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Measurement of non-ionizing radiation from a LTE base station: Inter-laboratory comparison – November 2013

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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], as well as a technical report for LTE [5]. The validation of these measurement recommendations is obtained through comparison campaigns with competent laboratories. METAS has already organised measurement comparisons for GSM (2002) [6], UMTS (2006) [7] and broadcasting (2008) [8] radiation. The current report describes a similar inter-laboratory comparison for measurements of radiation produced by a LTE base station.

1.2 Scope of the comparison

The scope of the comparison was to measure the radiation of a LTE base station operating in the frequency band 800 MHz to 900 MHz. Three different scenarios have been defined to simulate low, middle and high LTE traffic from the base station. Moreover, in one of the scenarios, a GSM signal was also produced in order to make relative comparisons between the LTE and the GSM measurement quality.

This exercise was performed in three different rooms in the METAS buildings. To produce the LTE signals, a dummy LTE base station with two sets of cross-polarized antennas has been installed by METAS (see chapter 2 for more details). Measurements were performed in three rooms: first in a room with a large window opening, directly exposed to the radiation of the base station. In a second room, there was a small window opening but still a direct sight to the radiation of the base station. And finally we chose a third room without opening (no window) towards the base station. This scenario was selected to simulate a room with indirect exposure to the radiation. This yields a total of 3x3 different variants.

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 technical report 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 total uncertainty for such measurements. This total uncertainty is made up of two main contributions: instrumental uncertainties and uncertainties intrinsic to the measurement method itself. The latter contribution - called sampling uncertainty in the draft of the 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 previous measurement recommendations [2, 3, 4] as well as in the LTE technical report [5].

1.4 List of participants

Name	Address	Swiss Accreditation Service Number (if accredited for LTE measurements)
BAKOM	2501 Biel	-
em prevent ag	5000 Aarau	STS 437
ENKOM INVENTIS AG	3073 Gümligen	STS 353
Maxwave	8050 Zürich	STS 395
METAS	3003 Bern-Wabern	-
Electrosuisse Montena EMC	1728 Rossens	-
NED-TECH GmbH	4543 Deitingen	STS 575
SUPSI-DACD	6952 Canobbio	STS 309
Swisscom (Schweiz) AG	3050 Bern	STS 121

Name	Address	Swiss Accreditation Service Number (if accredited for LTE measurements)
Prof. Matthias Wuschek, Technische Hochschule Deggendorf (THD)	D-94469 Deggendorf	-

Table 1: Participants to the comparison.

1.5 Schedule

The measurements were performed from 18th to 29th of November 2013, with one participant per day, except for one day 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. This report was reviewed by the Swiss Federal Office for the Environment (FOEN).

2 Measurement task

2.1 General description of the setup

The measurements were performed at METAS in Wabern. For the goal of this comparison, METAS installed a dummy base station consisting of two transmit antennas, each transmitting in two polarisations. The following Figure represents the setup installed at METAS, as well as the rooms where measurements were performed.

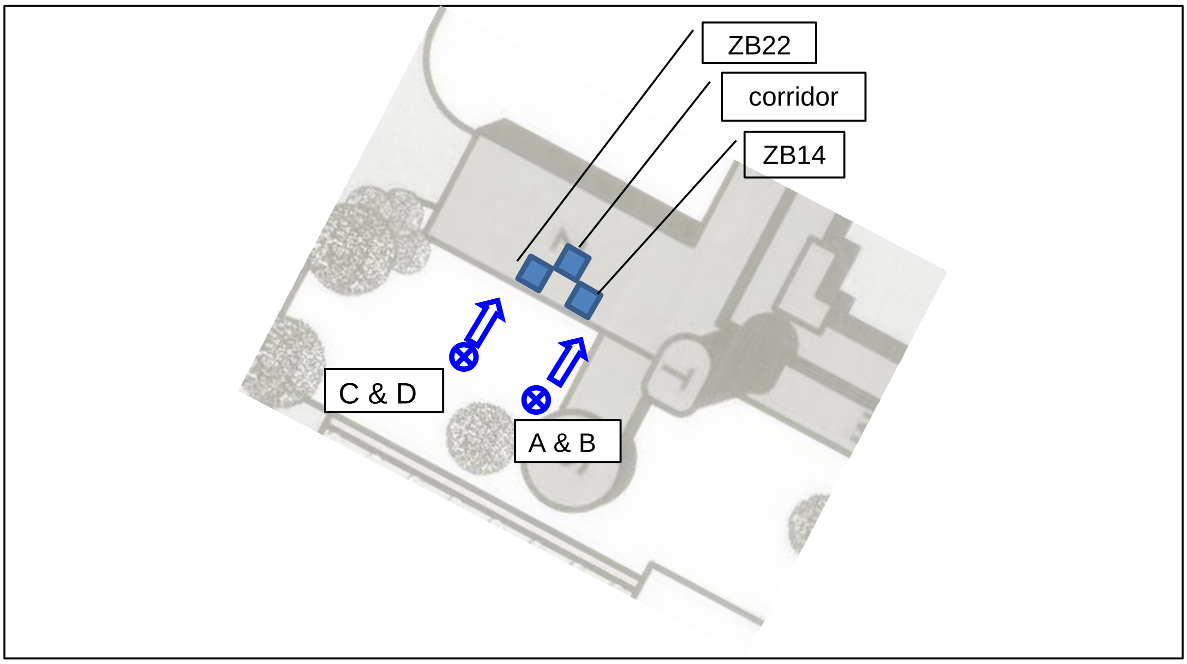


Figure 1: Schematic representation of the setup. Two antennas (in blue crossed circles on this representation) radiate in direction of the METAS building. Three rooms are considered: room ZB14 and room ZB22 with direct sight to the antennas, and the corridor behind without direct sight to the antennas.

A cabinet was installed on the visitor parking lot of METAS. It contained the LTE generator, the GSM generator, four amplifiers, a set of four directional couplers and power meters. The following Figure provides an overview of the physical setup. The distance between the antennas and the METAS building was about 23 m.

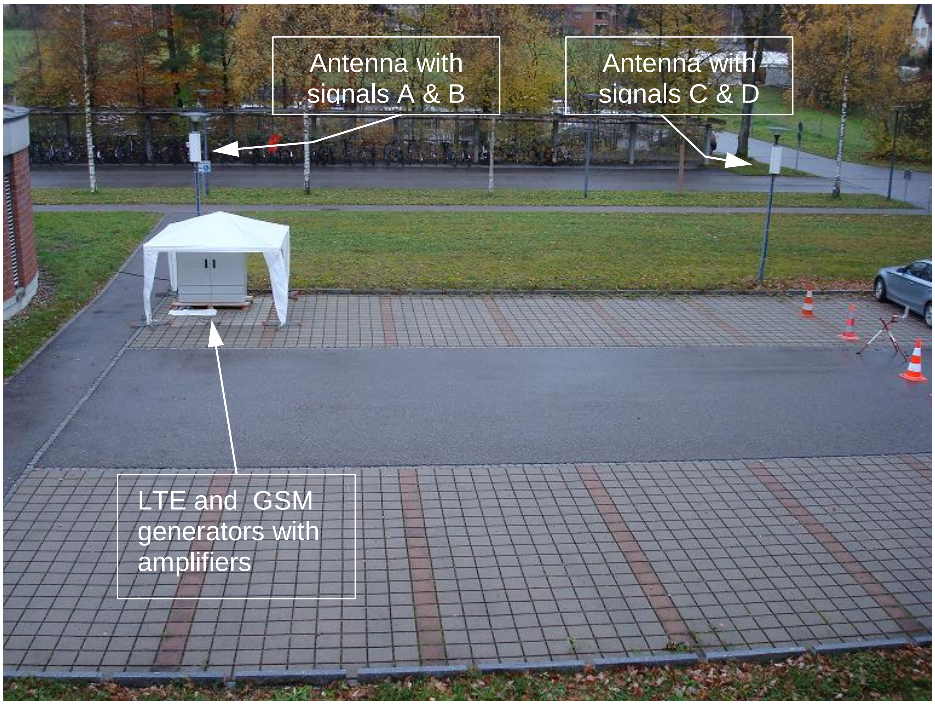


Figure 2: The dummy base station equipment is placed in the cabinet (left on the Figure). Two antennas, each with two ports, are fed with the signals of the dummy base station.

The antenna axes have been mounted almost parallel as drawn in the schematic drawing. During the participant's measurements, the visitor parking access was restricted as shown on the Figure.

2.2 LTE base station and list of material

The LTE base station consisted of arbitrary waveform generators able to generate dummy LTE and GSM traffic. They were installed in a cabinet as shown in the following Figure.

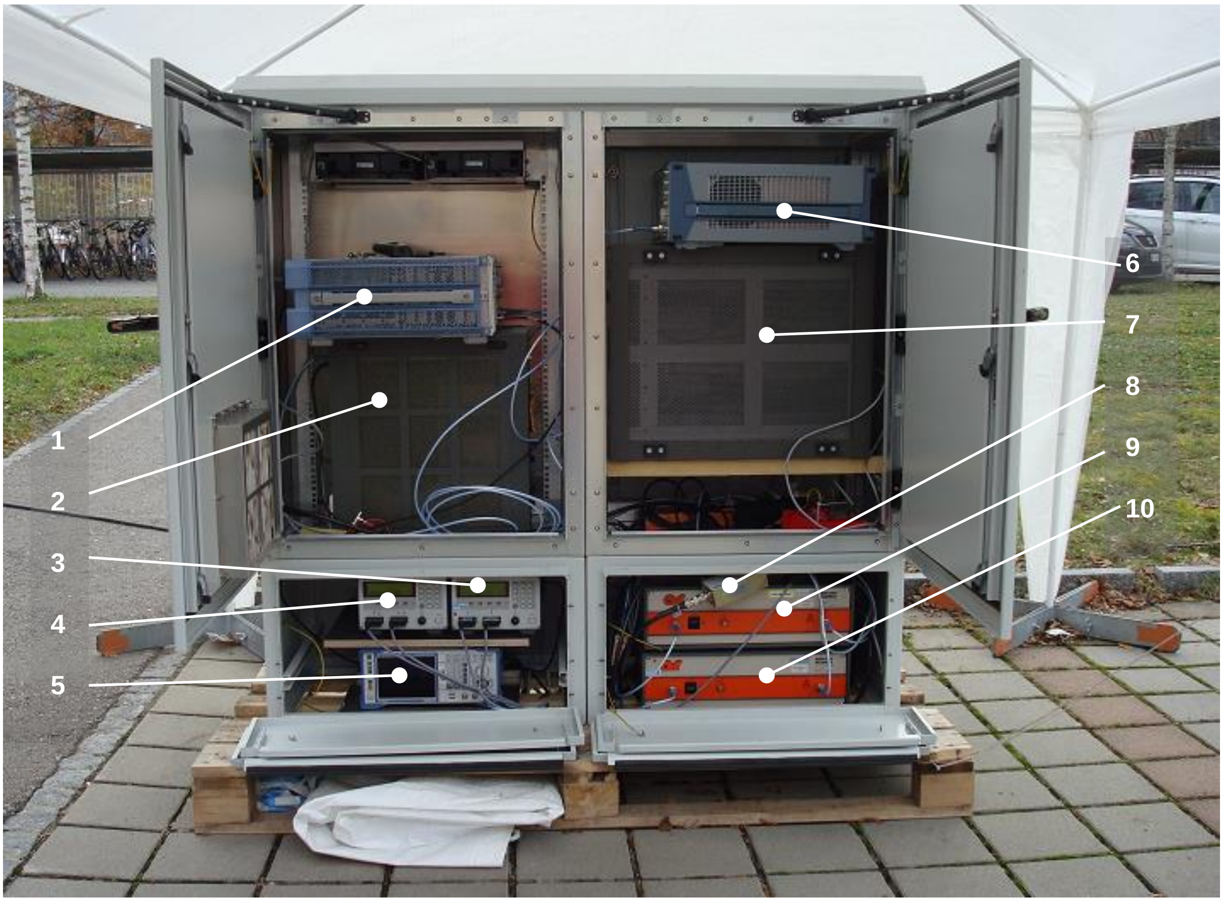


Figure 3: Detailed overview of the dummy base station equipment.

Nb	Device	Manufacturer	Model
1	2 Path LTE Generator	Rohde & Schwarz	SMW 200 A
2	Amplifier 100W	Amplifier Research	100W1000M4A
3	2 Channels Powermeter	Rohde & Schwarz	NRVD
4	2 Channels Powermeter	Rohde & Schwarz	NRVD
5	R&S Vector Signal Generator, 9kHz – 6GHz	Rohde & Schwarz	MBV100A (Model 1407.6004K02)
6	GSM Generator	Rohde & Schwarz	SMIQ
7	Amplifier 125 W	Amplifier Research	125S1G4
8	Directional Coupler (four units)	MEB Bonn Elektronik	RK 100 (3 units) BDC 0842-30 (1 unit)
9	Amplifier	Amplifier Research	10W1000BM2
10	Amplifier	Amplifier Research	10W1000BM2
-	Transmit Antennas	Kathrein	739620V01 (2 units)

Table 2: Equipment list.

2.3 Scenarios

Four signals, here denoted as A, B, C, and D, were generated. Each of the signals A and B was feeding one of the two ports of the first antenna (left on the Figure 2). Each of the signals C and D was feeding one of the two ports of the second antenna (right on Figure). Both antennas were identical and each had two ports connected to crossed-polarised arrays.

The A and B signals were intended to simulate a LTE base station with RS0 and RS1 signals. Therefore, the signals A and B were generated and amplified independently in order to produce RS0 (signal A) and RS1 (signal B). However, in order to simulate the real behaviour of a LTE base station, it was important to synchronise both signals. Moreover, since the signal C is simulating a second LTE base station on the same frequency as signals A and B (for scenario 1 and 2), it was also important to synchronize the signal C with the signals A and B.

