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Effets biologiques potentiels des micro-ondes modulées – Annexes –

6 février 2008

Annexe 1: Les composantes à très basses fréquences dans les systèmes de radiocommunication. Stockbroeckx B. [mai 2007].

1. Introduction

Les systèmes modernes de radiocommunication mettent en œuvre des techniques de multiplexage et d'accès multiple qui impliquent une modulation en amplitude de la porteuse micro-onde. On peut citer par exemple l'accès multiple par répartition dans le temps (*TDMA*) des systèmes GSM et TETRA, l'accès multiple par répartition dans le code (*CDMA*) de l'UMTS et le multiplexage temporel (*TDD*) de l'UMTS et du WiMax. Lorsqu'un signal modulé en amplitude est observé dans le domaine spectral, on retrouve la raie correspondant à la fréquence porteuse ainsi que des raies latérales avec un décalage fréquentiel correspondant à la fréquence de modulation. Dans certains cas, cette modulation en amplitude est produite à une fréquence très basse. Lorsque cette fréquence est inférieure à quelques centaines de hertz, on parle de composantes à très basse fréquence (*ELF, extremely low frequency components*). Ces basses fréquences n'existent donc pas par elles-mêmes, elles modulent une porteuse à haute fréquence. Un processus de démodulation est nécessaire pour les faire exister en tant que telles. Signalons cependant que la consommation d'énergie sur la batterie d'un téléphone portable, par exemple, se produit à une cadence correspondant aux fréquences des ELF qui modulent la porteuse. On retrouve donc à proximité du portable un champ magnétique variant dans le temps à une fréquence extrêmement basse. Ces très basses fréquences existent donc à proximité du portable indépendamment de tout processus de démodulation. La présence de telles composantes ELF pourrait produire des effets biologiques différents de ceux observés pour une porteuse non modulée.

Ce texte présente une analyse des composantes ELF rencontrées dans différents systèmes de radiocommunication.

On en trouvera une version plus détaillée dans B. Stockbroeckx, ELF Components in Radio Communication Systems, February 2007.

2. Description des ELF pour quelques systèmes

2.1. Système GSM

Le système GSM applique un accès multiple par répartition dans le temps (*TDMA*) selon lequel chaque communication utilise la porteuse micro-onde pendant un huitième du temps. La porteuse est émise par le portable toutes les 4,6 ms sous la forme d'une salve (*timeslot*) de 0,577 ms. Il en résulte une composante ELF à 217 Hz et aux harmoniques de cette fréquence. À cela s'ajoute une structure temporelle en trames et super trames qui introduit une composante ELF à 8,3 Hz et ses harmoniques. Dans le cas du portable GSM, l'essentiel de la puissance est concentré dans la composante à 217 Hz. Dans le cas de la station base qui gère de nombreuses communications

simultanées, la distribution statistique des salves produit un signal global pour lequel l'essentiel de la puissance est concentré sur la porteuse elle-même et les composantes à 8,3 et 217 Hz sont faibles.

2.2. Système DECT

Le système de téléphonie sans fil d'intérieur DECT est très semblable au système GSM. La base qui est raccordée au réseau de téléphonie fixe est capable de gérer jusqu'à 10 portables différents. Pour cela, elle émet en permanence (que l'on téléphone ou non) un signal de balise afin de se signaler aux éventuels portables qui se trouvent dans son champ d'action. Dans le cas du DECT, une salve est envoyée toutes les 10 ms, ce qui produit une composante ELF à 100 Hz et ses harmoniques. La puissance émise par la base ainsi que celle émise par le portable est essentiellement concentrée dans les composantes ELF.

2.3. Télédiffusion analogique

Le signal émis par une antenne de télédiffusion analogique est modulé en amplitude. On y trouve en particulier un top de synchronisation du balayage de l'écran à la fin de chaque ligne. Ce top est donc produit toutes les 64 microsecondes ce qui est équivalent à une composante à 15,6 kHz. Il ne s'agit donc pas d'une composante à très basse fréquence. On trouve une composante ELF à 50 Hz et ses harmoniques mais ces composantes ne contiennent qu'une très faible partie de la puissance du signal.

2.4. Télédiffusion numérique (DAB-T)

La porteuse DAB est interrompue toutes les 100 ms environ, ce qui produit une composante ELF à 10,42 Hz. Cette composante contient cependant très peu de puissance.

