May 18, 2007

Exposure of the general public to the indoor RF-radiation of picocells in train stations and an airport and to the outdoor RF-radiation of microcells in shopping streets

Gilbert Decat
VITO

1 Introduction

The GSM network consists of cells. One cell is a zone covered by a signal produced by a determined base station. Beside the well known macrocells we usually see on roofs and masts we distinguish the micro- and picocells used for enlarging the signal capacity in specific locations such as shopping streets, railway stations, airports, big building etc. Microcells are almost always fixed at the front wall of houses in shopping streets whereas picocells are mostly hanging indoor on the ceiling of the construction. The operation principle of the micro- and picocell system is that the signal which is produced by the base station is locally distributed by these small cells. The average output power of micro- and picocells is 2,5 watts (W) and 1 W respectively. Of these cells three different models exist: omni-directional, semi-directional and directional cell. Notice that both cell types are often confused and generally called microcells.

The present document, from which the results are derived of a VITO-study on order of LNE (department of Leefmilieu, Natuur en Energie of the Flemish Gouvernment) [1], deals with the exposure of the general public to the RF-radiation indoor produced by picocells in train stations and the national airport and outdoor produced by microcells in shopping streets of Belgian cities. The operating frequency of both cell types is 900 and 1800 MHz with weak low frequency components of 8.3 and 217 Hz respectively. Notice that with GSM handhelds the essential power output is focused on the 217 Hz component [2].

2 Material and methods

2.1 General

The electric field (E-field) of both GSM-cell types were selectively recorded by means of two spectrometers (FIELDCOP and the NARDA SRM 3000). The measurement heights depended on the position of persons, namely if persons are mostly standing or sitting in the sampled location area: in railway stations and shopping streets where people are mostly standing/walking, measurements were performed at 0.1, 1.0 and 1.70 m above the floor. In the gate waiting rooms of the airport where people are mostly sitting the measurements were performed at head height which corresponds with an average height of 1.30 m.

For compliance testing with the Belgian standard [3] the rms of the peak value ($E^2_{peak}/\sqrt{2}$) recorded over a 6 minutes' period was used. This is the worst case value of the rms averaged over a 6 minute period [4]: it means that if the rms of the peak value is in compliance with the exposure reference level the 6 min. averaged rms-value will certainly do.

Table 1 summarizes the reference levels of the Belgian exposure standard for single frequency electromagnetic fields between 10 MHz and 10 GHz.

Table 1: Reference levels of the Belgian EMF exposure standard

Frequency	Power density (W/m²)	Elektric field (V/m)
10 MHz - 400 MHz	0,5	13,7
400 MHz - 2 GHz	f/800	$0{,}686.f^{1/2}$
2 GHz - 10 GHz	2,5	30,7

** f in MHz*

The summation formula for multiple frequencies is given by:

$$\sum_{10MHz}^{10GHz} \left(\frac{E^2 i}{E^2 i - ref}\right) < 1$$

with :

E^2_i *= square of measured field at frequency i*

$E^2_{i\text{-}ref}$ *= square of the reference E-field level at frequency i*

2.2 *Indoor RF-exposure from picocells*

2.2.1 Railway stations

The RF exposure of picocells was evaluated by measuring the E-field in the 3 railway stations and in the national airport of Brussels respectively. The E-field was measured at heights of 0.1, 1.0 and 1.70 m.

Figure 1 shows an example of the measurement setup for recording the E-field (see 2.1) of a picocell. In this specific case the picocell is hanging at the ceiling (h = 3.2 m) of the building and the E-field is measured in 4 different radiation axes (R1 – R4) around the picocell.