The following scenarios were established.

Scenario 1

Signal	**A**	**B**	**C**	**D**
Comment	Simulating one LTE base station with RS0 and RS1 signal		Simulating one LTE base station with only RS0	
Traffic	High traffic		Low traffic	
Frequency	806 MHz		806 MHz	-
Technology	LTE		LTE	-
Cell ID	12		1	-
Bandwidth	10 MHz		10 MHz	-
Signal	RS0	RS1	RS0	-
Max ERP[1]	18 W * 1.64	18 W * 1.64	(72 W) * 1.64	-
Control channel	RS0		RS0	-
ERP Power of the control channel	(30 mW) * 1.64		(120 mW) * 1.64	-
Calculated field strength[2]	1.4 V/m		2 V/m	-

Table 3: Settings for scenario 1.

Scenario 2

Signal	**A**	**B**	**C**	**D**
Comment	Simulating one LTE base station with RS0 and RS1 signal		Simulating one LTE base station with only RS0	
Traffic	Low traffic		Low traffic	
Frequency	806 MHz		806 MHz	-
Technology	LTE		LTE	-
Cell ID	12		1	-
Bandwidth	10 MHz		10 MHz	-
Signal	RS0	RS1	RS0	-
Max ERP	60 W * 1.64	60 W * 1.64	(50 W) * 1.64	-
Control channel	RS0		RS0	-
ERP Power of the control channel	(100 mW) * 1.64		(83.3 mW) * 1.64	-
Calculated field strength[2]	2.5 V/m		1.6 V/m	-

Table 4: Settings for scenario 2.

[1] Equivalent radiated power

[2] Maximum extrapolated field strength values at the METAS building outside façade, calculated using the max ERP value.

Scenario 3

Signal	A	B	C	D
Comment	Simulating one LTE base station with RS0 and RS1 signal		Simulating one LTE base station with only RS0	Simulating one GSM base station
Traffic	Medium traffic		Medium traffic	Only one channel
Frequency	803.5 MHz		803.5 MHz	810
Technology	LTE		LTE	GSM
Cell ID	12		1	**-**
Bandwidth	5 MHz		5 MHz	200 kHz
Signal	RS0	RS1	RS0	-
Max ERP	36 W * 1.64	36 W * 1.64	(9 W) * 1.64	(4 W)*1.64
Control channel	RS0		RS0	BBCH
ERP Power of the control channel	(120 mW) * 1.64		(30 mW) * 1.64	(4 W) * 1.64
Calculated field strength	2 V/m		0.7 V/m	0.5 V/m

Table 5: Settings for scenario 3.

2.4 Measurement sites

The measurements were performed in three rooms identified as:

- **ZB 14**: Small room with direct sight to the base station, small window. The Figure shows the room ZB14 with the window opened as during the measurements.

Figure 4: Room ZB 14 with the window opened.

- **ZB 22**: Larger room (about 36 m^2) with direct sight to the base station, large window. In order to simplify the task of the participants, a surface of 12 m^2 located directly in front of the window was delimited (see the mark on the floor). The Figure shows the room ZB22 with closed window. For the measurement, both parts of the window were opened.

Figure 5: Room ZB 22 with the window closed. During the measurements the window was opened.

- **Corridor** between room ZB 14 and ZB 22. The measurements were performed with closed doors and closed windows in both rooms ZB14 and ZB22. Here too, a measurement surface has been de-limited.

Figure 6: The corridor had no direct sight to the base station.

The following Figure shows the METAS building from outside.

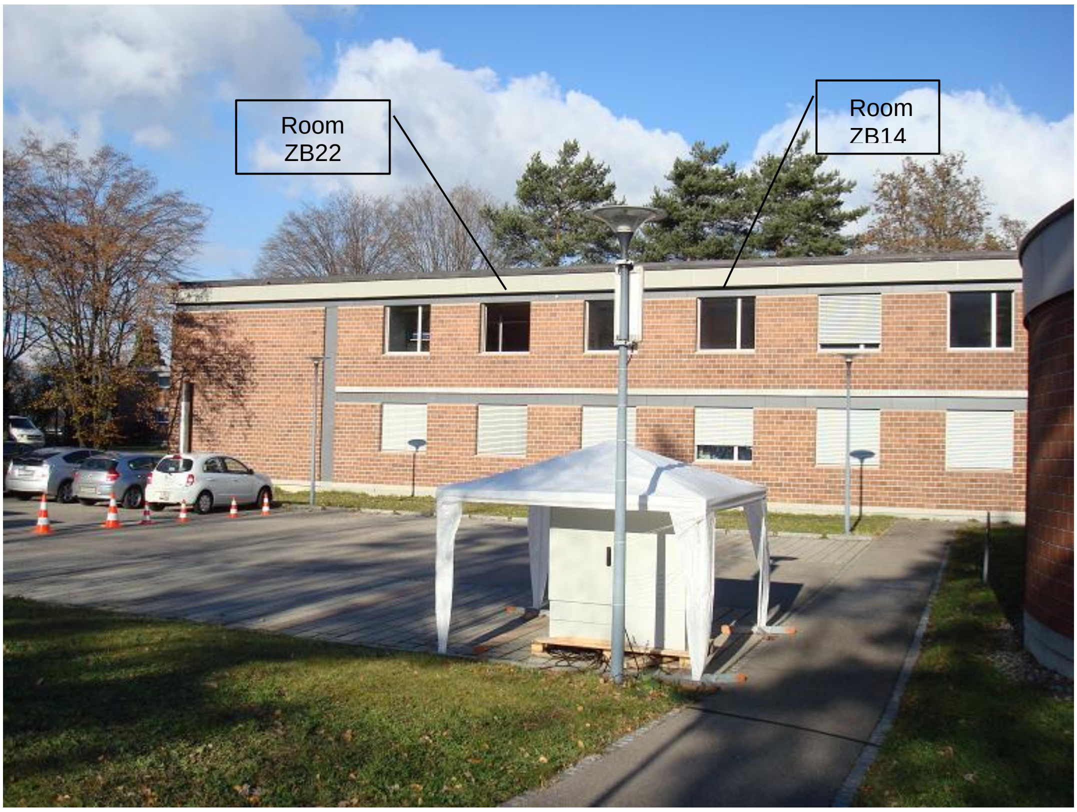


Figure 7: View of the outside of the METAS building.

2.5 Measurement task

The laboratories were asked to find and measure the spatial maximum of the electric field strength in the volume of the room or above the delimited area (with height and wall distance limitations as specified in the measurement recommendations) for each signal listed in section 2.3 individually, and to extrapolate the reading according to the technical report [5] / measurement recommendations [2] to the maximum ERP (Equivalent Radiated Power) as given in section 2.3. Moreover, they had to determine the overall field strength for operation at the maximum ERP.

3 Stability measurements

3.1 Method

In order to guarantee that the electric field strength did not significantly change during the two weeks measurement period, METAS took the following precautions:

1. **Monitoring of the input power to each antenna input**: During the participant's measurements, the input power of each signal was measured by a power meter connected to a coupler.

2. **Field stability measurements**: Once a day, stability measurements were carried out with the following equipment:
   - Antenna Schwarzbeck VUSLP 9111.
   - Rohde & Schwarz ESU EMI Test Receiver.

   The measurements of the incident field strength were performed at a fixed position in front of the open window in room ZV14 (see Figure). These measurements have been compared with the signal power measured simultaneously.

Figure 8: Stability measurements are performed with an antenna placed at a fixed position in front of the opened window.

3.2 Correlation between the input power and the incident field

The measurements of the input power and of the incident field as described in section 3.1 are reported in Annex A. Variations of the difference between the input power and the incident field are a measure of the stability of the wave propagation between the antenna input connector and the position of the test receiving antenna. The standard deviation of this difference is found to be between 0.23 dB and 0.61 dB depending on the antenna signal (A, B, C, or D). This means that for a given signal power, the incident field measured in V/m, as measured by the setup shown in Figure 8, would vary with a standard deviation of 2.5 % to 7%.

3.3 Stability of input power measurements

The power measurements for the whole measurement campaign are reported in Annex B. The power of the signals B, C, and D had standard deviations ranging between 0.08 dB and 0.39 dB. These signals can, therefore, be considered as stable. This is not the case for the signal A that exhibits a standard deviation of more than 1dB (more than 10% in field). This dispersion of these values is explained by the instability of the amplifier.

Therefore, the signal A has been discarded. The evaluation of the total field strength has, thus, been obtained by extrapolating the measured field values of signal B (RS1) instead of signal A (RS0). This is a small deviation to the measurement report for LTE [5]. However, since RS0 and RS1 should be equal, we considered that this should not affect the quality of the comparison, neither should it impair the conclusions of this study.

4 Measurement equipment and methods

4.1 Measurement apparatus

The following table provides a summary of the measurement equipment used by the participants. Some laboratories performed more than one measurement. The total number of measurements is therefore larger than the number of participants.

Meas.	Receiver for LTE	Receiver for GSM	Antenna / Field Probe
L1.1	Rohde & Schwarz, TSMW	Rohde & Schwarz, TSMW	Log-Periodic
L2	Rohde & Schwarz, TSMW	Rohde & Schwarz, FSH3	Log-Periodic
L3.1	Rohde & Schwarz, TSMW	Rohde & Schwarz, TSMW	Log-Periodic
L1.2	Rohde & Schwarz TSMW	Rohde & Schwarz TSMW	Log-Periodic
L4	Narda SRM-3006	Narda SRM-3006	Log-Periodic
L5	Rohde & Schwarz, TSMW	Rohde & Schwarz, TSMW	Log-Periodic
L6.1	Narda SRM-3006	Narda SRM-3006	Log-Periodic
L7	Narda SRM-3006	Narda SRM-3006	Log-Periodic
L8	Narda SRM-3006	Narda SRM-3006	Isotropic
L9.1	Narda SRM-3006	Narda SRM-3006	Isotropic
L9.2	Narda SRM-3006	Narda SRM-3006	Isotropic
L9.3	Narda SRM-3006	Narda SRM-3006	Isotropic
L3.2	Narda SRM-3006	Narda SRM-3006	Isotropic
L10	Narda SRM-3006	Narda SRM-3006	Isotropic
L6.2	Narda SRM-3006	Narda SRM-3006	Isotropic (each axis sequentially)

Table 6: Overview of the equipment used for the measurements.

Note: All accredited laboratories made measurements with log-periodic antenna. One accredited laboratory also performed an additional measurement with an isotropic antenna.

4.2 Instrument settings and search strategy

For measurements of the LTE-reference signals R_0 and R_1, all participants used code selective measurement instruments. The measurement bandwidth ranged from 1.08 MHz to 1.4 MHz.

Some laboratories tried to find the spatial maximum by continuous observation of the value displayed by their instruments. Other laboratories worked “blindly”, scanning the volume of the room systematically and only at the end reading out the maximum for each service.

5 Measurement results

Each participating laboratory submitted the electric field strength in V/m for each room and each service to METAS. No stability correction has been applied to the participant’s 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 36% to 45% including the sampling uncertainty set to 15% (k=1) according to the technical report (see Annex C for detailed values).

6 Comparison reference value (CRV)

6.1 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 the respective service measured in a room. This was done in order to avoid overestimating the weight of a laboratory, providing, for example, 2 measurements. In this way, every laboratory has 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 equipment) or with the same equipment (in this case by different persons). The detailed mathematics of this evaluation is described in Annex D.

6.2 Outliers

The overall consistency check has been applied to the measurements according to Annex D (chi-squared test). The consistency check fails when its value is smaller than 5%. It was not straightforward to identify clearly the outliers and the reasons for all inconsistencies. The observation of the way the participants found the maximum lead us to one observation: Measurements L3.2 have been generally performed too close to the walls, especially in the corridor. Here, the finding of the maximum was difficult, because the field was rather homogeneous within the measurement volume. The measurement recommendation [2] specifies that the distance between antenna and wall, floor, ceiling, or furniture should always be larger than 0.5 m. Therefore, all measurements L3.2 have been declared as outliers. L3.2 measurements are further represented in the Figures, but on the other hand, L3.2 measurements are excluded from all evaluations further reported in this document, as for example the comparison reference value and the standard deviation.

6.3 Separate evaluation for directive and for isotropic antennas

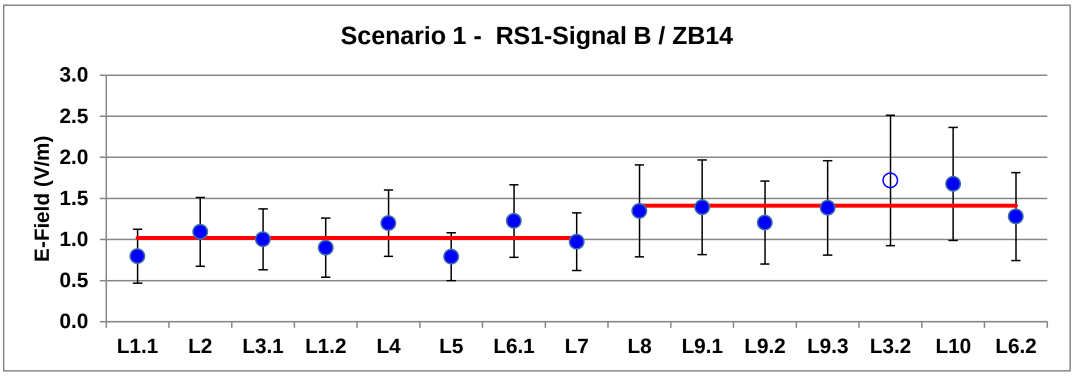
The preliminary evaluation of the measurements has revealed a systematic difference between measurements performed with a directive antenna (eight first measurements according to Table 6), as compared to measurements performed with an isotropic antenna (last seven measurements according to Table 6). Therefore, an independent evaluation of the results has been performed for measurements performed with a directive antenna and for the measurements performed with an isotropic antenna. The results have been represented on the same Figure.