2.5. Système UMTS

Le standard UMTS exploite un système d'accès multiple par répartition dans le code (*CDMA*) ce qui implique que chaque bit d'information est multiplié par un code binaire (*chip*). Cela produit une composante à 3,84 MHz. Ce n'est donc pas une ELF. En dehors de cela, on peut retrouver un système de contrôle de puissance qui est également une sorte de modulation lente qui produit des composantes entre 10 et 100 Hz ainsi qu'à 1,5 kHz. Ces composantes contiennent peu de puissance. Si le portable et la station de base UMTS fonctionnent en duplex temporel (*TDD*, dans les picocellules), une composante à 100 Hz et ses harmoniques contiennent l'essentiel de la puissance du signal. Si la station de base fonctionne en duplex fréquentiel (*FDD*, dans les macrocellules), sa puissance varie avec le nombre d'utilisateurs. On trouve alors une composante ELF aux environs de 1 Hz qui contient une grande partie de la puissance du signal.

2.6. Système WiFi

Le WiFi utilise comme le GSM une répartition dans le temps (*TDMA*). La salve est envoyée toutes les 7 à 13 ms en fonction de la quantité de données à transmettre. Il en résulte donc une composante ELF de 77 à 143 Hz qui contient l'essentiel de la puissance du signal.

2.7. Système Bluetooth

Le standard Bluetooth fait également du TDMA avec une salve toutes les 0,7 ms, soit une composante à 1,4 kHz. Il ne s'agit donc pas d'une composante ELF.

2.8. Four à micro-ondes

Un four à micro-ondes de cuisine produit un rayonnement modulé par impulsion également. Une impulsion dure 5 à 6 ms et est envoyée toutes les 20 ms, ce qui produit une composante ELF à 50 Hz qui contient l'essentiel de la puissance du signal.

2.9. Système pré-WiMax

Un précurseur du système WiMax a été analysé du point de vue de ses composantes ELF. Il travaille en duplex temporel (*TDD*). La station de base envoie des salves de 1,55 ms toutes les 2,68 ms, soit une composante ELF à 373 Hz et ses harmoniques qui contiennent l'essentiel de la puissance du signal. Le modem du client (*CPE*) envoie des salves de 1,13 ms toutes les 2,68 ms, soit également une composante ELF à 373 Hz qui contient l'essentiel de la puissance du signal.

3. Critère de puissance

On a vu que, selon les systèmes, les composantes ELF peuvent contenir une part significative ou non de la puissance du signal. Pour quantifier cet aspect, plusieurs définitions sont possibles:

$$R_{t0} = \frac{P_{ELFi}}{P_0}; R_{\Sigma 0} = \frac{\sum_{i=1}^N P_{ELFi}}{P_0}; R_{\Sigma p} = \frac{\sum_{i=1}^N P_{ELFi}}{P_{peak}}$$

La plupart des normes et recommandations, dont celles de l'ICNIRP, considèrent une exposition moyennée sur 6 minutes. Il s'agit donc de P_0 dans les formules ci-dessus. Il est alors intéressant de constater que, lorsque les composantes ELF contiennent l'essentiel de la puissance, les rapports R_{t0} et $R_{\Sigma 0}$ ci-dessus sont supérieurs à l'unité. Ainsi, dans l'hypothèse où les composantes ELF ont un impact en termes d'effet biologique, la moyenne utilisée sous-estime le niveau d'exposition.

4. Résumé

Le tableau ci-dessous résume le propos de ce texte. Il présente le rapport R_{t0} pour une série de composantes ELF. Une simple croix représente une composante ELF qui n'a pas été quantifiée précisément. Un nombre ou une croix en caractère gras rouge représente une composante ELF qui contient une part importante de la puissance du signal.