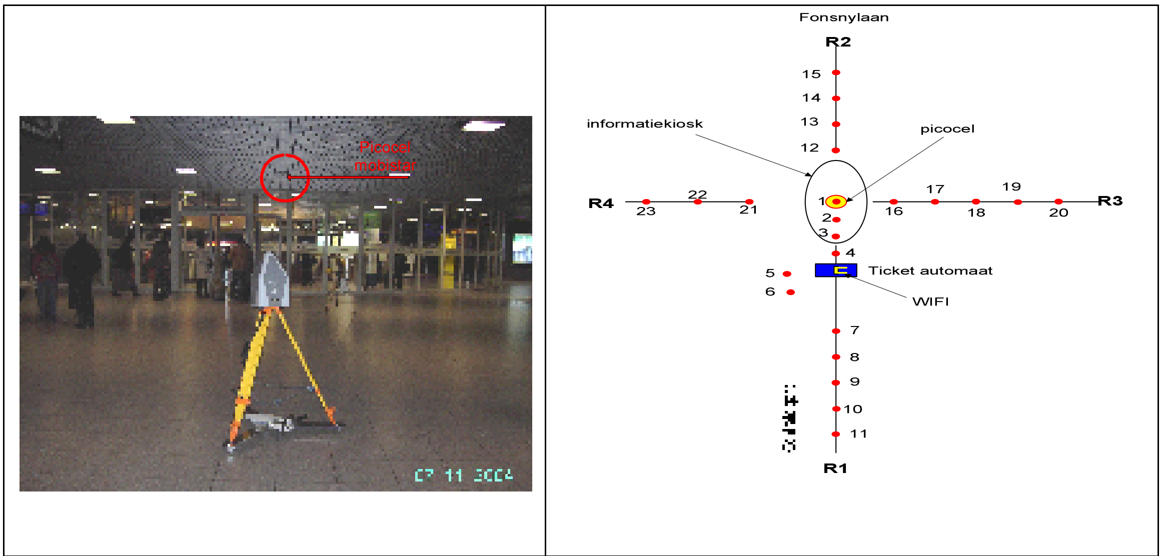

Figure 1: Setup example for evaluating the indoor E-field exposure of picocells

2.2.2 Airport

Figure 2 and 3 respectively show the measurement schemes for the evaluation the E-field distribution in the departure hall and the waiting rooms at the different gates of PIER A.

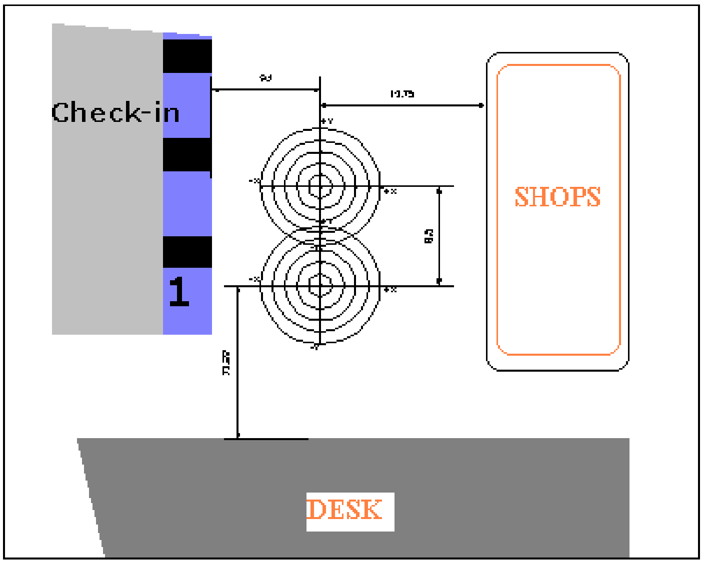

Figure 2: Measurement scheme in the departure hall

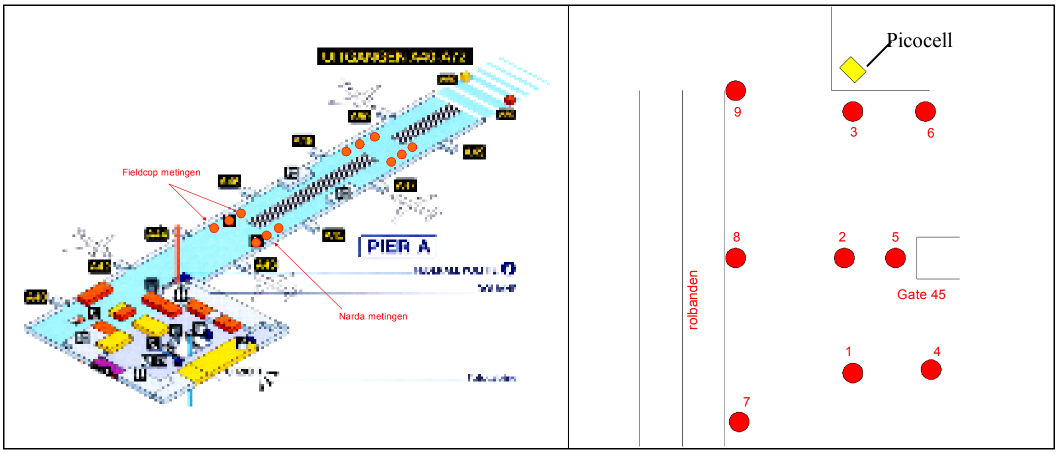

Figure 3: Measurement scheme in the PIER A for evaluating the E-field distribution in the waiting rooms at the different gates

For evaluating the RF-exposure in a statistical reliable way the E-field was recorded during 6 minutes in 134 points distributed over the departure halls and the PIER A.
In the PIER A the E-field distribution was evaluated in 30 waiting rooms adjacent to the departure gates. The E-field was measured at a 1.30 m' height which corresponds with the position of the head of a sitting person waiting for his flight. The GSM-covering was

provided by 4 picocells (Kathrein) in the departure hall and by 13 picocells (Kathrein) in PIER A. The cells were fixed on the walls of the construction at a height of 7 m.

