EXPOSURE ASSESSMENT OF NON-IONISING RADIATION FROM 5 HZ TO 3 GHZ

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Abstract

The paper describes the assessment of the exposure to non-ionising electromagnetic radiation at today's office workplaces. The measured exposure values are compared with the exposure limits defined for the general public. The here presented method, which uses general purpose LF- and RF-test instrumentation, is applied to a limited sample of workplaces. So far, 14 workplaces at 5 different locations have been characterized with the method described. The exposure in the range of 100 kHz to 3 GHz is found to lie in between 0.08 % and 2.12 % of the general public exposure limit recommended by ICNIRP, whereas in the frequency range from 5 Hz to 10 MHz values between 0.29 % and 2.23 % have been determined.

Introduction

Modern workplaces are more than more equipped with a multitude of wireless services and devices. In addition, personal devices owned by the employees themselves are also used at work. Especially in business areas, a high density of indoor and outdoor transmitter sites for wireless telecommunication services can be observed. The goal of the project was to get a better knowledge of the typical exposure to non-ionising radiation at these locations. Of special interest are the contributions from different services, respectively frequency ranges to the total exposure. In addition, the results were compared to the recommendations of ICNIRP [1], which are identical to the legal limits used in Switzerland [2]. As this method is not aimed towards an assessment of the absorbed energy in the body of the person at the workplace, the test methods, the number and the distribution of the samples acquired at every workplace have been chosen to allow for a relative fast and straightforward test procedure. The presented results from 14 typical office workplaces were acquired between April 2005 and March 2006 in 5 different buildings.

Methods

For an assessment of workplace exposure to electromagnetic fields, the definition of the measurement sampling area, the choice of the test equipment and instruments settings are of main importance.

Since it was not the goal of this work to gain a correct picture of the exposure with respect to the basic limits or SAR values, but to get a general overview of the exposure with respect to the reference levels defined for the general public, some simplifications for the measurements procedure are possible. The time needed for the data acquisition can thus be limited to about 30 minutes per workplace with the described test procedure.

Sample taking

Due to the large frequency range and the need for several antennas and test instruments, the number of spatially distributed samples at each workplace has to be restricted. The disadvantage is that a valuable averaging over the body volume will not be possible. To get a

limited sampling over the shape of the human body, it was decided to make three measurements at different spots on each workplace (Fig. 1, left hand side). Spot 1 represents the head of the person sitting at the workplace. Spot 2 represents the trunk and spot 3 the legs. In case of a workplace where the person is standing at a desk (Fig. 1, right hand side), we substituted spot 3 with spot 4. In this case, spot 4 represents the location of the head, spot 1 the trunk and spot 3 the legs. With this modification spot 1 and 3 are still comparable in both setups.
In the frequency range 30 MHz - 3 GHz all spots were measured. Due to the small spatial variations to be expected in the lower frequency range from 5 Hz - 30 MHz only spot 1 is used.