ELF comp. Hz	GSM hands. %	GSM BTS %	DECT hands. %	Analog TV %	DAB -T %	UMTS FDD hands.	UMTS TDD hands.	UMTS FDD BTS	UMTS TDD BTS	WiFi	pre-WiMax BTS	pre-WiMax CPE	Blue-tooth	Microw. oven
1-15	2.6				0.016	x	x	x						
15-25	1.3				0.018	x	x	x						
25-35					0.015	x	x	x						
35-45					0.015	x	x	x						
45-55				0.29	0.016	x	x	x						x
75-125			166	0.029		x	x	x	x	x				
125-175				0.009					x	x				
175-225	179	0.89	163	0.015					x					
225-275				0.088					x					
275-350			159						x					
350-500	145	0.43	154						x		x	x		
500-700	109	0.43							x					

5. Références

- Stockbroeckx B, Colette Th, Gérard P. FieldCop: low-cost instrument for the frequency-selective monitoring of the level produced by discontinuous radiocommunication signals. In Proc. Intern. Conf. on Emerging EMF-Technologies, Potential Sensitive Groups and Health, Graz, Austria, April 2006.
- Stockbroeckx B, Moreau O, Vander Vorst A. Measured ELF components of radio-communication systems. In Proc. 2nd Int. Workshop Biological Effects of Electrom. Fields, Rhodes, Greece, Oct. 2002, p. 260-265.
- Bach Andersen J, Mogensen PE, Frolund Pedersen G. Exposure Aspects of W-CDMA. Report to the GSM Association, December 2001, 14 pages.
- Stockbroeckx B, Clerckx B. Les systèmes de communication mobile: principes et technologie. Annales de l'association belge de Radioprotection 2001; 26(4):265-91.

Annexe 2: 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. Decat G. – VITO [18 mai 2007].



"HGR 8194 Bijlage
2.pdf"

Annexe 3: Elektrisch veld van DECT basisstation en handset. Decat G., Deckx L. – VITO [novembre 2007].



"HGR 8194 Bijlage
3.pdf"

Annexe 4: RF-straling van antennes van het ASTRID-Netwerk. Decat G. [16 mai 2007].

2.1 Inleiding

ASTRID is een vereniging van publiek recht in verband met de radiocommunicaties van de hulp- en veiligheidsdiensten. ASTRID is een operator van gespecialiseerde telecommunicatie die een geïntegreerd radiocommunicatienetwerk voor de stem en de gegevens ter beschikking stelt van de Belgische hulp- en veiligheidsdiensten. Het doel van ASTRID is een einde maken aan de problemen die de brandweer, politie en ziekenwagendiensten ondervinden om met elkaar te communiceren. De antennes worden bij voorkeur geplaatst waar de impact op de omgeving beperkt is zoals industriegebieden of industriële gebouwen, watertorens, ...

Het netwerk van ASTRID bestaat uit ongeveer 500 basisstations. Een basisstation bestaat uit een pyloon of mast waarop antennes worden gemonteerd. Waar mogelijk wordt soms een antenne rechtstreeks op een bestaande infrastructuur gebouwd. De meeste basisstations tellen 3 antennes: 1 zendantenne en 2 ontvangstantennes.

De ASTRID-antennes zijn meestal rondstraalantennes en in sommige gevallen worden ook gerichte paneelantennes gebruikt. De antennes zenden uit met hogere vermogens (10 W) dan de mobiele en draagbare toestellen, die uitzenden met een maximaal vermogen van respectievelijk 3 W en 1 W (www.astrid.be).

Ofschoon het ASTRID-netwerk geen pulserende eigenschappen heeft en aldus geen lage frequentiecomponent bezit die een demodulerings-effect zou kunnen inhouden is dit een informatief document dat wil aantonen of de RF-straling die door de antennes van dit netwerk geproduceerd worden sterk genoeg zijn om volgens de interpretatie van de huidige Belgische normen risico's in te houden voor de gezondheid van de mens. Om hierop een antwoord te geven wordt uitgegaan van de worst case situatie waarbij de RF-blootstelling in de werkomgeving gemeten werd en geëxtrapoleerd wordt naar het algemene publiek dat zich doorgaans veel verder van de bron bevindt dan werknemers.

2.2 Karakteristieken en opstelling van de antennes

Tabel 1 en Figuur 1 geven respectievelijk de karakteristieken en de opstelling van de antennes waarvan de sterkte van de RF-blootstelling in de burelen van werknemers gemeten werd.

Tabel 1: Karakteristieken van de bemonsterde ASTRID antennes.