2.3 Outdoor RF-exposure from microcells

Figure 4 shows an example of the measurement setup for recording the E-field in a shopping street where the microcell is fixed (h = 6 m) at the front wall of a house. The field is recorded in several points of the 3 measurement axes (R1 – R3).

Figure 4: Setup example for evaluating the indoor E-field exposure of picocells

The locations of the microcells to be sampled were selected by generating random numbers on a Belgian microwave location file we obtained from the operators Base, Mobistar and Proximus. In total 30 microcells were sampled in 30 different shopping streets of Antwerp, Brussels, Gent, Brugge, Hasselt, Liège.

3 Results

3.1 Indoor RF-exposure from picocells

3.1.1 RF-exposure in railway stations

Figure 5 shows the whole body exposure (E-field averaged over the 0.1, 1.0 and 1.7 m) versus the radial distance to the virtual vertical projection line of the picocells in the 3 railway stations of Brussels. The height at which the sampled picocells were hanging in the Brussels North (N), Central (C) and South (S) stations was 5.0, 2.6 and 3.2 m respectively. The power output at the moment of the measurements was unknown.

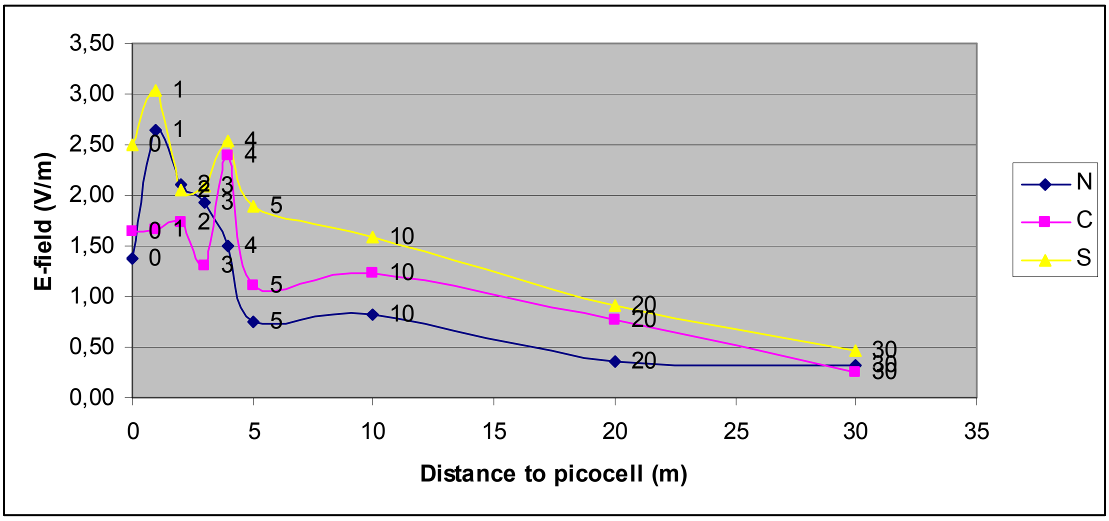

Figure 5: E-field versus distance in the Brussels railway stations North (N), Central (C) and South (S)

Depending on the station, the maximum E-field lies between about 1 and 5 m from the virtual vertical projection line below the picocells. All values are conform with the maximal limit value (20.6 V/m at 900 MHz and 29,5 V/m at 1800 V/m) of the Belgian exposure standard for the general public (see table 1).

3.1.2 RF-exposure in the national airport of Brussels

Figure 6 shows the histogram on base of the rms of the peak E-field obtained over a 6 minute sampling period and figure 5 shows the peak values of the 6 minutes sampling period. Both histograms are based on 134 measurement points distributed over the departure halls and the PIER A. In every point the E-field was recorded during 6 minutes at a height of 1.30 m.