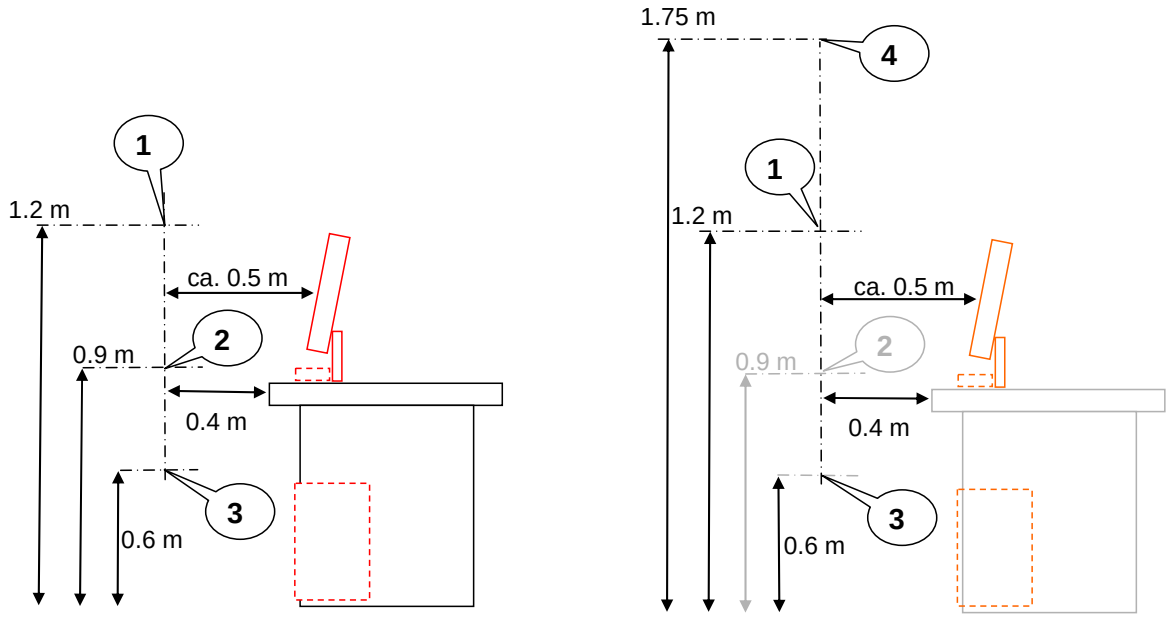


Fig. 1: Sample taking: Office workplaces (left hand side); standing workplaces (right hand side)

Measurement Instruments
To cover the entire frequency range from 5 Hz to 3 GHz the following instruments were used:

- 30 MHz - 3 GHz: The RF-measurement system TS-EMF from Rohde & Schwarz with its tri-axial antenna was used.
- 30 kHz - 30 MHz: The software RFEX from the TS-EMF system was also used, but with a loop antenna Rohde & Schwarz HFH2-Z2. The antenna was consecutively positioned in three orthogonal directions to obtain a quasi-isotropic characteristic. The results were corrected with the specific antenna factors and expressed either as electric field or magnetic field strength values.

The software controlled frequency selective measurements were made with a Rohde & Schwarz FSU8 spectrum analyzer.

- The measurements in the frequency range from 5 Hz to 30 kHz were carried out with a Wandel & Goltermann type EFA 3 device with an isotropic probe. Only magnetic field strength was assessed in this frequency range.

Instrument settings
The used software RFEX allows the operator to define several frequency ranges with individual spectrum analyzer settings. These ranges are called “packets”. We defined

specific packets for each known telecommunication service and for all ranges in between a generic instrument setup. To get representative measurement results for complex modulated telecommunication services, the RMS value (root mean square) of the signal during a typical relevant period (e.g. a TDMA frame duration) has been determined. To detect signals with a small duty cycle the acquisition time for some packets was extended to a defined time period depending on the characteristics of the expected signals. The resolution bandwidth (RBW) was also selected in accordance with the bandwidth of the expected signals. The following two examples explain the practical implementation of this philosophy:

- For all GSM measurements (up- and downlink) the following settings of the spectrum analyzer were used: RBW 200 kHz. The sweep time was set in a way that the measurement time for every pixel of the displayed trace on the spectrum analyzer corresponds to the duration of a frame of the GSM signal (4.62 ms). With this procedure the frame is weighted according to the active time slots. Thus the correct RMS value of a GSM channel will be measured.
- In the ISM band from 2.4 to 2.5 GHz with many different RF devices and applications like WLAN (IEEE 802.11b/g), Bluetooth, wireless video systems, microwave ovens and others, measurement settings considering all possible sources will be very difficult. The initial selected RBW of 20 MHz leads to incorrect results due to the overlapping of the measurement ranges especially for WLAN channels with 22 MHz bandwidth and 5 MHz channel spacing. After some experiments we decided to measure in this band with a RBW of 5 MHz and a channel spacing according to WLAN (5 MHz). In addition, the RMS detector of the spectrum analyser is used and the max-hold function is activated for one second per packet.

For the frequency ranges below 30 MHz the same RBW's were selected as defined for electromagnetic compatibility (EMC) measurements.