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 D. The results of these calculations are represented in the next Figures. The error bars represent the coverage interval at the 95% level confidence for the degree of equivalence according to Annex D. Outlier values have been represented by empty circles. Outliers have not been included in the calculation of the values reported in each Figure.

A measurement value is considered consistent with the CRV, if it differs by less than the uncertainty 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 uncertainty bar from the CRV.

7.1 Scenario 1

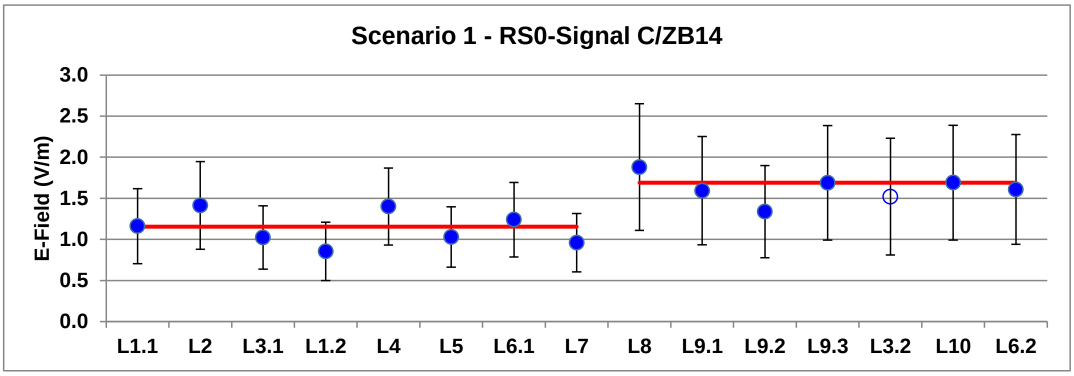


CRV	(V/m)	1.018
u(CRV)	(V/m)	0.075
Std dev.		15%
Nb meas		8
Nb not conform		0
Chisq test		50.0%

CRV	(V/m)	1.412
u(CRV)	(V/m)	0.132
Std dev.		11%
Nb meas		6
Nb not conform		0
Chisq test		89.1%

Ratio CRV (isotropic)/CRV (directive)	1.39

Figure 9: Results for the field of signal B measured in the room ZB14.

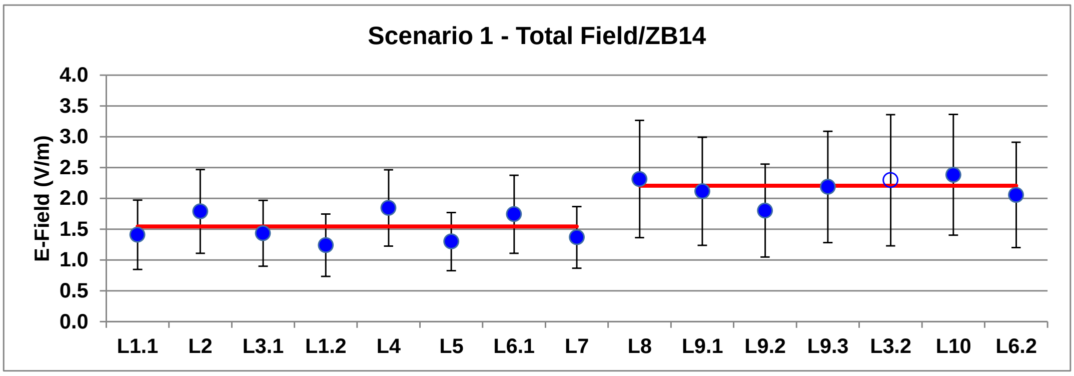


CRV	(V/m)	1.154
u(CRV)	(V/m)	0.085
Std dev.		16%
Nb meas		8
Nb not conform		0
Chisq test		44.4%

CRV	(V/m)	1.689
u(CRV)	(V/m)	0.158
Std dev.		8%
Nb meas		6
Nb not conform		0
Chisq test		83.0%

Ratio CRV (isotropic)/CRV (directive)	1.46

Figure 10: Results for the field of signal C measured in the room ZB14.

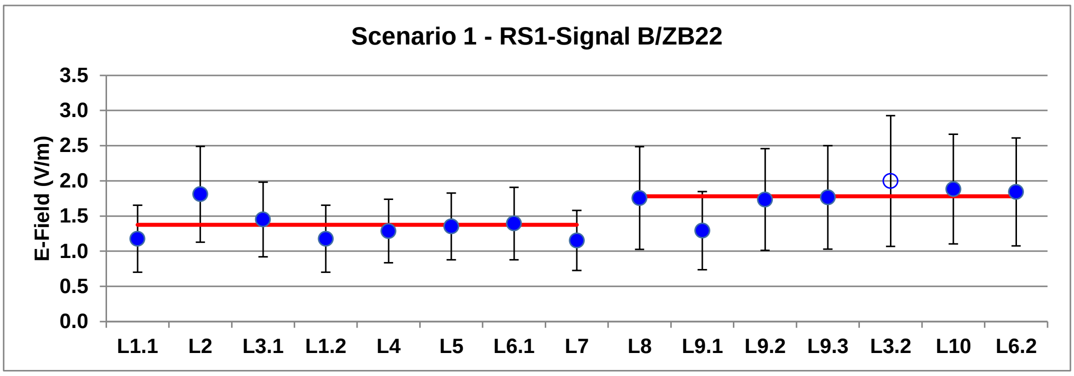


CRV	(V/m)	1.542
u(CRV)	(V/m)	0.113
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		67.7%

CRV	(V/m)	2.205
u(CRV)	(V/m)	0.206
Std dev.		7%
Nb meas		6
Nb not conform		0
Chisq test		89.8%

Ratio CRV (isotropic)/CRV (directive)	1.43

Figure 11: Results for the total field measured in the room ZB14.

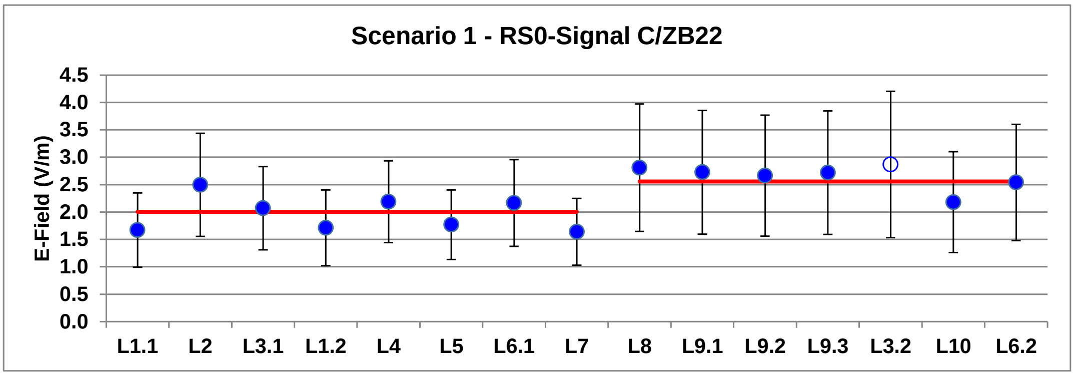


CRV	(V/m)	1.375
u(CRV)	(V/m)	0.102
Std dev.		15%
Nb meas		8
Nb not conform		0
Chisq test		78.6%

CRV	(V/m)	1.780
u(CRV)	(V/m)	0.167
Std dev.		8%
Nb meas		6
Nb not conform		0
Chisq test		59.6%

Ratio CRV (isotropic)/CRV (directive)	1.29

Figure 12: Results for the field of signal B measured in the room ZB22.

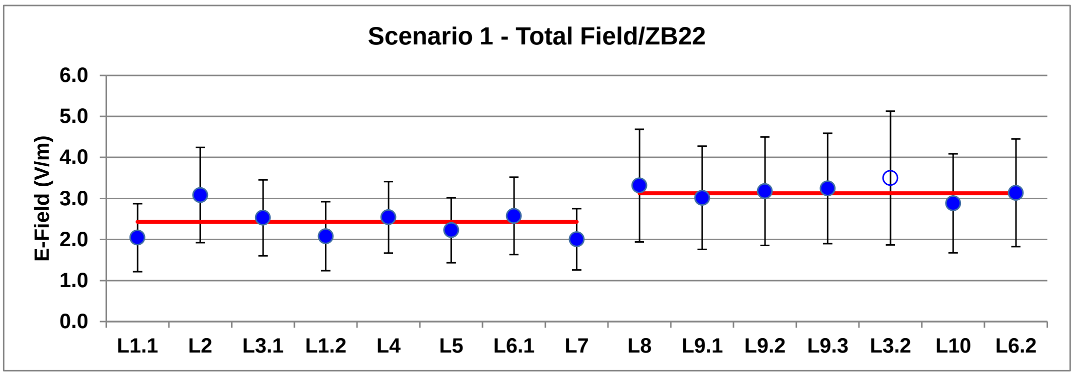


CRV	(V/m)	2.003
u(CRV)	(V/m)	0.148
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		68.3%

CRV	(V/m)	2.559
u(CRV)	(V/m)	0.234
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		94.7%

Ratio CRV (isotropic)/CRV (directive)	1.28

Figure 13: Results for the field of signal C measured in the room ZB22.

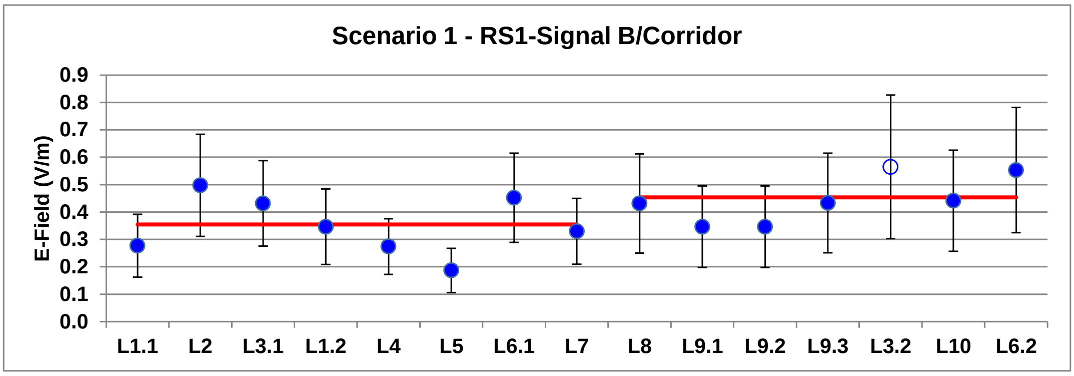


CRV	(V/m)	2.431
u(CRV)	(V/m)	0.179
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		74.7%

CRV	(V/m)	3.125
u(CRV)	(V/m)	0.287
Std dev.		5%
Nb meas		6
Nb not conform		0
Chisq test		99.7%

Ratio CRV (isotropic)/CRV (directive)	1.29

Figure 14: Results for the total field measured in the room ZB22.

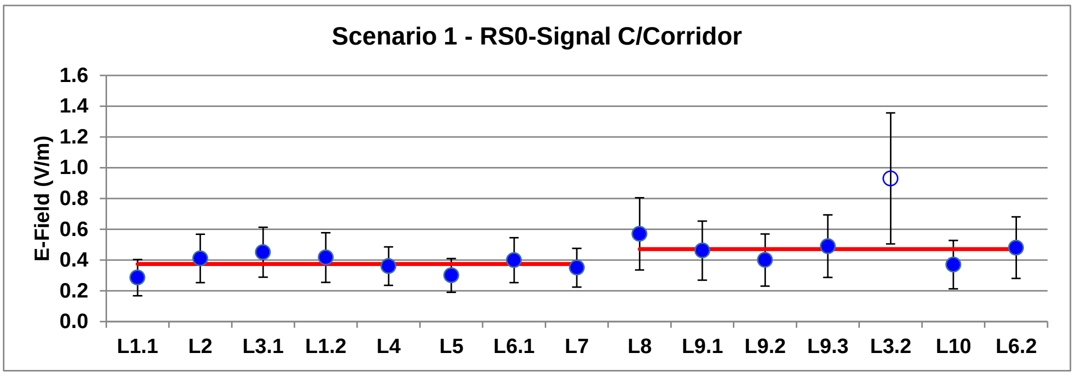


CRV	(V/m)	0.355
u(CRV)	(V/m)	0.027
Std dev.		29%
Nb meas		8
Nb not conform		1
Chisq test		0.0%

CRV	(V/m)	0.454
u(CRV)	(V/m)	0.043
Std dev.		14%
Nb meas		6
Nb not conform		0
Chisq test		32.8%

Ratio CRV (isotropic)/CRV (directive)	1.28

Figure 15: Results for the field of signal B measured in the corridor.