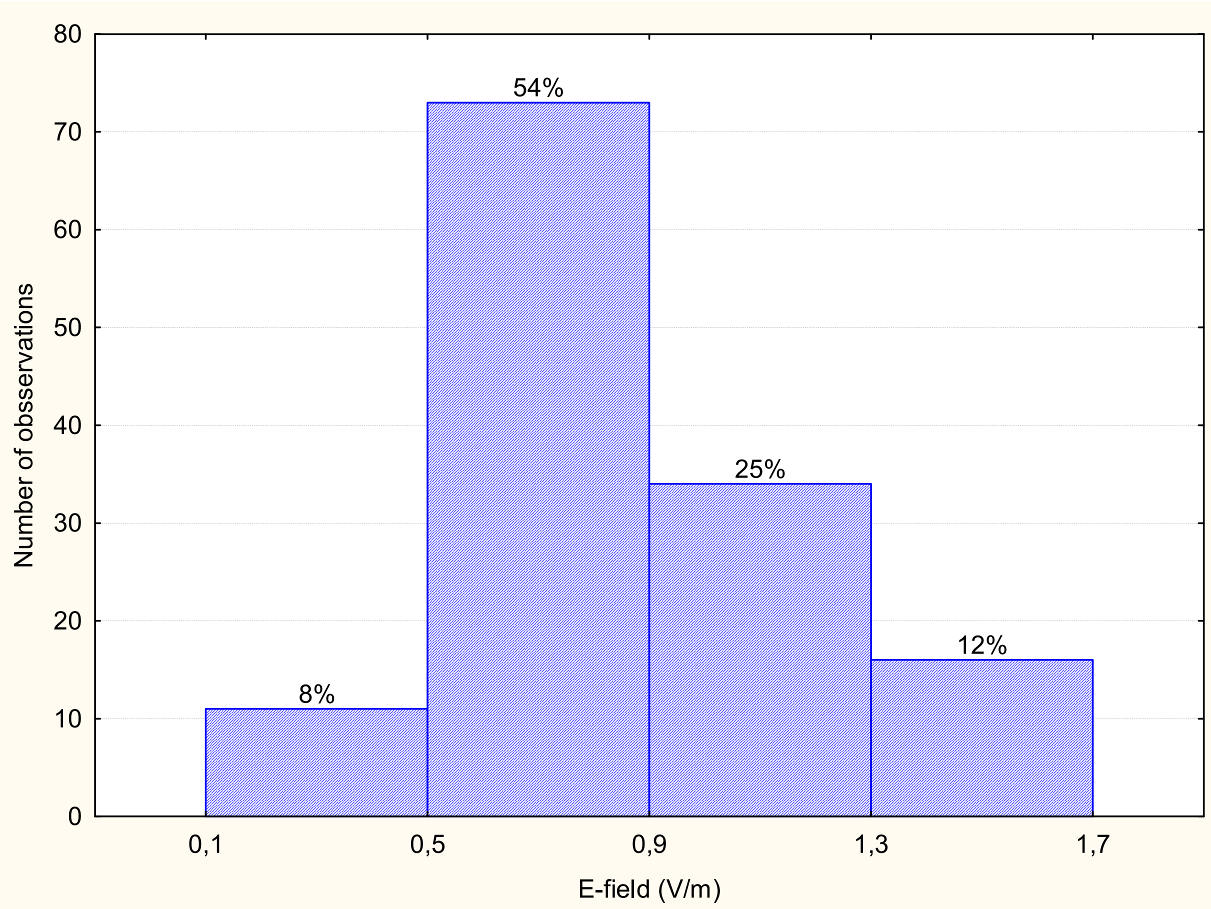

Figure 6: Histogram of RMS E-field

This histogram shows that the rms field strength in the airport varies between 0.1 and 1.7 V/m, 79% varies between 0.5 and 1.3 V/m and only 12% between 1.3 and 1.7 V/m.