Conditioning of the raw data

If there are no measured signals present with levels higher than the noise level of the test equipment, summing up of this noise background has to be prevented. For this reason, the following additional procedure was applied:

- Only measurement values with a level of 5 dB above the noise level and on dedicated predefined channel frequencies were considered.

Therefore, the output result of every measured packet is the RMS value of all signals higher than 5 dB above the noise level in the three orthogonal antenna directions.

Frequency ranges

The frequency domain above 100 kHz was divided in 33 sub-bands. Table 1 shows the subset of the radio communication bands. The frequency range of every sub-band is sufficiently small so that the individual field strength values of every sub-band can be compared with the exposure limit value at the respective centre-band frequency. If no valid signal (i.e. below the selected threshold of 5 dB) is available, no comparison is made and no value is used for the summation to calculate the overall exposure value. The exposure limits were calculated according to [2] chapter 22, item 222.

Table 1: Frequency range fragmentation from 100 kHz to 3 GHz (mainly radio communication bands)

Service or range	Frequency range [MHz]	Center frequency, f [MHz]	Electric field strength limit value, $E_{G,f}$ [V/m]	Achieved measurement sensitivity in this range [V/m]
TV VHF I	47 – 68	57.5	28	0.028
UKW	87.5 – 108	97.75	28	0.01
Telepage I & II	147.35	147.35	28	0.008
Telepage Erm.	169.5625	169.5625	28	0.007

TV VHF III	174 – 223	198.5	28		0.009
Prop. Telepage	425 – 470	447.5	29.1		0.002
TV UHF	470 – 790	630	34.5		0.0045
GSM 900 UL	880 – 915	902.5	41.3		0.0011
GSM 900 DL	925 – 960	947.5	42.3		0.0011
GSM 1800 UL	1710 – 1760	1735.1	57.3		0.0032
GSM 1800 DL	1805 – 1855	1830.1	58.8		0.0022
DECT	1880 – 1900	1889.6	59.8		0.0063
UMTS FDD UL	1920 – 1980	1950	60.7		0.0089
UMTS FDD DL	2110 – 2170	2140	61		0.01
ISM	2400 – 2500	2449.5	61		0.016
100 kHz -1 MHz	0.1 – 1	0.55	87		0.00016
1 MHz -10 MHz	1 – 10	5.5	37.1		0.000063
10 MHz-30 MHz	10 – 30	20	28		0.000032

The frequency range below 10 MHz is divided in 4 areas according to table 2. The exposure limit values in the lower frequency range were calculated according to [2] chapter 22, item 221.

Table 2: Frequency range fragmentation from 5 Hz to 10 MHz

Service or range	Frequency range [kHz]	Centre frequency, f [kHz]	Magnetic field strength limit value, $H_{G,f}$ [A/m]		Achieved measurement sensitivity in this range [A/m]
30 kHz -100kHz	30 – 100	65	5		0.0000005
100 kHz -1 MHz	100 – 1000	550	5		0.0000004
1 MHz -10 MHz	1000 – 10'000	5500	5		0.0000002
5 Hz – 30 kHz	0.05 – 30	15	5		0.000796

Measurement uncertainty and sensitivity impact

The overall measurement uncertainty of the RF measurement system is approximately 2.5 dB. In case of low signal levels an additional impact of the limited sensitivity of the system appears. If there would exist an undetected RF signal in every packet on a level just under the sensitivity threshold, 0.26 % of the exposure limit would be missed in the upper frequency range. In the lower frequency range a contribution of 0.16 % would not be taken into account.

Results

In this paper results from 14 workplaces at 5 different locations are reported. 12 of them were office workplaces. 1 is a standing workplace.

Results in the frequency range 100 kHz - 3 GHz

As shown in Fig. 2 all results in the frequency range 100 kHz to 3 GHz are in between 0.08 % and 2.12 % of the exposure limits.