Rundstrahler
370 – 430 MHz / 406 – 470 MHz
737 003, K 75 11 21

KATHREIN
 Antennen · Electronic

Omni 450 360° 2dBi

Typ Nr.	737 003	K 75 11 21
Eingang	N Buchse	
Frequenzbereich	370 – 430 MHz	406 – 470 MHz
VSWR	< 1,5	
Gewinn	2 dBi	
Impedanz	50 Ω	
Polarisation	Vertikal	
Max. Belastung	100 Watt (bei 50 °C Umgebungstemperatur)	
Gewicht	1 kg	0,8 kg
Windlast	20 N (bei 150km/h)	
Max. Windgeschwindigkeit	200 km/h	
Verpackungsgröße	112 x 97 x 654 mm	112 x 97 x 614 mm
Antennenhöhe	552 mm	510 mm

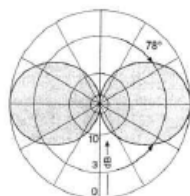
Material: Strahler: Messing.
 Schutzrohr: Fiberglas, Ø 21 mm, Farbe: Grau.
 Antennenfuß: Aluminium.
 Befestigungsbügel, alle Schrauben und Muttern:
 Rostfreier Stahl.

Befestigung: Die Antenne kann mit mitgelieferter Klemm-
 vorrichtung auf zwei Arten montiert werden:
 1. Auf die Mastspitze von Rohrmasten mit
 40 – 54 mm Ø. Das Anschlusskabel wird
 innerhalb des Mastes geführt.
 2. Seitlich an der Mastspitze von Rohrmasten mit
 20 – 54 mm Ø. Das Anschlusskabel wird
 außerhalb des Mastes geführt.

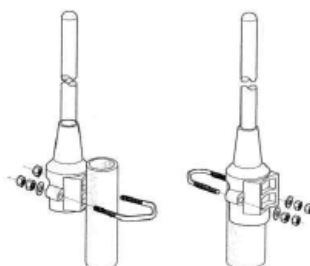
Blitzschutz: Alle Metallteile der Antenne, die mitgelieferte
 Klemmvorrichtung und der Innenleiter liegen an
 Masse.



936.03/7b Änderungen vorbehalten.



Strahlungsdiagramm vertikal



Seitlich am Mast

Auf der Mastspitze

KATHREIN-Werke KG · Anton-Kathrein-Straße 1 – 3 · Postfach 10 04 44 · D-83004 Rosenheim · Deutschland · Telefon (0 80 31) 18 40 · Fax (0 80 31) 18 49 91

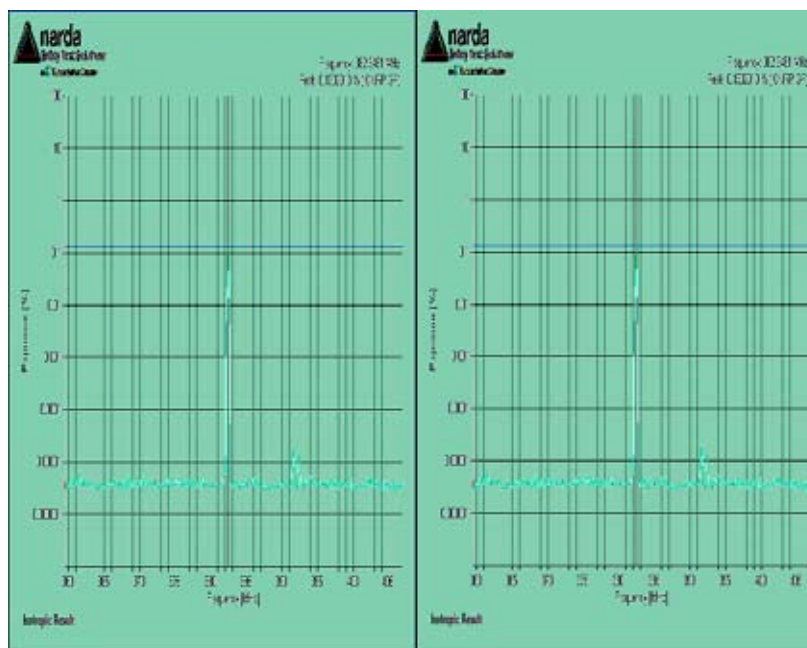


Figuur 1: Opstelling van ASTRID antennes.

Deze antennes bevinden zich tegen de buitenmuur van een bureelruimte. Het bureel van de bedienden staat op een afstand van 4 m van de antennes.