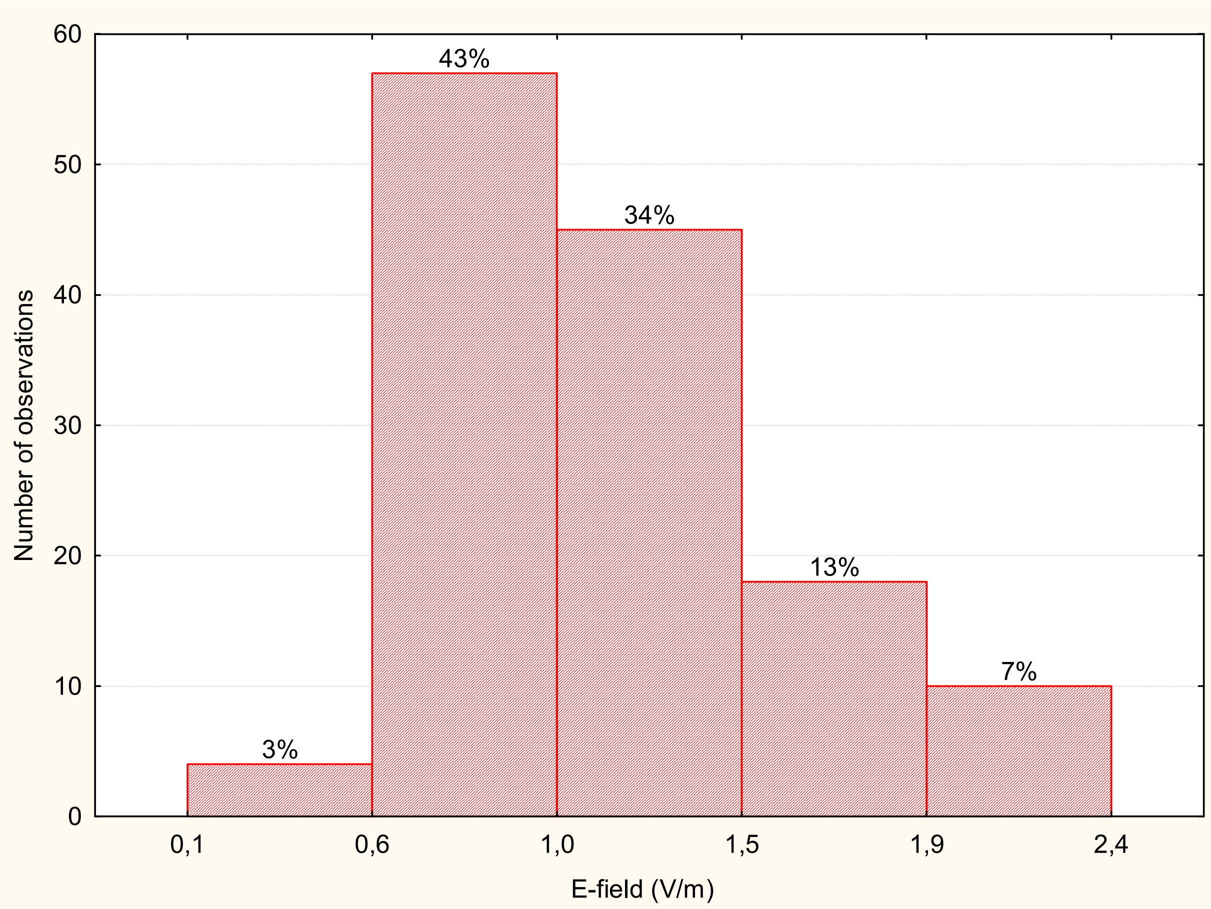

***Figure** 7: Histogram of the peak E-field*

This histogram shows that the peak field strength in the airport varies between 0.1 and 2.4 V/m, 77% varies between 0.5 and 1.5 V/m and the remaining part is less than 2.4 V/m.

Table 2 shows the location and dispersion statistics of the RF-exposure from picocells in the airport.

Table 2: Descriptive exposure statistics

E-field (V/m)	N	Mean ± St. dev.	C.L. -95%	C.L. +95%	Median	Min.	Max.
Rms	134	0.82 ± 0.31	0.77	0.88	0.74	0.07	1.70
Peak	134	1.16 ± 0.44	1.09	1.24	1.04	0.10	2.40

From this table we can conclude that we are 95% confident that the rms exposure mean lies between 0.77 and 0.88 V/m and the mean peak between 1.09 and 1.24 V/m. Even the maximum peak value of 2.40 V/m is much weaker than the reference level of the Belgian standard (see table 1). According to the interpretation of the standard we can conclude that no health risks have to be expected from the exposure of the RF-radiation from picocells in the airport.

3.2 Outdoor RF-exposure from microcells in shopping streets

3.2.1 Relation between E-field, measurement height and distance

Figure 8 shows the relation between the response variable and the explanatory variables. The E-field represents for each of the 9 distance points (0 – 30 m) the mean field strength of the rms values obtained in the 30 streets where at least one microcell was active.
The mean E-field strength obtained from the field values at the 3 different heights (0.1, 1 and 1.7 m) can be considered as the averaged whole body exposure when a person is crossing a microcell active street.