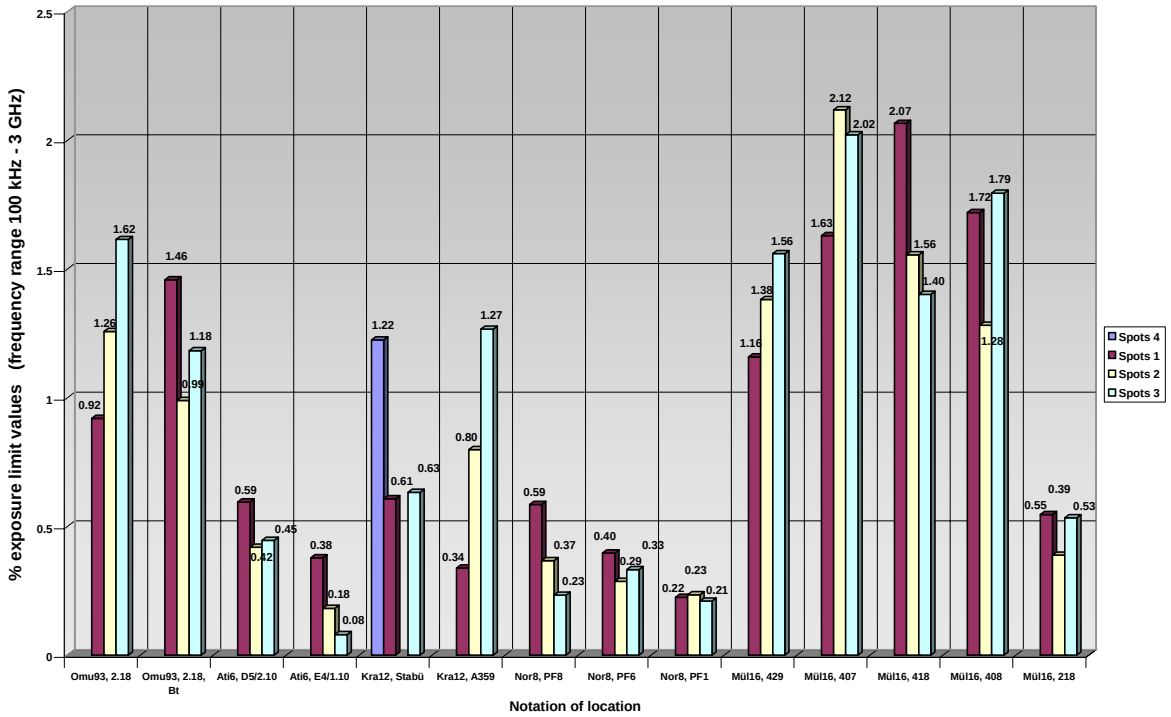
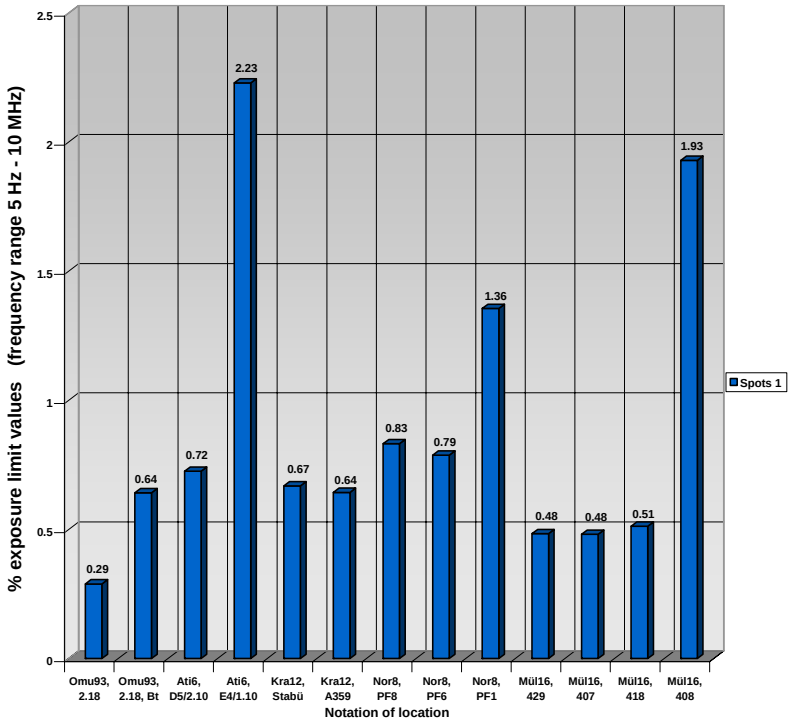


