

“NIR Monitoring Central Switzerland” Project: Recording the Exposure of Citizens to High-Frequency Electromagnetic Fields

Matthias Wuschek, Alfred Bürgi, Klaus Woweries and Niklas Joos

High-frequency emissions at a total of 24 locations in six Swiss cantons have been permanently recorded since the summer of 2006 by means of automatic measuring systems, and the results shown on a website. These measurements are part of a comprehensive project for recording non-ionizing radiation in Central Switzerland. The conceptual design of this and some typical results are presented in this article.

Purpose of the project

The main purpose of the “NIR Monitoring Central Switzerland” project is to provide the general public with independent and factual information about the subject of non-ionizing radiation (NIR). At the time that the project was started, non-ionizing radiation, particularly the high-frequency emissions from mobile phone base stations, was one of the environmental topics most often discussed by the public in the cantons concerned. The project is divided into the following three sections:

1. Measurement

NIR monitoring in Central Switzerland covers permanent measurement of the electromagnetic radiation from mobile phone and broadcasting transmitters, regular transfer of the measured values into a database, and graphical representation of the results on the Internet.

Measurements are made at a total of 24 locations spread across the six cantons of Central Switzerland. Long-term measurements are made at each location during a period of about three months per year.

The measurements are focused on determining the level of high frequency electromagnetic radiation (mobile telephony, broadcasting). Low frequency fields from high-tension lines or transformer stations are not recorded by these measurements.

2. Simulation

The measurements are complemented by simulation of the exposure to high frequency fields. This makes it possible to provide exposure maps covering the entire area of Central Switzerland. The low frequency magnetic fields caused by high-tension lines or transformer stations are not taken into account in the simulation.

3. Information

The *e-smogmessung.ch* website provides the general public of Central Switzerland with general information about NIR emissions and their biological effects as well as about the legal regulations regarding their limitation. The latest measurement results from the probes together with the simulation calculation results can also be accessed from this website.

The project is financed by the cantons concerned: Uri, Schwyz, Obwalden, Nidwalden, Luzern, and Zug. ENKOM Inventis AG (Zürich) and EM-Institut GmbH (Regensburg) were assigned to take care of the measuring probes, and ARIAS (Bern) was given responsibility to produce the simulation calculations.

The measurement network

The measurement network is described in detail on *e-smogmessung.ch* under the heading "Einführung Messnetz" (Measurement network introduction). The measuring probes are typically installed in residential areas or in town centers and on school buildings, hospitals, and retirement homes (on patios, roofs or facades). There is also usually a radio transmitter (such as a mobile phone base station) not far from the measurement location. Figure 1 shows a typical measurement location. Detailed descriptions of all the locations are found on the project website.



Figure 1: Measuring probe located at "Sarnen" (flat roof of a retirement home). A mobile phone transmitter mast can be seen in the background.

The Multiband Area Monitor AMB-8057 from Narda STS is used for making the measurements. It measures the NIR exposure separately for each of the four frequency bands listed in Table 1.

Frequency band	Frequency range	Emissions recorded
GSM 900	925 - 960 MHz	Emissions due only to GSM 900 base stations
GSM 1800	1805 - 1880 MHz	Emissions due only to GSM 1800 base stations
UMTS	2110 - 2170 MHz	Emissions due only to UMTS base stations
Wideband	0.1 MHz - 3000 MHz	Emissions due to all important radio signal sources

Table 1: Frequency bands that are measured separately by the measuring probes.

The probes operate fully automatically and transmit the measurement results via mobile phone daily to a central station where the results are stored in a database.