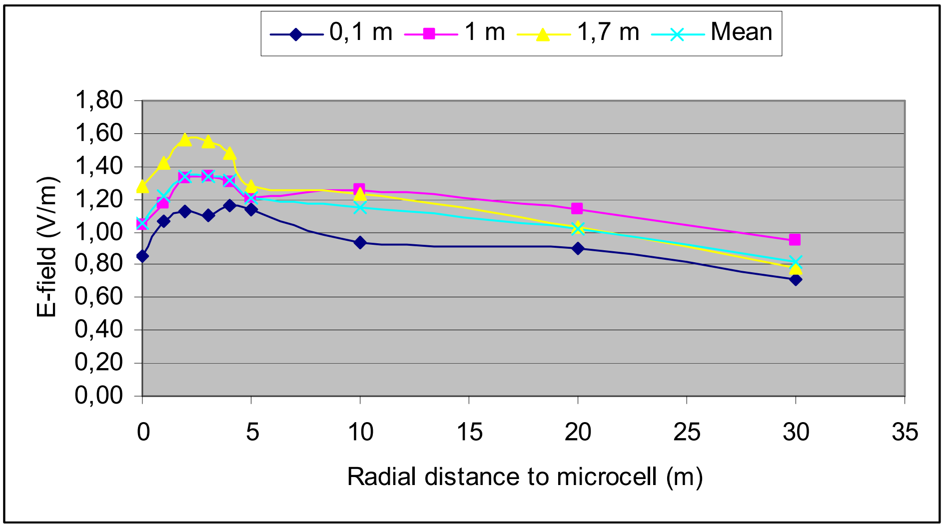

Figure 8: Relation between E-field strength, measurement height and radial distance to microcell

The graphs of figure 8 show that, as to be expected, the exposure is strongest at a measurement height of 1.70 m, followed by 1 m and 0.1 m respectively. The differences seem to be biggest between 0 and 4 m but are in some cases in a less extend observable at a radial distance of more than 30 m from the microcell. Notice that at about 10 m, the exposure becomes stronger at a height of 1 m than at a height of 1.70 m. Perhaps that ground wave reflections are a part of the factors which cause this switch.

3.2.2 RF-exposure distribution in the shopping streets

Figure 9 shows the cumulative frequency distribution of the E-field in the shopping streets. This histogram as well as the one of figure 10 is based on about 300 measurement points in 30 streets from 10 different Belgian cities. The E-field represents the rms of the peak value of the E-field measured during 6 minutes at a height of 1.70 m. Certainly within a distance of 5 m from the microcell, the measurement height of 1.70 m is considered as the worst case exposure situation. Compliance at this height involves compliance at 1 and 0.10 m.