2.3 Meetresultaten

Figuur 2 toont de sterkte van de piekwaarde van het E-veld van het ASTRID netwerk dat selectief gemeten werd bij een frequentie van 382,346 MHz. De piekwaarde wordt uitgedrukt als percent van het ICNIRP(1998) referentieniveau van 28 V/m dat voor de betrokken frequentie aanbevolen wordt voor het algemeen publiek. De meting gebeurde tijdens een testoproep buiten het raam en op drie meter van de ASTRID antenne.

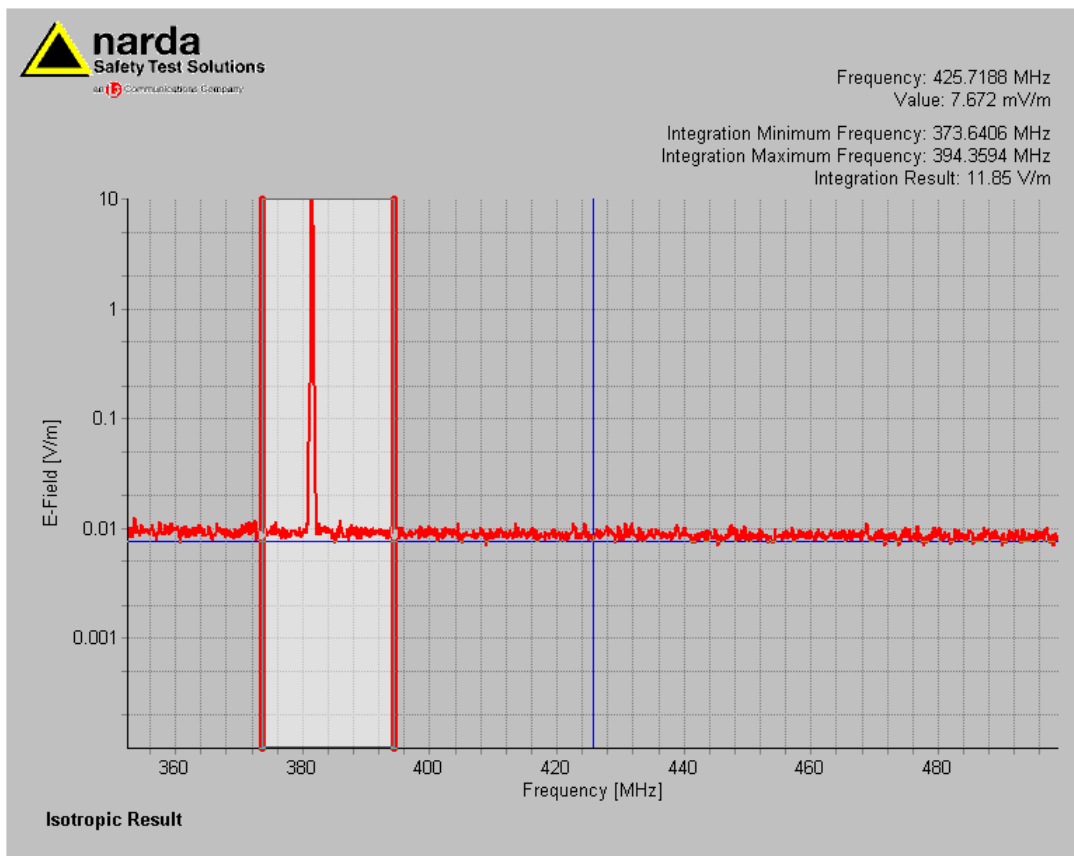


Figuur 2: E-veld (V/m) van ASTRID antenne bij frequentie van 382,346 MHz.

Op 3 m van de antenne bedroeg piekwaarde 36,5 mV/m en de rms van 25,7 mV/m. Zoals figuur 2 aantoont komt de piekveldsterkte overeen met 0,13 % (= rms van 0,09 %) van 28 V/m die door het ICNIRP(1998)[1] en de Europese raad (1999)[2] aanbevolen wordt als referentieniveau voor de blootstelling van het algemene publiek aan RF-straling in het betrokken frequentiegebied. Bij

vergelijking van de van de effectieve meetwaarde ($\text{rms} = \text{piek}/\sqrt{2}$) van 25,7 mV/m met de Belgisch blootstellingsnorm [3] die bij een frequentie van 382,346 MHz 13,414 V/m ($13,41 = 0,686\sqrt{f}$) bedraagt, stellen we vast dat de waargenomen blootstelling op een afstand van 3 m volgens de interpretatie van deze norm geen risico inhoudt voor de gezondheid van de mens.