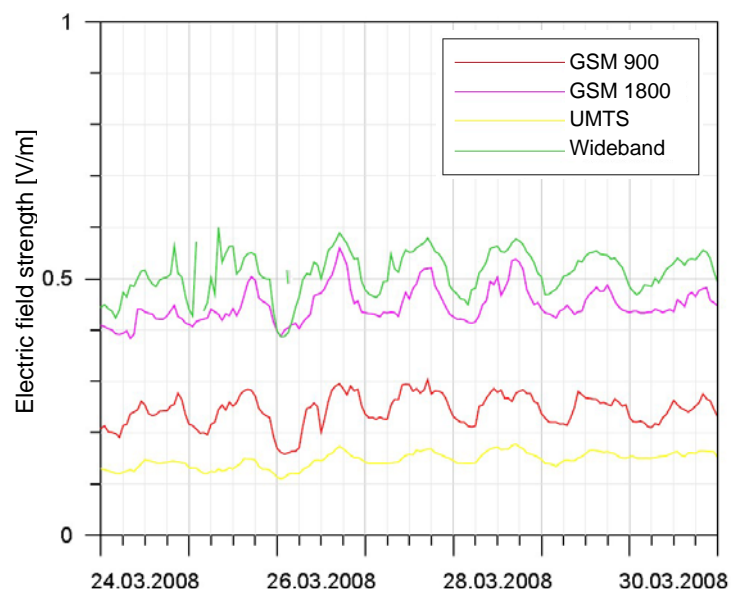
The probes save the measured values once a minute internally. To keep a clear overview of the results, the measurement data is compressed into 6-minute, hourly, and daily average values for the display on the Internet of the four separately investigated frequency bands. These values are plotted as a collective graph against time for each measurement location.

Six measuring probes are available. Since mid-2006, each probe has been installed at a different one of the 24 designated locations for a period of about three months at a time, so that all the locations have been surveyed once by the end of twelve months. The project is scheduled to end at the end of 2009.

According to the manufacturer, the measuring probes have an accuracy of about 2 dB and a thermal characteristic of 0.1 dB/°C. The measurement range is from 0.2 to 200 V/m (wideband) or 0.03 to 30 V/m (GSM and UMTS bands). In practice, the fields measured are in the lower part of the measurement range, often close to the limit of sensitivity.

A typical result display is shown in Figure 2 (location "Freienbach canton school"). Since the nearest mobile phone transmitter here is located several hundred meters from the measurement location, the measured values are comparatively low. Nevertheless, the variations in emissions at certain times of the day that are typical of mobile phone transmissions are clearly seen.

Figure 2: Hourly values for the location "Freienbach canton school" for a selected week (Monday to Sunday).