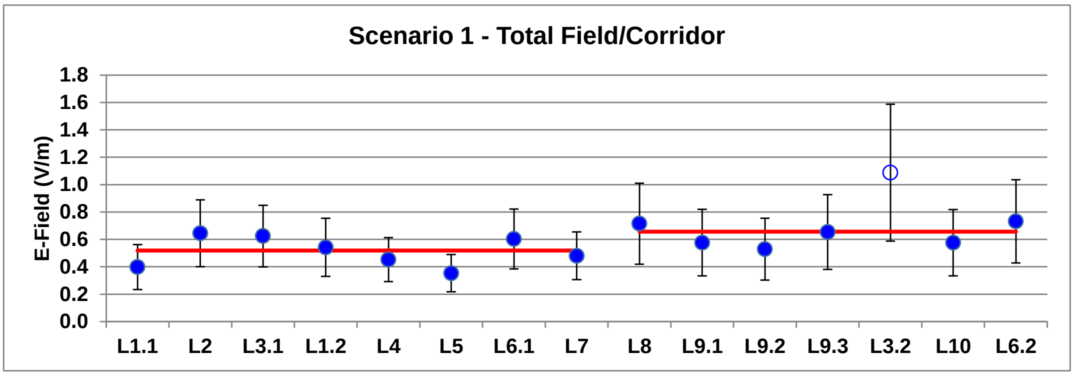


CRV	(V/m)	0.374
u(CRV)	(V/m)	0.027
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		58.3%

CRV	(V/m)	0.470
u(CRV)	(V/m)	0.044
Std dev.		16%
Nb meas		6
Nb not conform		0
Chisq test		63.4%

Ratio CRV (isotropic)/CRV (directive)	1.26

Figure 16: Results for the field of signal C measured in the corridor.



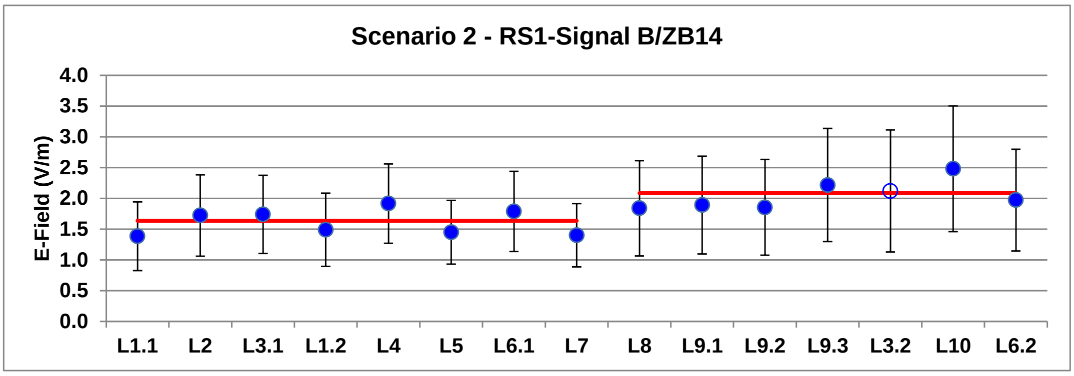
CRV	(V/m)	0.518
u(CRV)	(V/m)	0.039
Std dev.		20%
Nb meas		8
Nb not conform		1
Chisq test		12.1%

CRV	(V/m)	0.656
u(CRV)	(V/m)	0.062
Std dev.		11%
Nb meas		6
Nb not conform		0
Chisq test		72.2%

Ratio CRV (isotropic)/CRV (directive)	1.27

Figure 17: Results for the total field measured in the corridor.

7.2 Scenario 2

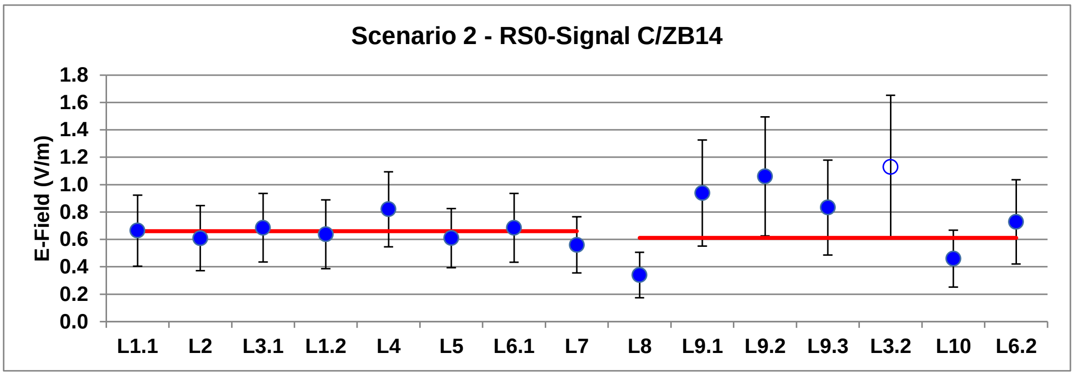


CRV	(V/m)	1.636
u(CRV)	(V/m)	0.119
Std dev.		12%
Nb meas		8
Nb not conform		0
Chisq test		85.8%

CRV	(V/m)	2.084
u(CRV)	(V/m)	0.194
Std dev.		12%
Nb meas		6
Nb not conform		0
Chisq test		86.2%

Ratio CRV (isotropic)/CRV (directive)	1.27

Figure 18: Results for the field of signal B measured in the room ZB14.

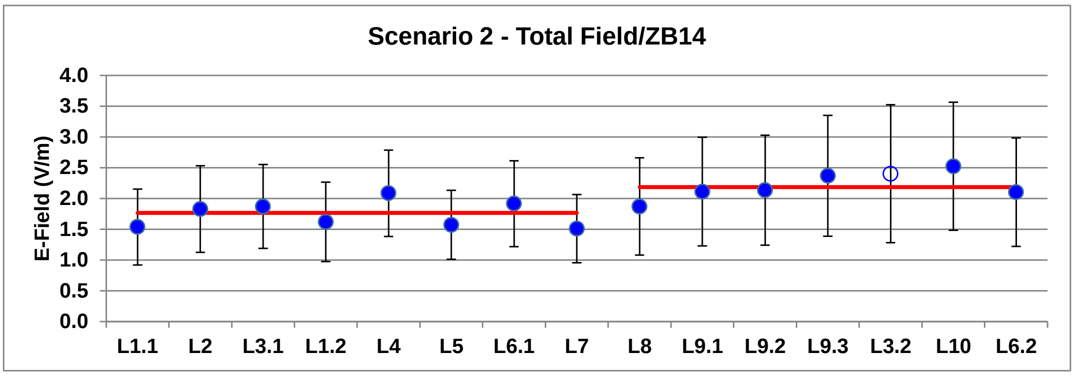


CRV	(V/m)	0.660
u(CRV)	(V/m)	0.047
Std dev.		12%
Nb meas		8
Nb not conform		0
Chisq test		93.3%

CRV	(V/m)	0.611
u(CRV)	(V/m)	0.054
Std dev.		38%
Nb meas		6
Nb not conform		2
Chisq test		0.0%

Ratio CRV (isotropic)/CRV (directive)	0.93

Figure 19: Results for the field of signal C measured in the room ZB14.

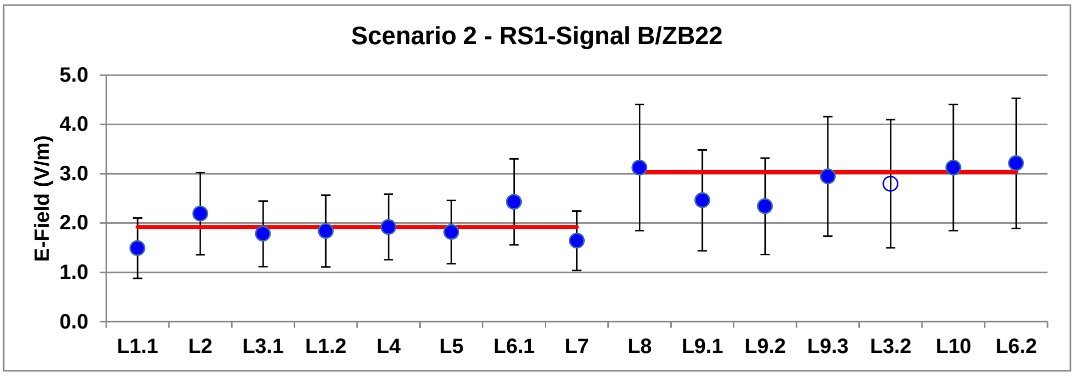


CRV	(V/m)	1.765
u(CRV)	(V/m)	0.128
Std dev.		11%
Nb meas		8
Nb not conform		0
Chisq test		89.2%

CRV	(V/m)	2.185
u(CRV)	(V/m)	0.202
Std dev.		11%
Nb meas		6
Nb not conform		0
Chisq test		92.5%

Ratio CRV (isotropic)/CRV (directive)	1.24

Figure 20: Results for the total field measured in the room ZB14.

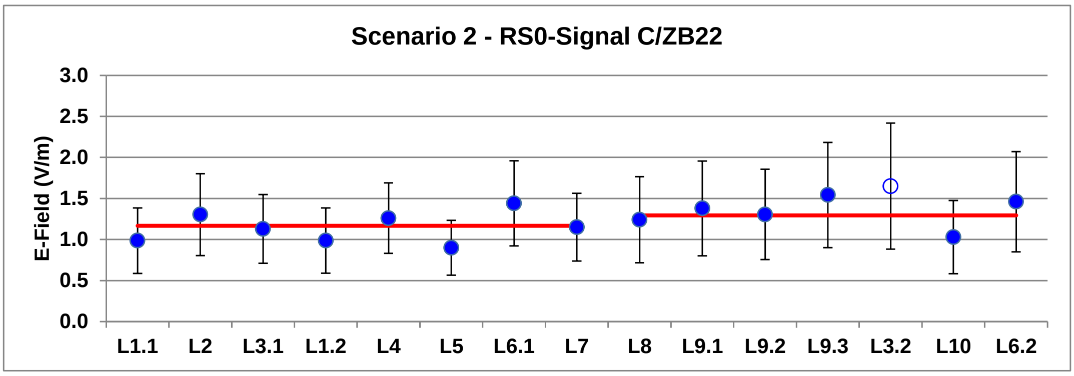


CRV	(V/m)	1.920
u(CRV)	(V/m)	0.141
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		70.3%

CRV	(V/m)	3.033
u(CRV)	(V/m)	0.286
Std dev.		8%
Nb meas		6
Nb not conform		0
Chisq test		59.3%

Ratio CRV (isotropic)/CRV (directive)	1.58

Figure 21: Results for the field of signal B measured in the room ZB22.

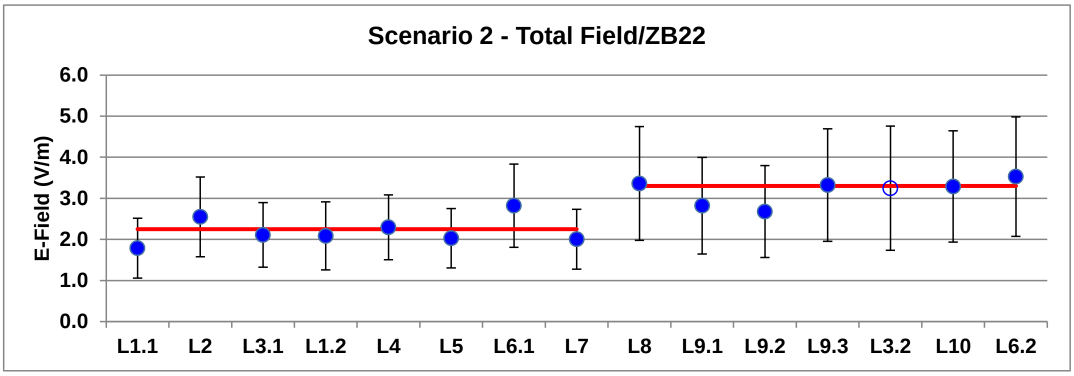


CRV	(V/m)	1.167
u(CRV)	(V/m)	0.086
Std dev.		15%
Nb meas		8
Nb not conform		0
Chisq test		59.3%

CRV	(V/m)	1.293
u(CRV)	(V/m)	0.118
Std dev.		14%
Nb meas		6
Nb not conform		0
Chisq test		73.7%

Ratio CRV (isotropic)/CRV (directive)	1.11

Figure 22: Results for the field of signal C measured in the room ZB22.

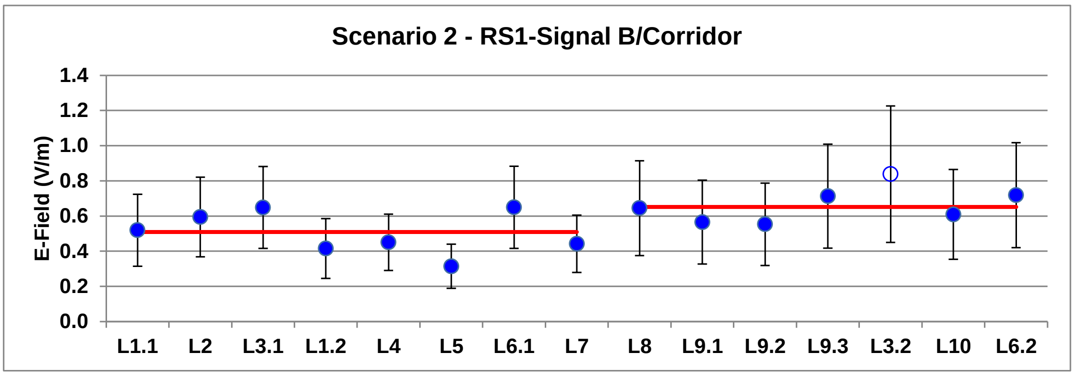


CRV	(V/m)	2.249
u(CRV)	(V/m)	0.165
Std dev.		14%
Nb meas		8
Nb not conform		0
Chisq test		77.0%

CRV	(V/m)	3.304
u(CRV)	(V/m)	0.310
Std dev.		7%
Nb meas		6
Nb not conform		0
Chisq test		81.9%

Ratio CRV (isotropic)/CRV (directive)	1.47

Figure 23: Results for the total field measured in the room ZB22.