Fig. 2: Range of the measured values in % of the exposure limit according to [2] chapter 22, item 222

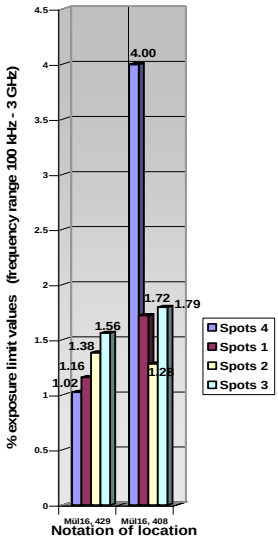
Results in the frequency range 5 Hz - 10 MHz



As shown in Fig. 3 all results in the frequency range 5 Hz to 10 MHz lie between 0.29 % and 2.23 % of the exposure limits. In this frequency range measurements are taken only at the position of the head (i.e. spot 1).

Fig. 3: Range of the measured values in % of the exposure limit values to [2] chapter 22, item 221

Additional results in the frequency range 100 kHz - 3 GHz



Due to the presence of several WLAN access points (AP) at the ceiling of this particular building, we decided to perform an additional measurement of spot 4 at two locations (see Fig. 4), although both were not standing workplaces. The workplace at the left hand side in Fig. 4 is several meters away from the nearest WLAN AP. The workplace on the right hand side in Fig. 4 is closer than one meter from the nearest WLAN AP. It is not surprising that in the vicinity of the WLAN AP the electromagnetic field generated by this service becomes the dominant contribution to the total exposure. (The results of the locations in Fig. 4 are - with exception of the spot 4 data – also included in Fig. 2 and Fig. 5.)

Fig. 4: Range of the measured values in % of the exposure limit according to [2] chapter 22, item 222

Field strengths in the frequency range 80 MHz - 3 GHz

It is out of the scope of this contribution to discuss in all details the totality of the measurements performed. Nevertheless, Fig. 5 gives an overview of the exposure values for the frequency ranges and wireless services of public interest.

The electric field strength in V/m for the measurement packets up to 800 MHz is smaller than 0.08 V/m (see Fig. 5). On the one hand, the biggest observed single values originate from the downlink channels of nearby cellular radio network transmitters (in-house equipment was not installed at any of the measurement sites): GSM 900 with 0.9 V/m, GSM 1800 with 0.7 V/m and UMTS with 0.6 V/m. On the other hand, GSM 900 uplink contributed with 0.6 V/m at the maximum, DECT with 0.7 V/m and the ISM band at 2.5 GHz with 1.1 V/m reach similar values.