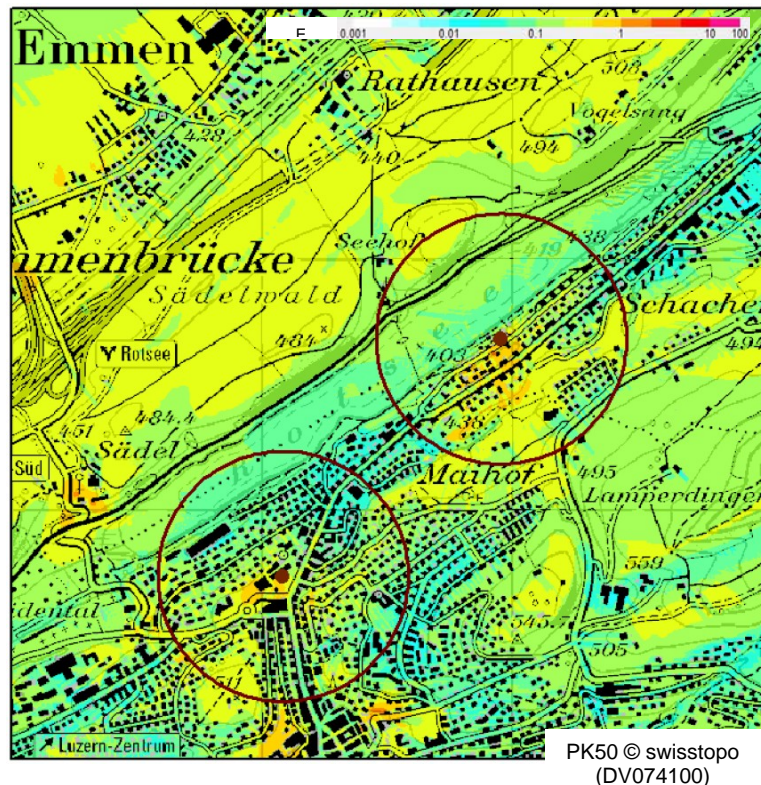


The simulation calculations

Simulation of the high-frequency NIR exposure is also described on the project website. The simulation calculates the sum total of HF NIR exposure due to mobile phone, broadcasting (medium-wave, UHF and DAB radio, and TV transmissions) and paging services covering the entire area of Central Switzerland to a resolution of 5 x 5 m in residential areas, taking the topography and buildings into account. Only the total HF field strength of all existing sources is stored and shown on the maps on the website. This corresponds to the wideband measurement value from the NIR measuring probes. The field strength values are calculated for open-air points at a height of 1.5 m above ground. The simulations therefore do not give values directly at the locations of the probes, as these are always set up higher than 1.5 meters above ground (to prevent them from being damaged, etc.).

Figure 3 shows a typical example of the NIR emission maps that can be accessed on the website.

Figure 3: Result of simulation for an area of 3 km x 3 km. The total electrical field strength in V/m at a height of 1.5 m above ground level is shown. The dots mark the locations of measuring probes at "Luzern Maihof" (lower left) and "Ebikon" (top right). Circles of radius 500 m are drawn around these locations.



To validate the simulation calculations, frequency selective measurements in the frequency range 80 MHz to 3 GHz were made in three measurement campaigns, each covering some 150 locations. Taken together, the three campaigns showed that the ratio of the calculated to the measured field strength was between 0.5 and 2 for more than half of the points measured. The ratio was between 0.25 and 4 for more than 90 % of the points measured. This shows that, on average, the simulations yield results that match the measurement results sufficiently well within the limits of expected variation (measurement or calculation uncertainties).

Comparison with the measurement results also shows that the simulation delivers more accurate results for flat, open terrain than in very narrow valleys, for example. The biggest differences between the simulation and measurement were due to transmitters that were not

taken into account or buildings that were missing or incorrectly modeled, and not to the propagation model used (COST-Walfisch-Ikegami for mobile phone, ITU-1546 for VHF/UHF broadcasts, free-space propagation for medium-wave taking topography and buildings into account).

Some important results of the project

The results obtained within the framework of the project described here as well as the additional simulation calculations provided answers to some interesting questions regarding the NIR emission situation in Central Switzerland, and it may be assumed that the knowledge gained here can be applied to regions of a similar nature.

What were the average emission values?

The situation shown in Table 2 results from taking the power-related average (RMS value) of all the available measurement results for the 24 locations.

Frequency band	Average field strength
GSM mobile telephony	0.83 V/m
GSM and UMTS mobile telephony	0.91 V/m
Other radio signals	0.46 V/m
Total	1.02 V/m

Table 2: NIR emissions: RMS field strength values calculated from the results of all measurements for the various frequency bands examined.

GSM signals clearly dominated at the measured locations, with GSM-900 and GSM-1800 having approximately equal shares in the total field strength. In contrast, UMTS signals only have a very small share in the total mobile phone emissions. The field strength due to other radio signals (such as broadcasting and pagers) was approximated by calculating the difference between the measured wideband signal and the total mobile phone emissions. Looking at the variation across all 24 measurement locations, the wideband total values were between a minimum of 0.35 and a maximum of 1.59 V/m.

However, the field strength values recorded in Table 2 should not be taken as the average exposure levels for the population of Central Switzerland, as they were determined from only 24 locations, which are also outdoors at a considerable height above ground and generally not too far away from a transmitter. A comparison with the simulation calculations is of interest here, though. For this purpose, the average field strength values for a defined area around each of the 24 locations were calculated from the results of the simulations. These are shown in Table 3.

Location	Calculated average field strength	Percentage of average measured value (1.02 V/m)
Close proximity (r = 20 m)	0.29 V/m	28 %
Further afield (r = 500 m)	0.20 V/m	20 %

Table 3: Average field strength (overall field) of the simulation (averaged over different areas) for all 24 measurement locations compared with the measured average total value from Table 2.