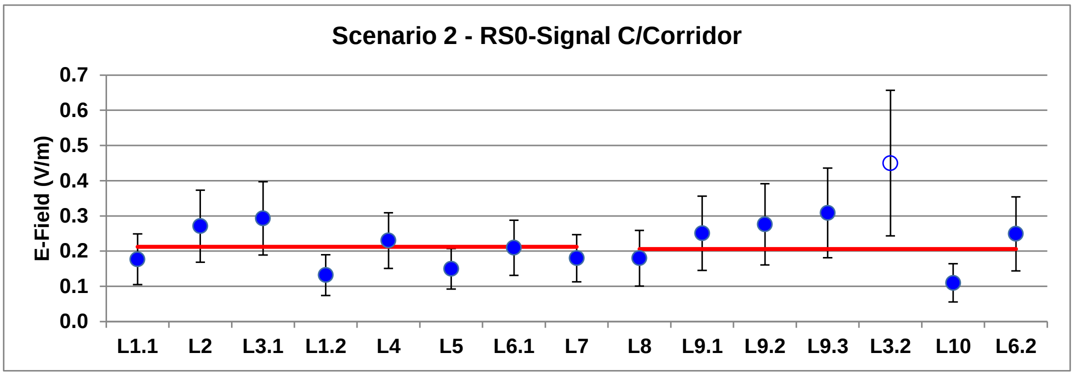


CRV	(V/m)	0.510
u(CRV)	(V/m)	0.038
Std dev.		23%
Nb meas		8
Nb not conform		1
Chisq test		2.4%

CRV	(V/m)	0.652
u(CRV)	(V/m)	0.061
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		86.2%

Ratio CRV (isotropic)/CRV (directive)	1.28

Figure 24: Results for the field of signal B measured in the corridor.

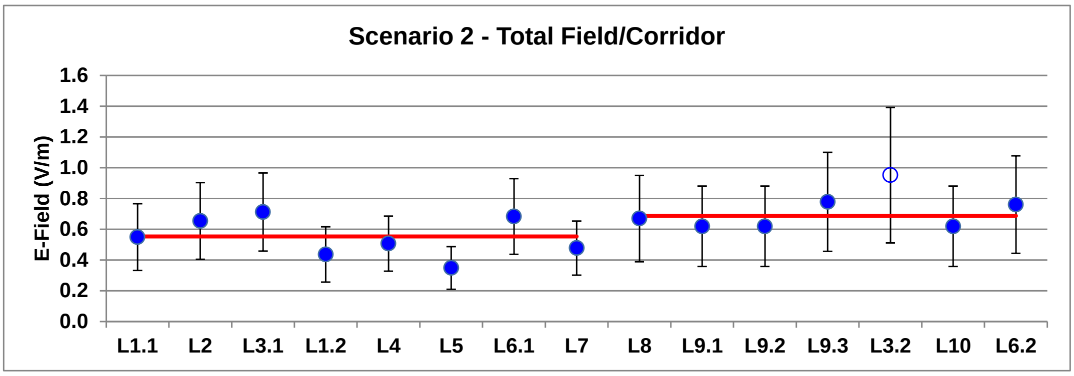


CRV	(V/m)	0.213
u(CRV)	(V/m)	0.016
Std dev.		25%
Nb meas		8
Nb not conform		2
Chisq test		0.7%

CRV	(V/m)	0.206
u(CRV)	(V/m)	0.019
Std dev.		33%
Nb meas		6
Nb not conform		1
Chisq test		0.0%

Ratio CRV (isotropic)/CRV (directive)	0.97

Figure 25: Results for the field of signal C measured in the corridor.



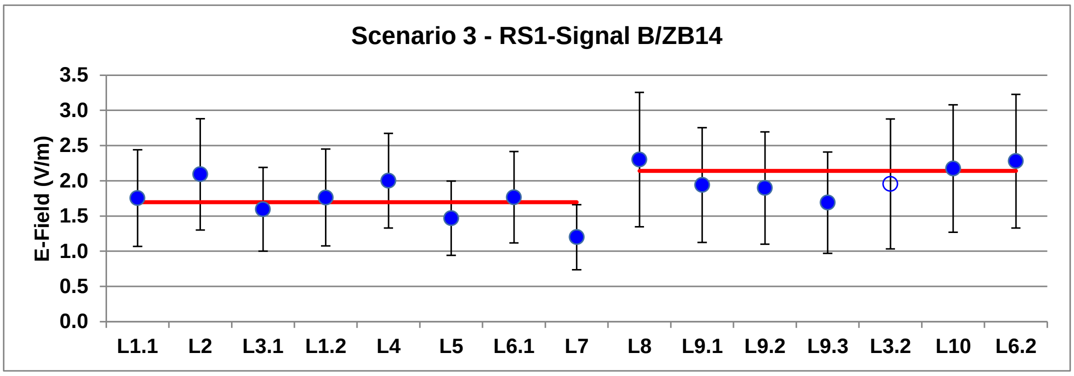
CRV	(V/m)	0.553
u(CRV)	(V/m)	0.042
Std dev.		23%
Nb meas		8
Nb not conform		1
Chisq test		3.3%

CRV	(V/m)	0.687
u(CRV)	(V/m)	0.064
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		91.4%

Ratio CRV (isotropic)/CRV (directive)	1.24

Figure 26: Results for the total field measured in the corridor.

7.3 Scenario 3

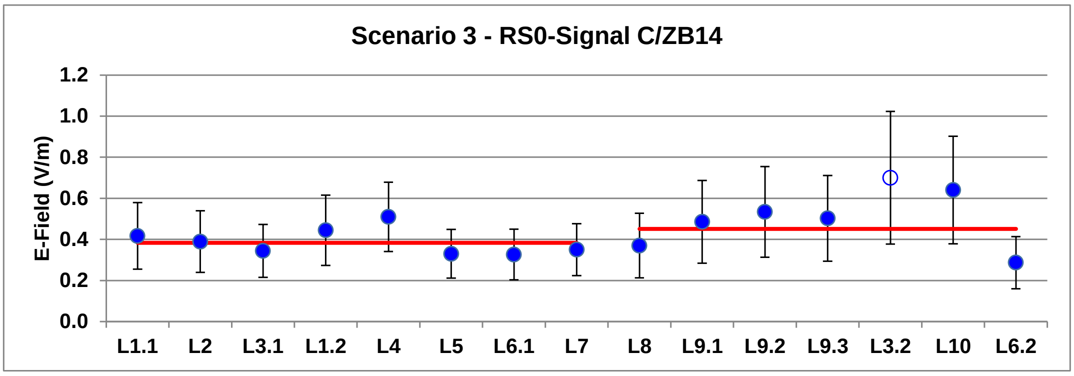


CRV	(V/m)	1.698
u(CRV)	(V/m)	0.124
Std dev.		17%
Nb meas		8
Nb not conform		1
Chisq test		43.0%

CRV	(V/m)	2.140
u(CRV)	(V/m)	0.203
Std dev.		10%
Nb meas		6
Nb not conform		0
Chisq test		75.1%

Ratio CRV (isotropic)/CRV (directive)	1.26

Figure 27: Results for the field of signal B measured in the room ZB14.

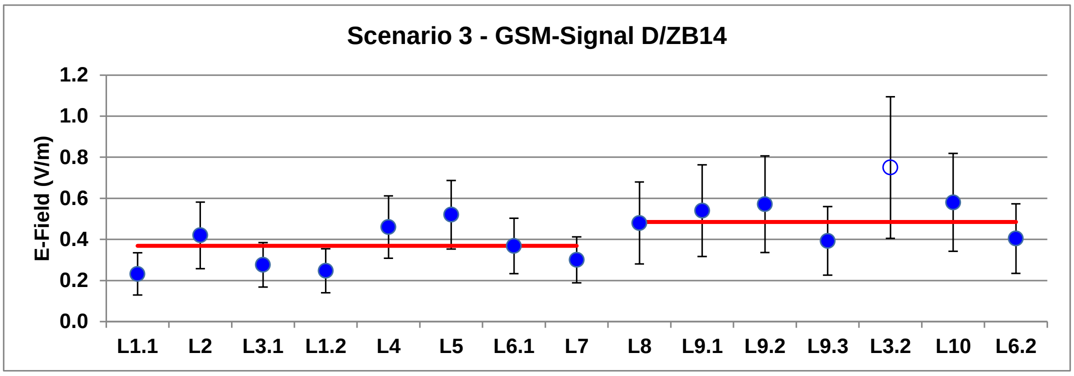


CRV	(V/m)	0.383
u(CRV)	(V/m)	0.027
Std dev.		16%
Nb meas		8
Nb not conform		0
Chisq test		71.9%

CRV	(V/m)	0.451
u(CRV)	(V/m)	0.043
Std dev.		30%
Nb meas		6
Nb not conform		1
Chisq test		2.9%

Ratio CRV (isotropic)/CRV (directive)	1.18

Figure 28: Results for the field of signal C measured in the room ZB14.

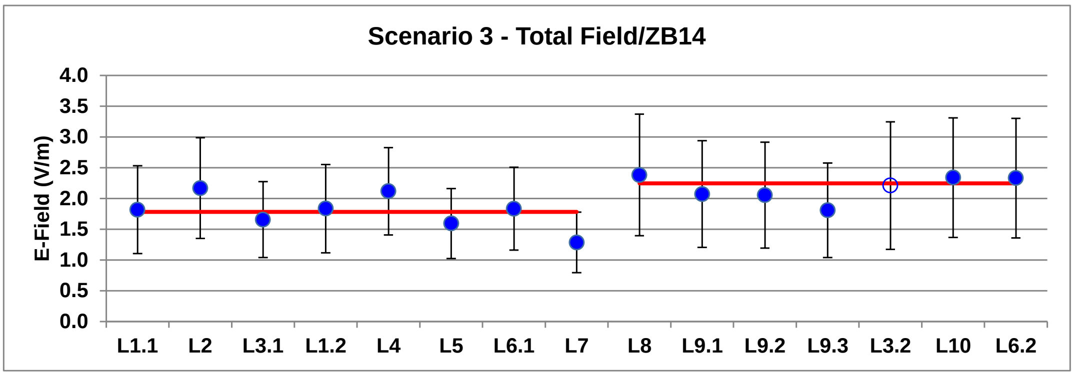


CRV	(V/m)	0.369
u(CRV)	(V/m)	0.027
Std dev.		26%
Nb meas		8
Nb not conform		2
Chisq test		0.2%

CRV	(V/m)	0.485
u(CRV)	(V/m)	0.045
Std dev.		15%
Nb meas		6
Nb not conform		0
Chisq test		56.7%

Ratio CRV (isotropic)/CRV (directive)	1.31

Figure 29: Results for the field of signal D measured in the room ZB14.

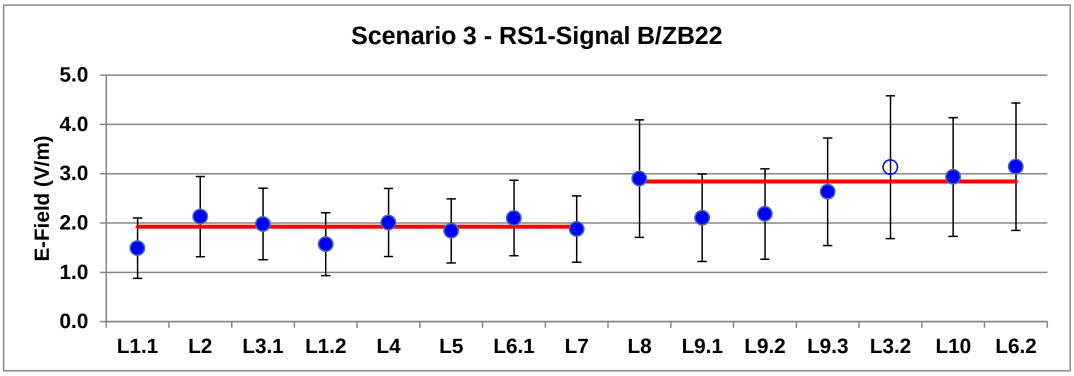


CRV	(V/m)	1.783
u(CRV)	(V/m)	0.130
Std dev.		16%
Nb meas		8
Nb not conform		1
Chisq test		53.2%

CRV	(V/m)	2.247
u(CRV)	(V/m)	0.212
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		84.4%

Ratio CRV (isotropic)/CRV (directive)	1.26

Figure 30: Results for the total field measured in the room ZB14.

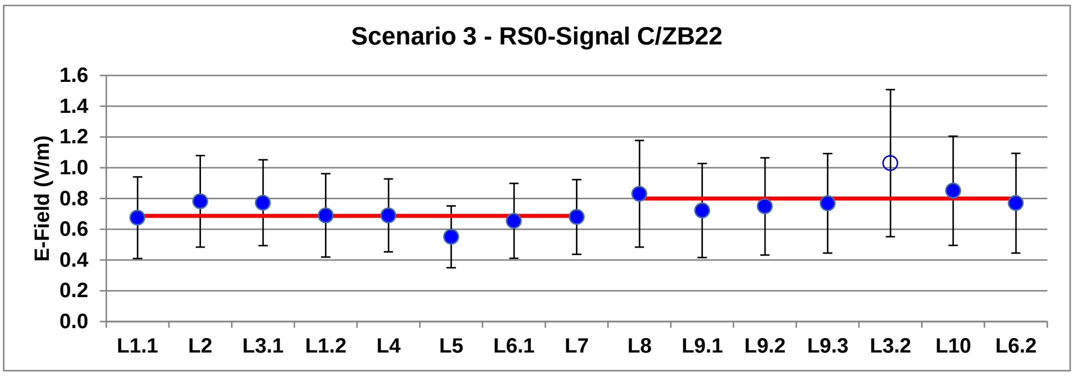


CRV	(V/m)	1.923
u(CRV)	(V/m)	0.141
Std dev.		10%
Nb meas		8
Nb not conform		0
Chisq test		77.2%

CRV	(V/m)	2.841
u(CRV)	(V/m)	0.270
Std dev.		11%
Nb meas		6
Nb not conform		0
Chisq test		33.2%

Ratio CRV (isotropic)/CRV (directive)	1.48

Figure 31: Results for the field of signal B measured in the room ZB22.