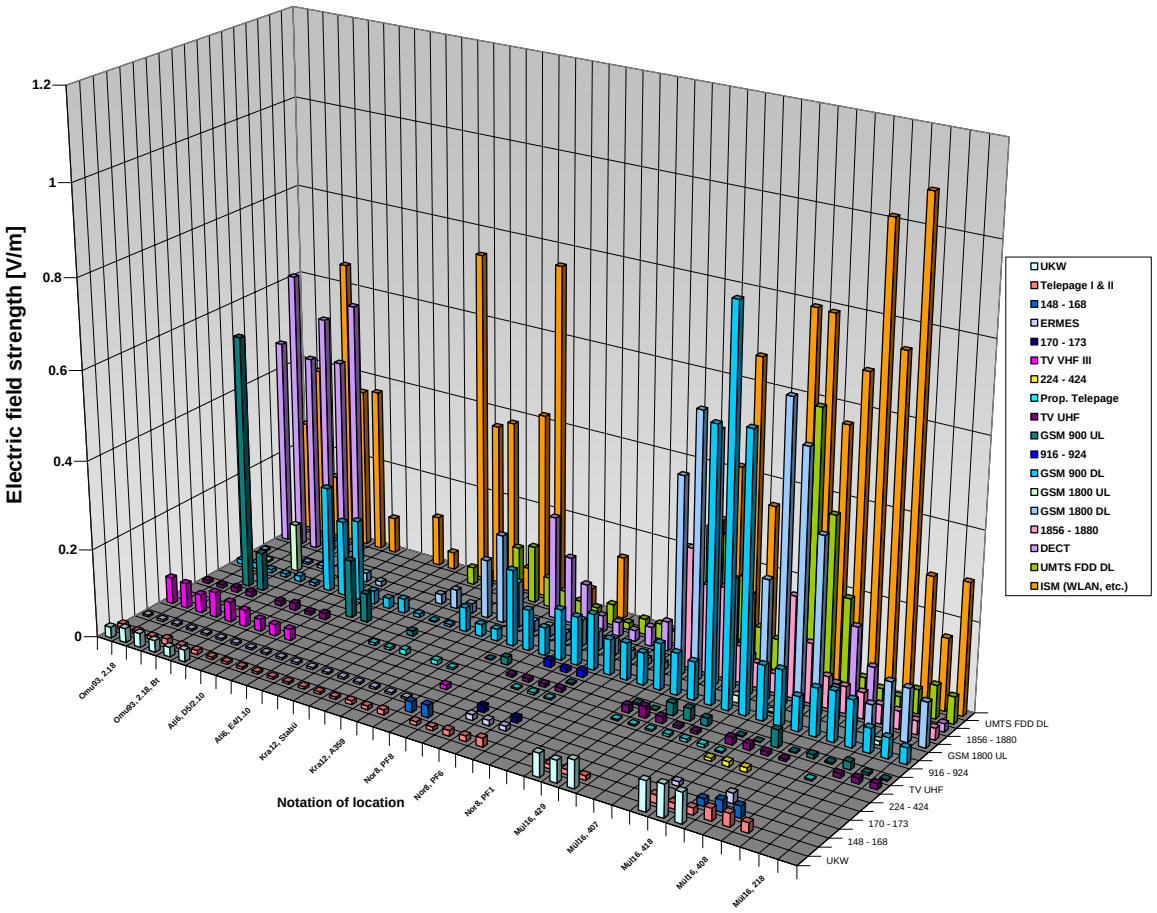


Fig. 5: Measured values in [V/m] in the frequency range from 80 MHz to 3 GHz

Fig. 5 illustrates also all the other measured field strengths over the measurement sensitivity. Due to the arbitrary choice of the sample of workplaces and locations, it would not be meaningful to calculate average values for each frequency range.

Discussion

The choice of the workplaces could have lead to bias of the measurement results difficult to quantify. This has several reasons: Some of the workplaces had to be measured by request of persons frightened of being exposed to various (internal or external) sources. Lay estimation of exposure does, however, not necessarily correspond to real “high exposure”. Other workplaces have been chosen by our test engineers for special interests with regard to a certain office concept. Only in a limited number of workplaces an attempt has been made to gain a representative sample. The measuring method applied permits a quantification of the exposure to non-ionising radiation with respect to the exposure limits. All results in the frequency range between 5 Hz and 3 GHz are between 0.08 % and 2.23 % of the exposure limits. It can be assumed that these values are representative for today’s home environment as well. The used test setup covers a wide frequency range and provides detailed results of every frequency range of interest. The sensitivity of the equipment is satisfactory and the system is open to define further packets in the desired frequency ranges with different instrument settings to perform state of the art exposure assessment of future wireless services.

Literature

[1] ICNIRP (1998): Guidelines for Limiting Exposure to Time Varying-Electric, Magnetic and Electromagnetic Fields (up to 300 GHz). Health Physics Vol. 74, No. 4, pp 498-522, 1998, http://www.icnirp.de/documents/emfgdl.pdf

[2] Swiss Federal Council (1. Feb. 2000): Ordinance relating to Protection from Non-Ionising Radiation (ONIR), SR 814.710. www.admin.ch/ch/d/sr/c814_710.html