In close proximity to the probe locations, the simulation for 1.5 m above ground level gives field strength values that are about 3.5 times less than those measured at greater height. If the average is taken over a larger area (500 meters) the difference between the measurement and the calculation increases still further to a factor of 5 times. In other words, the probe measurement values are not comparable to the area average emission value at a height of 1.5 meters, as they considerably overrate the average emission situation for the near area.

Where are the hot spots in Central Switzerland?

The clearest hot spot in Central Switzerland is the area around the "Beromünster" medium-wave transmitter (531 kHz). This dominates the whole of the northern part of Canton Luzern. The simulation calculations gave field strength values of over 2 V/m at distances of up to about 1.5 km from the transmitter, or over 1 V/m at up to approx. 3.5 km. The influence of the transmitter can also be clearly seen in the measurement results at a distance of up to about 30 km. However, the "Beromünster" medium-wave transmitter was shut down at the end of 2008, so this source of emissions is no longer present.

Figure 4: Hourly values for the location "Beromünster care home" for a selected week (Monday to Sunday). Key as in Figure 2

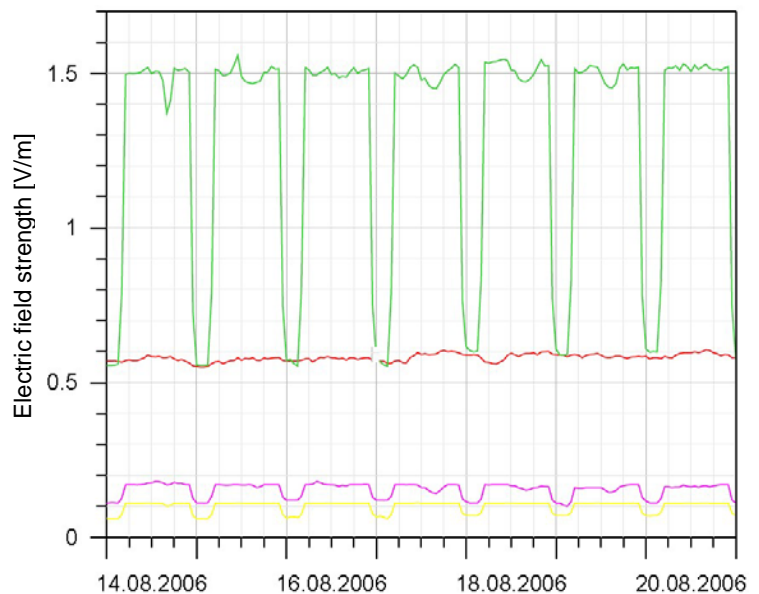


Figure 4 shows the measurement results for the "Beromünster care home" station for one week. Compared with the wideband measurement value (which results mainly from the medium-wave signal from the "Beromünster" transmitter), the mobile phone emissions are much less marked. The reduction in emissions during the nighttime when the medium-wave transmitter is switched off is also clearly seen. The limited selectivity of the narrow band measurements can also be recognized. "Crosstalk" from the strong medium-wave signal can be seen in the GSM-1800 and UMTS signals, which are very low here, as the reduction that occurs each night is seen in these narrow band signals as well as in the wideband signal. This is a typical characteristic of this kind of measuring probe and of personal dosimeters, and must be taken into account particularly when assessing comparatively low measurement values.

A second, slightly less conspicuous hot spot is located around the "Rigi-Kulm" broadcast transmitter site (mainly caused by UHF signals). Apart from this, practically all mobile phone and broadcasting transmitters with downward pointing antenna lobes produce small local hot spots. These small hot spots are found in towns and villages or also in isolated cases on mountains and hills. In these locations, field strengths of more than 1 V/m only occur within a radius of a few hundred meters. The strongest small area hot spots are often actually found in microcells with only a few Watts of effective radiation power if their antennas are mounted low down or have a relatively non-directional radiation pattern.

Are there differences in emissions between day / night and weekdays / weekends?