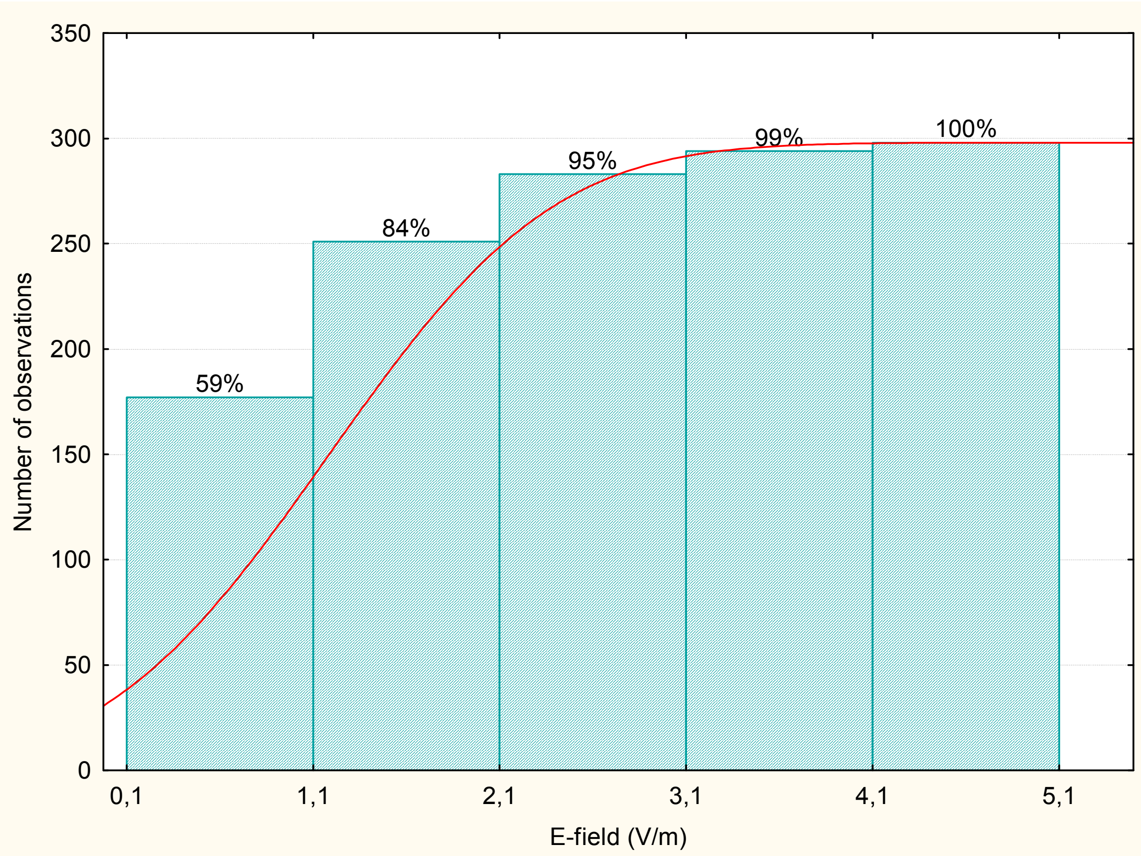

Figure 9: Cumulative distribution of the E-field strength in the shopping streets

From this figure we can conclude that all measured E-fields are smaller than 5.1 V/m and consequently that they are in compliance with the Belgian exposure standard (see table 1).

The exposure histogram (figure 10) shows that the biggest part (76%) of the exposure lies between 0 and 1.5 V/m, only 1% is observed between 4 and 5 µT.

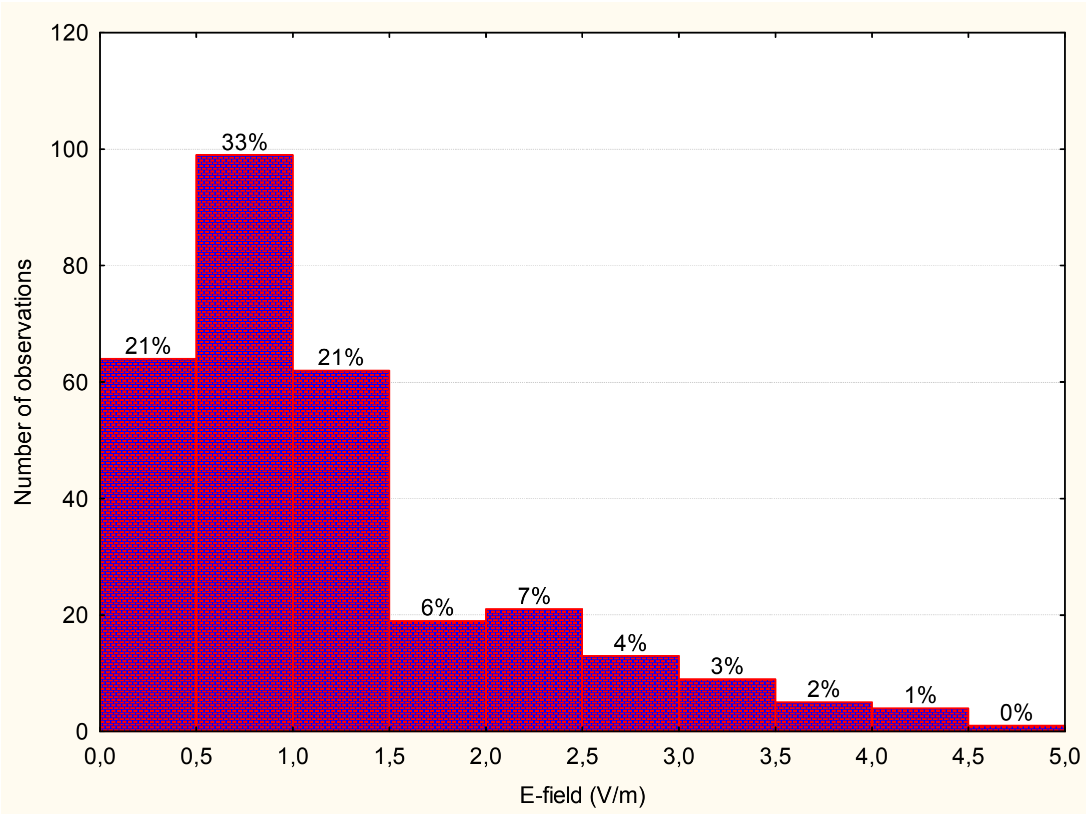

Figure 10: Distribution histogram of the RF-exposure in the shopping streets (worst case situation)

Table 3 shows that the probability is 95% that the exposure lies between 1.1 and 1.3 V/m if the E-field is randomly measured at a height of 1.70 m in a shopping street where a microcell is active.