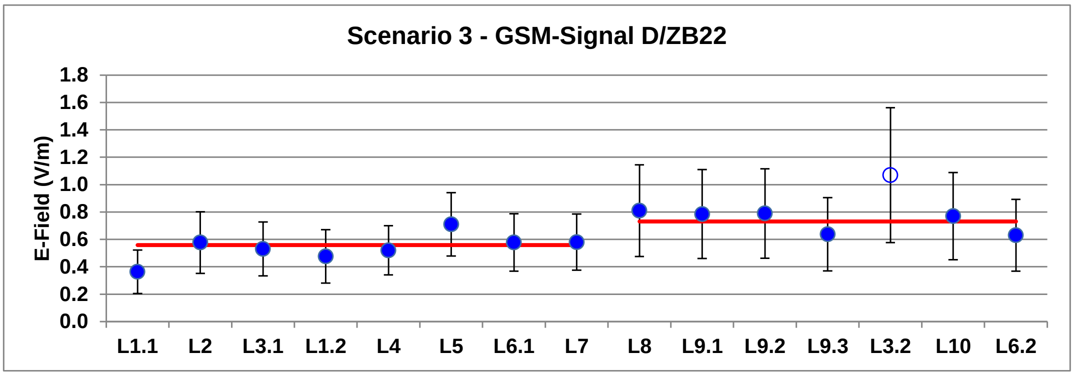


CRV	(V/m)	0.687
u(CRV)	(V/m)	0.050
Std dev.		10%
Nb meas		8
Nb not conform		0
Chisq test		93.0%

CRV	(V/m)	0.800
u(CRV)	(V/m)	0.075
Std dev.		5%
Nb meas		6
Nb not conform		0
Chisq test		98.7%

Ratio CRV (isotropic)/CRV (directive)	1.16

Figure 32: Results for the field of signal C measured in the room ZB22.

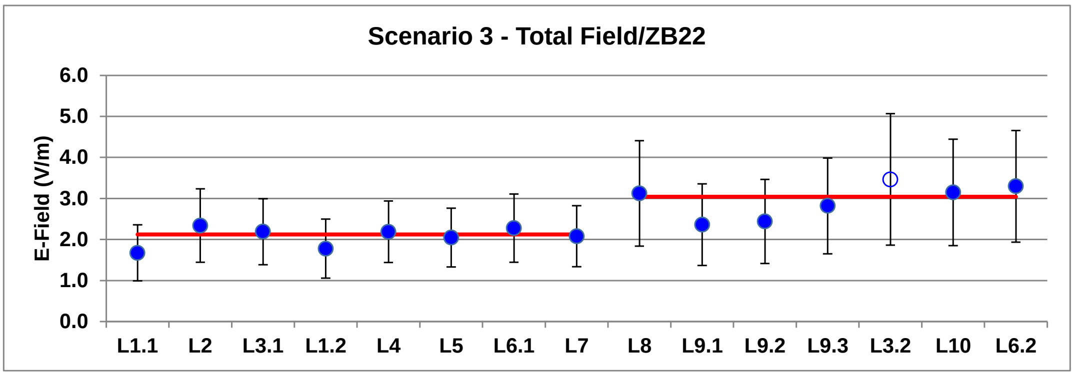


CRV	(V/m)	0.559
u(CRV)	(V/m)	0.041
Std dev.		15%
Nb meas		8
Nb not conform		1
Chisq test		21.5%

CRV	(V/m)	0.731
u(CRV)	(V/m)	0.067
Std dev.		11%
Nb meas		6
Nb not conform		0
Chisq test		88.2%

Ratio CRV (isotropic)/CRV (directive)	1.31

Figure 33: Results for the field of signal D measured in the room ZB22.

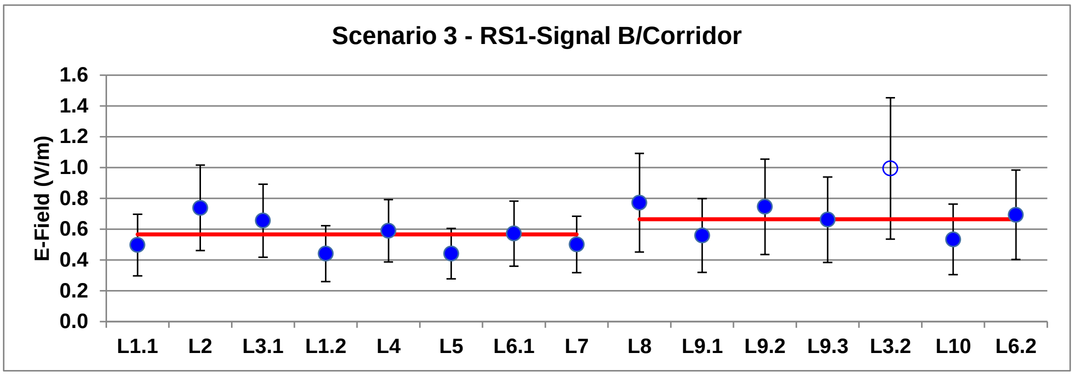


CRV	(V/m)	2.120
u(CRV)	(V/m)	0.155
Std dev.		9%
Nb meas		8
Nb not conform		0
Chisq test		86.6%

CRV	(V/m)	3.044
u(CRV)	(V/m)	0.289
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		55.1%

Ratio CRV (isotropic)/CRV (directive)	1.44

Figure 34: Results for the total field measured in the room ZB22.

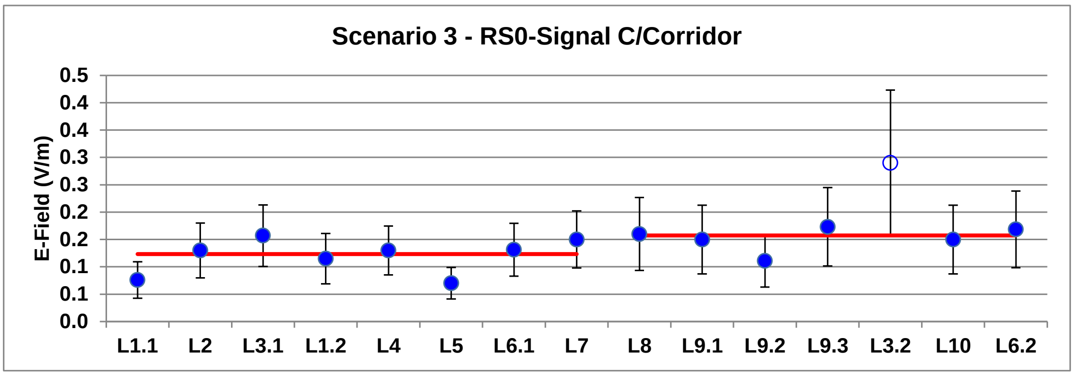


CRV	(V/m)	0.566
u(CRV)	(V/m)	0.042
Std dev.		17%
Nb meas		8
Nb not conform		0
Chisq test		42.3%

CRV	(V/m)	0.664
u(CRV)	(V/m)	0.062
Std dev.		14%
Nb meas		6
Nb not conform		0
Chisq test		66.9%

Ratio CRV (isotropic)/CRV (directive)	1.17

Figure 35: Results for the field of signal B measured in the corridor.

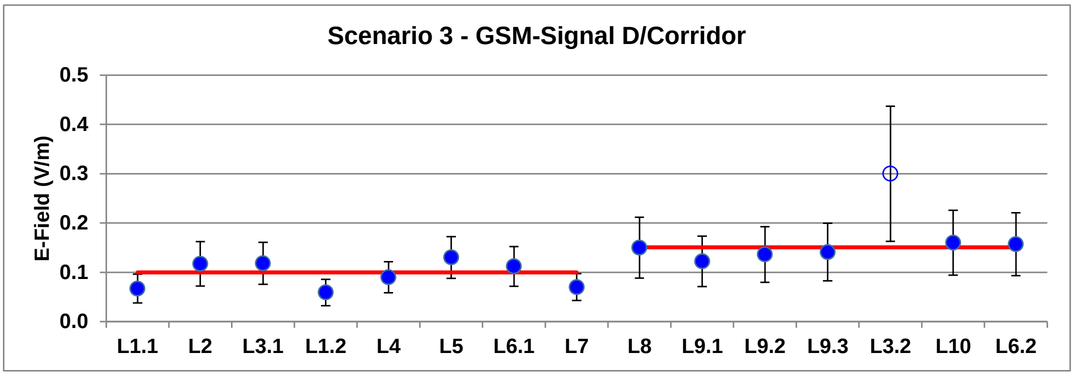


CRV	(V/m)	0.123
u(CRV)	(V/m)	0.009
Std dev.		24%
Nb meas		8
Nb not conform		2
Chisq test		0.0%

CRV	(V/m)	0.158
u(CRV)	(V/m)	0.015
Std dev.		9%
Nb meas		6
Nb not conform		0
Chisq test		43.6%

Ratio CRV (isotropic)/CRV (directive)	1.28

Figure 36: Results for the field of signal C measured in the corridor.

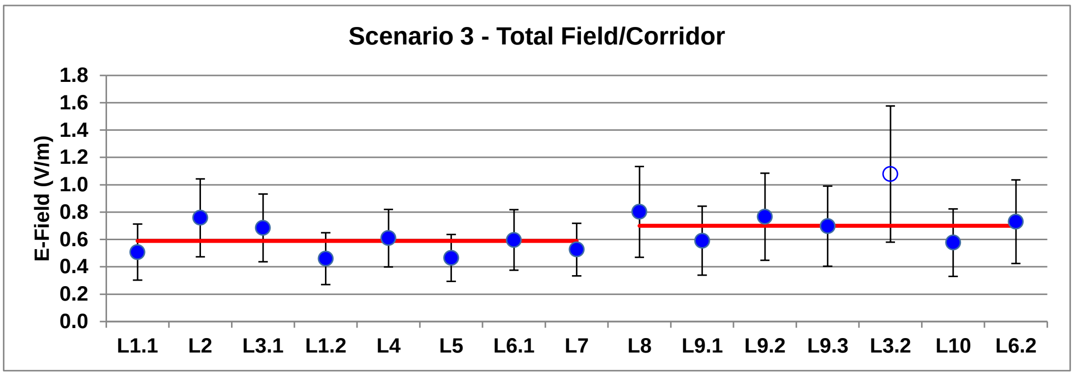


CRV	(V/m)	0.100
u(CRV)	(V/m)	0.008
Std dev.		24%
Nb meas		8
Nb not conform		3
Chisq test		0.0%

CRV	(V/m)	0.151
u(CRV)	(V/m)	0.014
Std dev.		7%
Nb meas		6
Nb not conform		0
Chisq test		86.9%

Ratio CRV (isotropic)/CRV (directive)	1.51

Figure 37: Results for the field of signal D measured in the corridor.



CRV	(V/m)	0.589
u(CRV)	(V/m)	0.044
Std dev.		17%
Nb meas		8
Nb not conform		0
Chisq test		45.5%

CRV	(V/m)	0.699
u(CRV)	(V/m)	0.065
Std dev.		12%
Nb meas		6
Nb not conform		0
Chisq test		76.1%

Ratio CRV (isotropic)/CRV (directive)	1.19

Figure 38: Results for the total field measured in the corridor.

8 Observations

8.1 Dispersion of measurement results and chi-squared test

As an estimate of the dispersion of the measurement results, the standard deviation of the participant's values has been computed for each situation (excluding the outliers):

Signal	Source	Scenario	Room	Standard Deviation (directive antenna)	Standard Deviation (isotropic antenna)
RS1	Signal B	Scenario 1	ZB14	15%	11%
RS0	Signal C	Scenario 1	ZB14	16%	8%
Total Field		**Scenario 1**	**ZB14**	**14%**	**7%**
RS1	Signal B	Scenario 1	ZB22	15%	8%
RS0	Signal C	Scenario 1	ZB22	14%	5%
Total Field		**Scenario 1**	**ZB22**	**14%**	**7%**
RS1	Signal B	Scenario 1	Corridor	(29%)	14%
RS0	Signal C	Scenario 1	Corridor	14%	16%
Total Field		**Scenario 1**	**Corridor**	**20%**	**11%**
RS1	Signal B	Scenario 2	ZB14	12%	12%
RS0	Signal C	Scenario 2	ZB14	12%	(38%)
Total Field		**Scenario 2**	**ZB14**	**11%**	**11%**
RS1	Signal B	Scenario 2	ZB22	14%	8%
RS0	Signal C	Scenario 2	ZB22	15%	14%
Total Field		**Scenario 2**	**ZB22**	**14%**	**7%**
RS1	Signal B	Scenario 2	Corridor	(23%)	9%
RS0	Signal C	Scenario 2	Corridor	(25%)	(33%)
Total Field		**Scenario 2**	**Corridor**	**(23%)**	**9%**
RS1	Signal B	Scenario 3	ZB14	17%	10%
RS0	Signal C	Scenario 3	ZB14	16%	(30%)
GSM	Signal D	Scenario 3	ZB14	(26%)	15%
Total Field		**Scenario 3**	**ZB14**	**16%**	**9%**
RS1	Signal B	Scenario 3	ZB22	10%	11%
RS0	Signal C	Scenario 3	ZB22	10%	5%
GSM	Signal D	Scenario 3	ZB22	15%	11%
Total Field		**Scenario 3**	**ZB22**	**9%**	**9%**
RS1	Signal B	Scenario 3	Corridor	17%	14%
RS0	Signal C	Scenario 3	Corridor	(24%)	9%
GSM	Signal D	Scenario 3	Corridor	(24%)	7%
Total Field		**Scenario 3**	**Corridor**	**17%**	**12%**

Table 7: List of the observed standard deviations. The numbers are in parenthesis in the cases where the chi-squared test failed. These numbers should be taken with care. In grey, the data relative to the measurements performed in the corridor, without direct sight to the antenna.