The greatest emission differences between day and night were seen around the "Beromünster" medium-wave transmitter, since this is switched off for a few hours every night. As well as this, the GSM emissions show a measurable daily trend, with a minimum during the night and a maximum during the day or evening. Looking at the hourly average values for electric field strength, this daily change is less than $\pm 20\%$ and in most cases actually less than $\pm 10\%$. This daily variation is less marked for UMTS, where the variation in the hourly average is less than $\pm 10\%$, and mostly below $\pm 5\%$ of the daily average. Presumably the volume of traffic carried by UMTS is not yet as much as by GSM. Apart from this, all the mobile phone signals can show brief maxima that are noticeably higher than the hourly average.

Although differences between weekdays and weekends can be seen at some measurement locations, they are very small. In many cases, the emissions at weekends are somewhat lower than during the week, but only by a few percent.

Is there a trend towards increased emissions?

So far, no such changes could be observed. With regard to minor changes in the emission situation (changes of less than about ± 2 dB), it must be said that these cannot be identified with sufficient statistical significance due to the existing measurement uncertainty. More distinct changes in emission could be observed, however: a drop in GSM emissions of around 3 dB at the "Rotkreuz" measurement location was caused by the shutting down of a mobile phone base station by the operator *Tele 2* in December 2008.

It is possible to more reliably determine long-term changes in emissions using the simulation calculations. An updated emission simulation for the area under consideration has been available since the start of 2009. As soon as the comparison with the earlier calculations (from the beginning of 2008) has been completed, reliable conclusions about possible changes in emissions can be drawn.

Summary: Comparison between measurement and calculation

The population of Central Switzerland has been provided with much information about NIR exposure levels in general as well as about the actual situation in the Cantons of Central Switzerland by means of the project described here. The results of measurements and calculations have by now been evaluated in various ways [1], so it is possible to make some fundamental comments about their strengths and weaknesses:

Measurement strengths

- Measurement enables detailed recording of the actual NIR exposure levels existing at numerous representative locations.
- Measurement shows the actual variations in emissions at the measurement location. Unlike simulation, it not only shows (load-dependent) changes in emissions, but also shows changes in the propagation conditions. Even if this often complicates interpretation of the measurement results, the measurement documents real wave propagation effects that occur.
- Measurement data can be evaluated according to many different criteria, such as average values, scope of variation, frequency bands, daily trends, weekly trends, and many more.
- Experience shows that the target group always more readily accepts real measurements than a model calculation.

Measurement weaknesses

- At the start of the project, the probe holders were dismantled at the end of each measurement period. This led to relatively large inaccuracies in positioning when the holders were reassembled for the second measurement period, which had a significant effect on the reproducibility of the measurement results (as a result of the existing inhomogeneities in the field). For this reason, fixed mounts for the probes were installed at all 24 measurement locations in order to minimize positioning uncertainty. Despite this, the measurement uncertainty is still considerable so the results of measurements can only be used in practice to demonstrate more distinct changes in emission levels in the order of not less than 2 to 3 dB.
- Regular function checks on the probes, preferably using a defined field, have proven absolutely necessary due to the various effects of the weather (particularly dampness) when the probes are used outdoors for an extended period. This is the only way to ensure that faults that occur are detected and rectified in a timely manner.

- The probes are adversely affected to some extent by wideband disturbances e.g. caused by a solar energy plant on the roof or "Christmas" illuminations.
- "Crosstalk" into other measured bands is seen with strong signals (e.g. effects of the "Beromünster" medium-wave transmitter signal on the GSM and UMTS measurement results).
- The physical size of the probes means that the various frequency bands are not measured at exactly the same location; as a result, the measured value in a narrow band may turn out to be higher than the wideband signal.

Simulation calculation strengths

- Simulation calculations give the magnitude of the NIR exposure level for the entire area of Central Switzerland.
- Simulation results are easily conveyed by means of color shading on a map.
- Simulation enables the recognition of hot spots.
- Changes can be detected and quantified by means of periodic updates of the location database and the simulations.
- Additional calculations and evaluations are possible using the location database that is now available.