Table 3: RF-exposure location and dispersion statistics

N	E-field (V/m)					
	Mean ± St.dev.	CL -95%	CL +95%	Median	Min.	Max.
298	1.2 ± 0.9	1.1	1.3	0.9	0.1	5.1

3.2.3 Whole body RF-exposure in the shopping streets

In order to estimate the whole body exposure when people are walking in a shopping street where microcells are working the E-fields (rms from peak over 6 minutes) of the 3 measurement heights were averaged for each measurement point and plotted against the distance to the cell (figure 11).

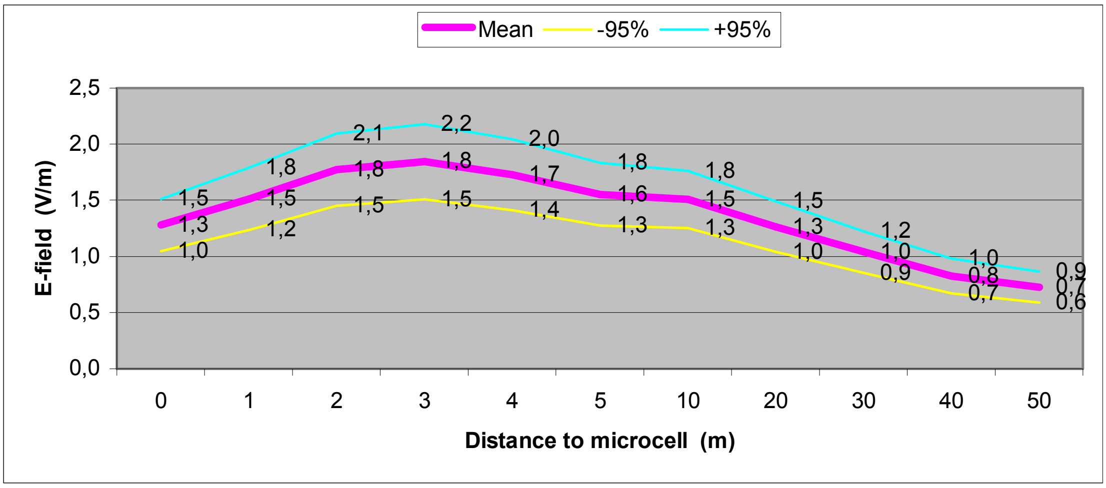

Figure 11: average RF-exposure recorded in 30 randomly selected streets

As shown by figure 11, the whole body exposure (1.8 V/m) is at maximum at 4 m from the microcell. With a confidence of 95% we can state that the E-field strength in this point lies between 1.5 and 2.2 V/m. The same statements but with other values can be made for the other distance points.

Out of 1294 measurements made in the 30 streets from the different cities we calculated that a person who is walking in a shopping street with an activated microcell has a probability of 95% to be exposed to an E-field between 1.12 and 1.62 V/m. There is a 5% chance of being wrong.

General conclusion

The RF-radiation of picocells and microcells is in compliance with the Belgian standard and after the interpretation of this standard no health effect has to be expected.

In terms of modulation we can state that this conclusion only holds for the GSM carrier waves (900, 1800 MHz). Since (1) the low frequency components were not measured and (2) we don't know if demodulation occurs in the human body and (3) nor the Belgian neither the ICNIRP(1998) standards provide any information or reference levels about this issue, conclusions about the modulation/demodulation phenomena cannot be drawn. However from the biological papers presented in the modulation working group [5] it seems to be that the RF-exposure of the pico- and microcells is too weak in order to trigger a demodulation effect in the human body, even if the body should have the capacity to demodulate GSM-signals. Certainly when exposure levels are in compliance with the ICNIRP (1998) guidelines [6] demodulation cannot be triggered.

References

Studie uitgevoerd door VITO in opdracht van de Vlaamse Overheid, Departement Leefmilieu, Natuur, Energie (LNE). Rapport wordt eerdaags op internet gepubliceerd.

[2] Stockbroeckx Benoît (May 2007). Les composantes à très basses fréquences dans les systèmes de radio-communication. Document made in the framework of the RF-modulation working group of the Belgian Health Council

[3] KB 10 augustus 2005. Koninklijk besluit houdende de normering van zendmasten voor elektromagnetische golven tussen 10 MHz en 10 GHz. Belgisch Staatstblad N. 2005 – 2394 (C-2005/22777) van 22 september 2005, Ed. 2, pp.41189 – 41193.

[4] 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 494-522, 1998. http://www.icnirp.de/documents/emfgdl.pdf.

[5] Adang Dirk (12/04/ 2007) Summary for the working group modulation: Biological effects of modulated microwave radiation: the microwave hearing effect

[6] Vanderstraeten Jacques (18/05/2007) Summary for the working group modulation: Effets biologiques des *ELF-amplitude modulated microwaves*