,2}}$$

C.3 Degree of equivalence (DoE)

In order to decide whether a value $x_{i,j}$ is consistent with the CRV, we determine the DoE $D_{i,j}$ as the difference between the value $x_{i,j}$ and the CRV as well as the uncertainty (k=1) $u(D_{i,j})$ of this difference:

$$D_{i,j} = x_{i,j} - CRV$$

$$u(D_{i,j}) = \sqrt{(1 - 2 \cdot w_i)u_{i,j}^{\,2} + u_{CRV}^{\,2}}$$

The coverage interval $U(D_{i,j})$ at the 95% level confidence for the degree of equivalence is computed as:

$$U(D_{i,j}) = 2 \cdot u(D_{i,j})$$

In the graphs of section 7 all individual values $x_{i,j}$ are plotted together with their coverage interval $\pm U(D_{i,j})$. References: [6,7].