8.2 Inconsistent measurements

A measurement value is considered consistent with the CRV, if it differs by less than the uncertainty bars from the CRV. In the other case it is declared as inconsistent.

Signal	Source	Scenario	Room	Inconsistent measurements
RS1	Signal B	Scenario 1	ZB14	-
RS0	Signal C	Scenario 1	ZB14	-
Total Field		**Scenario 1**	**ZB14**	**-**
RS1	Signal B	Scenario 1	ZB22	-
RS0	Signal C	Scenario 1	ZB22	-
Total Field		**Scenario 1**	**ZB22**	**-**
RS1	Signal B	Scenario 1	Corridor	L5
RS0	Signal C	Scenario 1	Corridor	-
Total Field		**Scenario 1**	**Corridor**	**L5**
RS1	Signal B	Scenario 2	ZB14	-
RS0	Signal C	Scenario 2	ZB14	L8, L9.2
Total Field		**Scenario 2**	**ZB14**	**-**
RS1	Signal B	Scenario 2	ZB22	-
RS0	Signal C	Scenario 2	ZB22	-
Total Field		**Scenario 2**	**ZB22**	**-**
RS1	Signal B	Scenario 2	Corridor	L5
RS0	Signal C	Scenario 2	Corridor	L1.2, L5, L10
Total Field		**Scenario 2**	**Corridor**	**L5**
RS1	Signal B	Scenario 3	ZB14	L7
RS0	Signal C	Scenario 3	ZB14	L6.2
GSM	Signal D	Scenario 3	ZB14	L1.1, L1.2
Total Field		**Scenario 3**	**ZB14**	**L7**
RS1	Signal B	Scenario 3	ZB22	-
RS0	Signal C	Scenario 3	ZB22	-
GSM	Signal D	Scenario 3	ZB22	L1.1
Total Field		**Scenario 3**	**ZB22**	-
RS1	Signal B	Scenario 3	Corridor	-
RS0	Signal C	Scenario 3	Corridor	L1.1, L5
GSM	Signal D	Scenario 3	Corridor	L1.1, L1.2, L7
Total Field		**Scenario 3**	**Corridor**	-

Table 8: List of measurements inconsistent with the CRV. In the list, all inconsistent measurements are below the CRV, except the measurement L9.2 (RS0 - Signal C - Scenario 2 - ZB14).

The total number of valid measurements (outliers excluded) is 420. This means 140 measurements in each room.

8.3 Isotropic versus directive antenna

The measurements performed with isotropic antennas are in average about 30% higher than measurements performed by directive antennas as shown by the following table.

Signal	Source	Scenario	Room	Field strength measured with isotropic antenna / field strength measured with directive antenna/	
				CRV (isotropic) versus CRV (directive)	**L6.2 versus L6.1**
RS1	Signal B	Scenario 1	ZB14	1.39	1.05
RS0	Signal C	Scenario 1	ZB14	1.46	1.30
Total Field		**Scenario 1**	**ZB14**	**1.43**	**1.18**
RS1	Signal B	Scenario 1	ZB22	1.29	1.32
RS0	Signal C	Scenario 1	ZB22	1.28	1.17
Total Field		**Scenario 1**	**ZB22**	**1.29**	**1.22**
RS1	Signal B	Scenario 1	Corridor	1.28	1.22
RS0	Signal C	Scenario 1	Corridor	1.26	1.20
Total Field		**Scenario 1**	**Corridor**	**1.27**	**1.21**
RS1	Signal B	Scenario 2	ZB14	1.27	1.10
RS0	Signal C	Scenario 2	ZB14	0.93	1.06
Total Field		**Scenario 2**	**ZB14**	**1.24**	**1.10**
RS1	Signal B	Scenario 2	ZB22	1.58	1.32
RS0	Signal C	Scenario 2	ZB22	1.11	1.01
Total Field		**Scenario 2**	**ZB22**	**1.47**	**1.25**
RS1	Signal B	Scenario 2	Corridor	1.28	1.16
RS0	Signal C	Scenario 2	Corridor	0.97	1.19
Total Field		**Scenario 2**	**Corridor**	**1.24**	**1.11**
RS1	Signal B	Scenario 3	ZB14	1.26	1.29
RS0	Signal C	Scenario 3	ZB14	1.18	0.88
GSM	Signal D	Scenario 3	ZB14	1.31	1.10
Total Field		**Scenario 3**	**ZB14**	**1.26**	**1.27**
RS1	Signal B	Scenario 3	ZB22	1.48	1.50
RS0	Signal C	Scenario 3	ZB22	1.16	1.18
GSM	Signal D	Scenario 3	ZB22	1.31	1.09
Total Field		**Scenario 3**	**ZB22**	1.44	1.45
RS1	Signal B	Scenario 3	Corridor	1.17	1.21
RS0	Signal C	Scenario 3	Corridor	1.28	1.28
GSM	Signal D	Scenario 3	Corridor	1.51	1.40
Total Field		**Scenario 3**	**Corridor**	1.19	1.22
Average				**1.29**	**1.20**

Table 9: Overview of the ratio of the field strength as measured with an isotropic antenna compared with measurements performed by a directive antenna.

The ratio has also been evaluated for the measurements L6.2 and L6.1 since these were produced by the same accredited laboratory: systematic effects of the operator can thus be excluded.

9 Discussion and conclusions

9.1 General comments on the quality of the results

According to Table 7, among all different comparisons reported here, there are 10 inconsistent cases according to the chi-squared test over a total of 60 different cases. From these 10 cases, 7 cases are in the corridor, which means with diffuse field (no direct sight to the antenna).

It is known that in case of diffuse fields (as in the corridor), the field is strongly influenced by the reflections of the radiation from the building elements. It is thus more difficult to find the local maximum: The local maximum is not necessarily located in the window opening as in the rooms with direct sight to the antenna. Finding the maximum requires, therefore, more time and a systematic scanning of the test volume.

We, therefore, believe that some participants did not spend enough time for finding the maximum. This can be observed in Table 8: Practically all inconsistent measurements are smaller than the CRV.

9.2 Capabilities of the measurement laboratories

It is important to recall that one participant (L3.2) did not respect the requirements of the measurement recommendation [2]. The measurement recommendation defines clearly the measurement volume in terms of the minimum distance between antenna and wall, floor, ceiling, or furniture (0.5 m). It also specifies the maximum scanning height to 1.75 m. If these conditions are not taken into account, it leads to an overestimation of the field strength. For this reasons, L3.2 measurements have been excluded from all evaluations.

A detailed analysis of Table 8, neglecting the declared outliers, provides the following findings:

- In room ZB14, 95.0 % of the measurements are consistent with the declared uncertainty
- In room ZB 22, 99.3 % of the measurements are consistent with the declared uncertainty
- In the corridor, 91.4 % of measurements are consistent with the declared uncertainty.

Taking into account that the uncertainty bars represent a 95% confidence interval, and assuming 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. This condition is well met for the measurements in rooms ZB14 and ZB22 which both had direct sight to the antennas. It is not met, however, for the measurements in the corridor which exhibited a more diffuse field pattern, in agreement with one of the previous comments. Indeed, as mentioned in section 9.1, some participants did not spend enough time or did not search systematically enough to find the maximum. The inconsistent measurements are listed in Table 8.

9.3 Experimental estimation of the measurement uncertainty

The uncertainty bars (representing a 95% confidence interval) as plotted in the Figures of section 7 are based on the declaration of the participating laboratories. An independent and complementary way to check the overall uncertainty of the measurements is to analyse the dispersion of the measured values and to compare it to the uncertainties provided by the different participants.

This dispersion, expressed as standard deviation of all measurements of the same scenario/situation (excluding identified outliers), is tabulated in Table 7 and it is regrouped in the following table:

	Directive antenna Total Direct sight / diffuse field	**Isotropic antenna** Total Direct sight / no direct sight
Number of cases	30 20 / 10	30 20 / 10

	Directive antenna Total Direct sight / diffuse field	**Isotropic antenna** Total Direct sight / no direct sight
Nb check failures (chi-squared test)	7 1 / 6	3 2 / 1
Range of std dev.	9%...20% (9%...29%) 9% ...17% / 14%…20% (9%…26%) / (14%...29%)	5%...16% (5%... 38%) 5%...15% / 7%...16% (5%...38%) / (7%...33%)

Table 10: Summary of dispersion results depicted in Table 7. The values in parenthesis have been determined by taking into account the cases where there was a failure check according to the chi-squared test.

On the other hand, the standard measurement uncertainty provided by the participants covers, according to Annex C, the range from 18% to 23% (k=1).

- If the standard deviation of the measurements is larger than the estimated measurement uncertainty, this means that the measurement uncertainty has been underestimated.
- If the standard deviation of the measurements is comparable to the estimated measurement uncertainty, this means that the measurement uncertainty is realistic.
- If the standard deviation of the measurements is smaller than the estimated measurement uncertainty, this means that the measurement uncertainty has been overestimated.

The standard deviation of the measurements satisfactorily matches the declared measurement uncertainty. The findings of the consistency check (section 9.1) are therefore qualitatively confirmed.

9.4 Sampling uncertainty

The consistency check (section 9.1) and the dispersion analysis (section 9.3) show that the sampling uncertainty (15% for k=1 according to the LTE technical report [5]) is a realistic estimate in case of direct illumination (line-of-sight conditions), a condition which was fulfilled in both rooms ZB14 and ZB22.

In case of more diffuse fields (as in the corridor), the overall measurement uncertainty estimated by the laboratories seems to be too low. However, as mentioned in sections 9.1 and 9.2, we observed that some laboratories did not spend enough time looking for the maximum. Would this have been done, we would have obtained better consistency between the measurements (chi-squared test).

From these observations we conclude that the uncertainty estimations of the participants are realistic. They all include the default value of 15% (k=1) for the sampling uncertainty that is specified in the LTE-technical report [5]. The 15 % (k=1) sampling uncertainty is a very robust estimate of the uncertainty that applies to a wide range of situations including direct illumination as well as diffuse environments.

9.5 Isotropic versus directive antennas

Table 9 shows clearly that measurements performed with isotropic antennas provide in average 20% to 30 % higher field strength values than measurements performed with directive antenna. This result was intuitively expected. In this report, it is now demonstrated with measurements performed in typical situations.

9.6 Conclusion

Based on our observations, we draw the following conclusions:

- Most participants, for the majority accredited labs, are able to measure the field strength of LTE-base stations with the claimed uncertainty. One laboratory did not respect the requirements of the measurement recommendations, e.g. providing too high values: its result has been excluded from the statistics. Other ones did not spend enough time looking for the maximum, especially in the corridor with diffuse field.
- The sampling uncertainty of 15% (*k*=1) mentioned in the LTE technical report [5] provides a realistic and robust value for estimating the measurement uncertainty due to the measurement method. Despite the technical development of precise code selective measuring instruments, this uncertainty has not decreased since 2002 when the first measurement recommendation [2] was published. The reason is that this uncertainty contribution is not related to the measuring instruments but to the nature of electromagnetic fields.
- The type of antenna used, directive or isotropic, has a direct impact on the measured values. This issue needs to be taken into account in the next revisions of the measurement recommendations. With respect to the measurement method itself, as outlined in the draft LTE technical report [5], no modification is necessary.

10 Literature

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Annex A: Input power versus incident field

The stability measurements of the field are performed by comparing the amplifier output with the incident field strength.

Date	Input power				Incident field				Incident field-input power			
	A	B	C	D	A	B	C	D	A	B	C	D
	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dBm)	(dB)	(dB)	(dB)	(dB)
19.11.2013	-26.1	-25.9	-8.5		-11.0	-12.0	-15.3		15.1	13.9	-6.8	
20.11.2013	-25.7	-26.5	-8.4		-11.4	-10.7	-14.5		14.3	15.8	-6.1	
21.11.2013	-27.2	-25.2	-8.4	-9.9	-12.3	-11.4	-15.3	-16.4	14.9	13.8	-7.0	-6.5
21.11.2013	-27.0	-25.5	-8.2		-12.2	-11.2	-15.7	-16.5	14.8	14.3	-7.5	
22.11.2013	-28.3	-25.8	-8.4	-9.2	-12.8	-11.0	-15.3	-16.3	15.5	14.8	-7.0	-7.1
22.11.2013	-28.8	-26.2	-8.3	-9.4	-13.0	-11.1	-15.5	-16.4	15.8	15.1	-7.3	-7.0
25.11.2013	-28.5	-25.7	-8.4	-9.2	-12.7	-11.3	-15.2	-15.9	15.8	14.4	-6.8	-6.7
26.11.2013	-28.2	-25.6	-8.2	-9.3	-13.1	-11.5	-14.8	-16.2	15.1	14.1	-6.6	-7.0
27.11.2013	-28.3	-25.5	-8.2	-9.4	-12.9	-11.4	-15.0	-16.2	15.4	14.1	-6.8	-6.9
28.11.2013	-28.2	-25.3	-8.1	-9.3	-12.2	-10.8	-15.0	-16.0	16.0	14.5	-6.9	-6.7

Standard deviation (dB)	0.53	0.61	0.38	0.23

Table 11: The input power values are measured at the forward output of the coupler placed shortly after the amplifier. These values are indirect measurements of the power to the antenna. The precise calibration factor has not been determined. The incident field values have been measured at the output of the receive antenna placed in front of the opened window (see Figure 8). The antenna factor is not included in this value.