Simulation calculation weaknesses

- Only the overall field (wideband) results of simulations are saved; the previously calculated information about the individual bands is therefore lost.
- Simulation results are only valid for ground proximity (1.5 meters above ground) and only outside of buildings. However, field strengths that are present where people remain for long periods of time e.g. in the home (i.e. indoors and also more than 1.5 meters above ground level) are particularly relevant to any comprehensive emission evaluation.
- Calculations for the inside of buildings are either extremely complex or less accurate, and the representation of the results is also a problem (e.g. difficulties with operating an appropriate user interface for an interactive map).
- Errors in the simulation result from incorrect or incomplete data for the transmitters present. The data recorded for the buildings is also never absolutely up to date, complete, and accurate for every location. Sometimes the heights of buildings are simply estimated by counting the number of floors, and the building footprints have not even been digitally recorded yet in many municipalities.

The general public is showing interest in the project. On average, the website *e-smogmessung.ch* registers around 200 hits per day. Any mention of the project in the media leads to a much higher number of hits in the short term.

Feedback to the authorities responsible for the project shows that particularly municipalities are also interested in the findings of the project as well as the general public.

Public discussion on the topic of NIR has become somewhat less intense in recent years in Central Switzerland, however. Whether the "NIR Monitoring Central Switzerland" project has had anything to do with this is difficult to determine. The reaction to specific plans to build new transmitters still shows that the general public basically still feels uncomfortable about electromagnetic pollution.

Outlook

A number of points that could be of importance for similar projects planned for the future are given here in conclusion. These are based on the experience gained within the framework of the project described, the results of the available evaluation, and the strengths and weaknesses listed above.

- Even small changes in the position of the measuring probes can have a significant effect on the reproducibility of the results. This problem was noted in a precursor project to "NIR Monitoring Central Switzerland" [2]. Reliable positioning of the probe is therefore absolutely essential.
- The results of the measurements can only demonstrate correspondingly large changes in emissions because of the comparatively large measurement uncertainty of the probes and the limited reproducibility when setting up the probes again for a subsequent measurement period, and the effects of aging on the probe electronics. In any case it is recommended that permanently installed probes or probe mountings should be used. The probe manufacturer needs to improve the weathering and long-term characteristics of the probes.
- Interference from the surrounding area (electrical equipment, motor controllers, electric blinds, etc.) need to be identified as part of a preliminary investigation at each measurement location and avoided wherever possible.
- Simulations should be updated at regular intervals if possible. Any changes in the emission situation can then be determined by comparing the simulation results once a first update has been evaluated.
- Measurement station coordinates should be determined as precisely as possible so that emission calculations can be carried out for these locations also for validation purposes.
- Simulation results should not only be shown as an overall field strength, but also separately for each mobile phone band, the same as for the measurements.
- Calculation of population-weighted NIR exposure for selected areas should be sought to get a better impression of the true average exposure level for the general public.

References

- [1] **A. Bürgi**, NIR Monitoring Central Switzerland: Evaluations 2006 – 2008, Report no. RP/2008/NISMon/134.1 (Status 01.12.2008), Bern (2008).
- [2] **M. Wuschek**, Long-term recording of high-frequency emissions from radio transmitters in Canton Schwyz – Report on commissioning an automatic measuring system and performing the first test measurements at three locations, Project Report Inventis AG / EM-Institut GmbH, Zürich / Regensburg 19.12.2003, (2003).

The authors:

Prof. Dr. Matthias Wuschek, Hochschule Deggendorf, Edlmairstr. 6+8, 94469 Deggendorf, matthias.wuschek@fh-deggendorf.de

Dr. Alfred Bürgi, ARIAS umwelt.forschung.beratung, Langmauerweg 12, CH-3011 Bern, alfred.buergi@arias.ch

Klaus Woweries, RF-IT-Consult GmbH, Kirchweg 36b, CH-5415 Nussbaumen, k.woweries@rf-it-consult.ch

Niklas Joos-Widmer, Amt für Umweltschutz Uri, Klausenstrasse 4, CH-6460 Altdorf, niklas.joos@ur.ch