Annex B: Stability measurements

Nb	Date	Scenario 1			Scenario 2			Scenario 3			
		A (dBm)	B (dBm)	C (dBm)	A (dBm)	B (dBm)	C (dBm)	A (dBm)	B (dBm)	C (dBm)	D (dBm)
1	18.11.2013	-25.6	-25.7	-8.3	-28.3	-27.7	-12.8	-28.8	-27.2	-17.2	-9.1
2	18.11.2013	-24.7	-25.9	-8.4	-27.3	-28.2	-12.6	-27.4	-26.9	-17.5	-9.1
3	18.11.2013	-26.1	-26.4	-8.5	-28.2	-27.9	-12.8	-27.5	-26.5	-17.4	-9.2
4	18.11.2013				-27.2	-28.0	-12.7	-27.9	-26.7	-17.4	-9.2
5	18.11.2013							-25.9	-26.4	-17.5	-9.0
6	18.11.2013							-27.0	-26.4	-17.5	-9.0
7	18.11.2013							-26.1	-26.6	-17.5	-9.1
8	18.11.2013							-25.3	-27.0	-17.5	-9.1
9											
10	20.11.2013	-25.7	-26.5	-8.4	-29.7	-27.8	-12.7				-9.2
11	20.11.2013	-26.7	-25.8		-30.3	-28.3		-28.9	-26.9	-17.5	-9.4
12	20.11.2013	-26.3	-25.9	-8.3	-30.5	-28.7	-12.7	-29.5	-26.9	-17.4	-9.5
13	20.11.2013	-26.6	-25.9	-8.3	-29.4	-27.7	-12.7	-29.0	-26.5	-17.3	-9.5
14	20.11.2013	-27.3	-26.3		-30.5	-28.8	-12.6				
15	20.11.2013	-28.3	-26.3	-8.2							
16	20.11.2013	-28.3	-26.0	-8.5							
17	20.11.2013	-28.3	-26.0	-8.4							
18											
19	21.11.2013				-29.3	-27.7	-12.7	-29.0	-26.8	-17.5	-9.4
20	21.11.2013	-27.2	-25.2	-8.4	-29.5	-28.4	-12.7	-29.1	-25.9	-17.4	-9.3
21	21.11.2013	-26.4	-26.1		-30.2	-28.5	-12.6				
22	21.11.2013	-27.0	-25.5	-8.2							
23	21.11.2013	-27.7	-25.7	-8.3							
24											
25	22.11.2013	-28.3	-25.8	-8.4	-30.2	-27.9	-12.7	-29.3	-26.7	-17.3	-9.4
26	22.11.2013	-28.8	-26.2	-8.3	-30.9	-27.8	-12.6	-30.2	-26.9	-17.5	-9.4
27											-9.4
28											
29	25.11.2013	-28.5	-25.7	-8.4	-29.9	-28.1	-12.7	-28.9	-26.9	-17.4	-9.3
30	25.11.2013	-27.9	-26.1	-8.4	-30.1	-27.9	-12.7	-28.9	-26.7	-17.3	-9.3
31	25.11.2013	-28.4	-25.8	-8.3							
32	25.11.2013	-28.9	-25.9	-8.4							
33	25.11.2013	-28.7	-25.8	-8.4							
34	25.11.2013	-28.8	-25.8	-8.4							
35											
36	26.11.2013	-28.2	-25.6	-8.2	-30.7	-27.5	-12.6	-29.2	-26.7	-17.3	-9.2
37	26.11.2013	-28.1	-25.6	-8.3	-31.3	-28.4	-12.6	-29.9	-26.7	-17.3	-9.2
38	26.11.2013	-28.2	-25.8	-8.3	-31.3	-27.9	-12.6	-29.6	-26.4	-17.4	-9.1
39	26.11.2013	-29.1	-25.5	-8.3							
40											
41	27.11.2013	-28.3	-25.5	-8.2	-29.5	-27.6	-12.5	-28.4	-26.4	-17.2	-9.3
42	27.11.2013	-28.4	-25.3	-8.1	-29.9	-27.8	-12.5	-29.3	-26.4	-17.1	
43	27.11.2013	-28.1	-25.3	-8.1	-30.2	-27.8	-12.5	-29.3	-26.7	-17.2	-9.3
44											
45	28.11.2013	-28.2	-25.3	-8.1	-29.8	-27.4	-12.6	-29.4	-26.6	-17.3	-9.3
46	28.11.2013	-28.5	-25.5	-8.1	-30.3	-27.5	-12.5	-29.6	-26.9	-17.3	-9.2
47	28.11.2013	-28.5	-25.7	-8.1	-30.4	-27.3	-12.5	-29.8	-26.6	-17.3	-9.2
48	28.11.2013							-30.2	-26.5	-17.3	-9.2
49											
50	29.11.2013	-28.2	-25.5	-8.3	-30.6	-27.6	-12.6	-29.4	-26.5	-17.3	-9.2
51	29.11.2013	-29.2	-25.6	-8.2	-31.3	-27.5	-12.5	-29.7	-26.9	-17.3	-9.2
52	29.11.2013	-29.3	-25.7	-8.3	-31.5	-27.6	-12.5	-31.3	-27.1	-17.3	-9.3
Standard Deviation (dB)		**1.12**	**0.32**	**0.11**	**1.11**	**0.39**	**0.08**	**1.35**	**0.27**	**0.11**	**0.12**

Table 12: Stability measurements performed at the forward output of the coupler placed shortly after the amplifier. These values are indirect measurements of the power to the antenna. The precise calibration factor has not been determined.

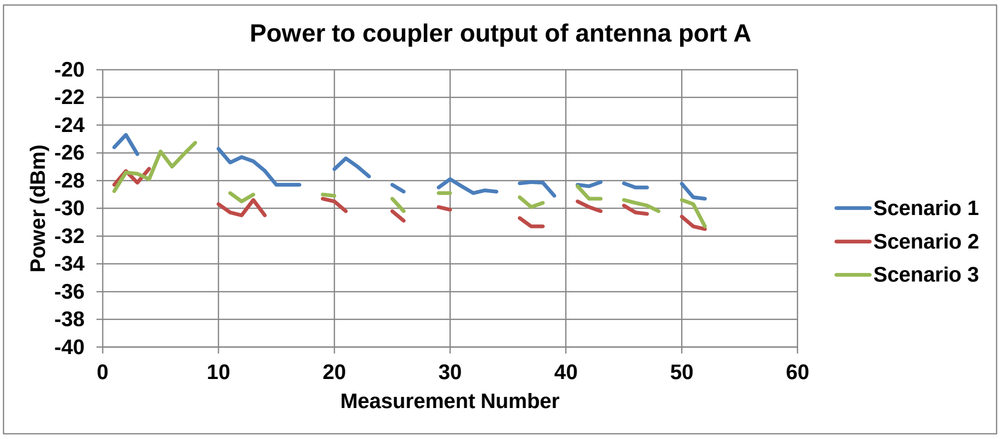

Figure 39: Graphical representation of the stability of the signal A.

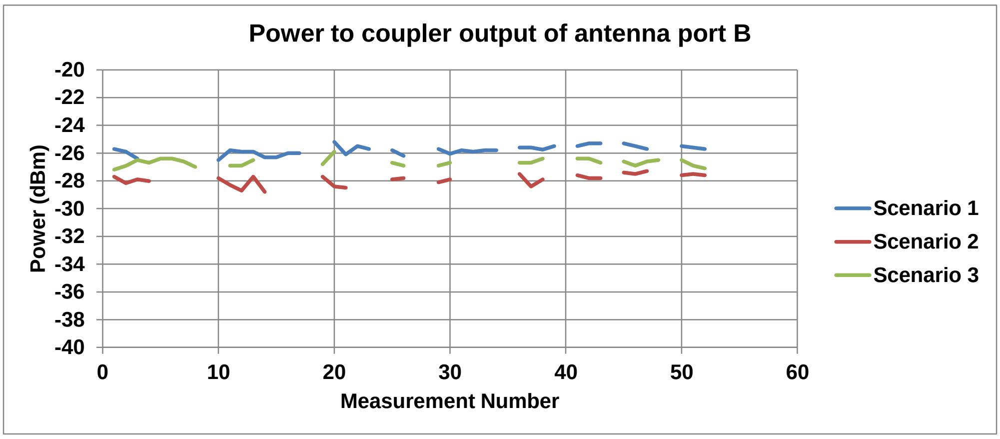

Figure 40: Graphical representation of the stability of the signal B.

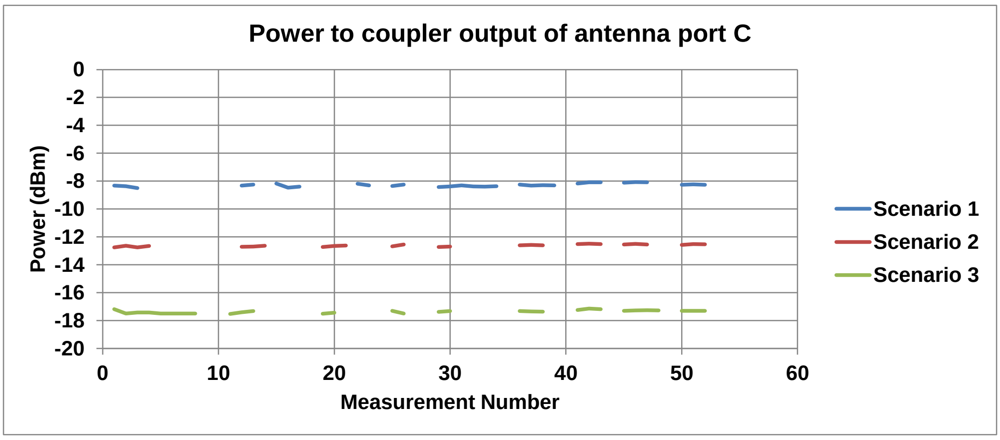

Figure 41: Graphical representation of the stability of the signal C.

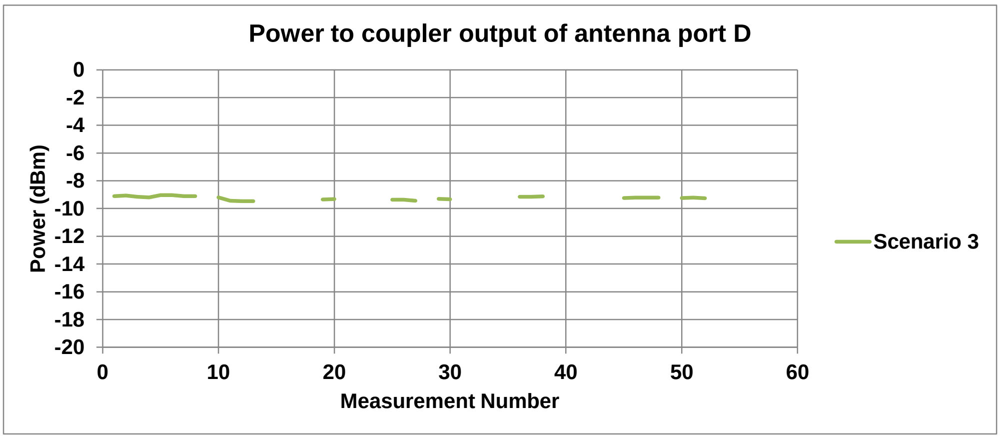

Figure 42: Graphical representation of the stability of the signal D.

Annex C: Measurement uncertainties of the participating laboratories

Measurement Number	Measurement uncertainty (k=2) including sampling uncertainty	
	for LTE	for GSM
L1.1	39%	40%
L2	42%	43%
L3.1	40%	40%
L1.2	39%	40%
L4	37%	36%
L5	38%	36%
L6.1	40%	40%
L7	38%	38%
L8	40%	40%
L9.1	40%	40%
L9.2	40%	40%
L9.3	40%	40%
L3.2	45%	45%
L10	40%	40%
L6.2	40%	40%

Table 13: 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 D: Comparison reference value mathematics

D.1 Weighting factor

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

$$w_{i,j} = \frac{1}{k_i \cdot n}$$

D.2 Comparison reference value (CRV)

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

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

and its uncertainty (k=1) as:

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

D.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:

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

$$u(D_{i,j}) = \sqrt{(1 - 2 \cdot w_{i,j}) {u_{i,j}}^2 + {u_{CRV}}^2}$$ for all measurements except outliers

$$u(D_{i,j}) = \sqrt{{u_{i,j}}^2 + {u_{CRV}}^2}$$ for outliers measurements

Note: since no outliers have been declared in this report, the second equation above has not been used.
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: [9,10].

D.4 Consistency check

The overall consistency check according to procedure A of [9] (chi-squared test) has been applied. It consists in determining the observed chi-square as:

$$\chi^2_{obs} = \sum_{i,j} \frac{{D_{i,j}}^2}{\left(u_{i,j}\right)^2}$$

The consistency check fails if

$$\Pr\left\{\chi^2(\nu) > \chi^2_{obs}\right\} < 0.05$$

Where “Pr” denotes “probability of”, and $\nu = N - 1$ is the degrees of freedom, N being the total number of measurements.

D.5 Standard deviation

The standard deviation σ of the measurements has been estimated as:

$$\sigma = \sqrt{\sum_{i,j} w_{i,j} \cdot {D_{i,j}}^2}$$

And it has been expressed in percent of the CRV.