Zoals figuur 3 aantoont kan de RF-veldsterkte in de frequentieband van 373,64 tot 394,36 MHz op 1 m afstand van de antenne oplopen tot 11,85 V/m. Dit komt overeen met ongeveer 88,5 % van de Belgische norm voor het algemene publiek en houdt in dat de blootstelling geen gevaar zou betekenen voor de gezondheid van de mens.



Figuur 3: Spectrumanalyse van ASTRID signaal op 1 m verwijderd van de antenne.

Noteer dat de aangehaalde resultaten bekomen werden in het werkmilieu (waarvan de naam niet meegedeeld wordt) waar de RF-blootstelling, omwille van de kortere afstand van de mens tot antenne meestal veel hoger dan die van het algemene publiek.

2.4 Besluit

Bij extrapolatie van de RF-blootstelling in de werkomgeving naar de blootstelling van het algemene publiek kan volgens de interpretatie van de Belgische norm besloten worden dat het zich bevinden in de nabijheid van ASTRID-netwerk (worst case situatie) zelfs geen risico's inhoudt voor de gezondheid van de mens. Deze conclusie houdt stand zolang de norm op basis van biologische en gezondheidseindpunten ongewijzigd blijft.

In het kader van de Europese richtlijn 2004/40/EC die in april 2008 voor de werkplek moet geïmplementeerd zijn, kan informatief kan gesteld worden dat de beroepsmatige blootstelling aan de RF-straling van het ASTRID-netwerk conform is met de actiewaarden van deze richtlijn en in de

gegeven omstandigheden dus geen bijkomende beschermingsmaatregelen moeten genomen worden.

2.5 Referenties

- [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 494-522, 1998. <http://www.icnirp.de/documents/emfgdl.pdf>.
- [2] EC Council Recommendation (1999), COUNCIL RECOMMENDATION of 12 July 1999 on the limitation of exposure of the general public to electromagnetic fields (0 Hz to 300 GHz) (1999/519/EC).
- [3] KB 10 augustus 2005. Koninklijk besluit houdende de normering van zendmasten voor elektromagnetische golven tussen 10 MHz en 10 GHz. Belgisch Staatsblad N. 2005 – 2394 (C-2005/22777) van 22 september 2005, Ed. 2, pp. 41189 – 41193.

Annexe 5: Comparison of TNO Study and Swiss Study on Well-Being. Vander Vorst A. [6 mars 2007].

This document compares two studies on well-being, one made in The Netherlands, TNO (1), and the other made in Switzerland, CH (2).

The comparison is made for the adhoc committee *Modulations* of the group New Communications Technology (NCT) of CSH.

It is largely based on the document *UMTS en gezondheid* 062-3871, Gezondheidsraad, The Netherlands (3).

Two evaluations, internal to the NCT-CSH, have also been taken into consideration (4)(5).

In brief

The TNO study was the first of its kind. Conclusions were that exposure of people to UMTS led to a decrease in well-being.

The CH study exhibited no effect on well-being.

As a conclusion, it is important to compare the two studies, in particular with respect to the experimental design of these.

TNO Study

Results (1)

TNO has published the results of its study about the effects of exposure of human beings to electromagnetic waves from GSM and UMTS antennas on cognitive functions and on well-being

The authors found a statistically significant relation between exposure to signals from an equivalent UMTS basis station and decrease of measures of well-being.

Furthermore, they found differences measured on diverse cognitive functions, for exposure to GSM signals and UMTS signals as well.

Comments on the experimental procedure (5)

The fields are GSM fields, 900 and 1800 MHz, respectively, and UMTS-like fields, 2100 MHz.

The study focuses on base-station exposure.

The authors assume the absence of cumulative effects and saturation.

The amplitude of the various electric fields is 1 V/m at a height of 1.5m: it characterizes the peak value of the electric field.

The GSM field has a duty cycle of 50 %. Hence, the power is half that calculated from 1 V/m, and the effective field strength under GSM exposure amounts to 0.7 V/m, average value of the GSM electric field.

The authors call internal field the field generated within the body, and external field the field that would be present without the body, which is not quite usual. This can be source or error in interpretation of results. It would be safer to call source field the field caused by the external source, and induced - or reaction - field that induced by the body under the external exposure. The source field is present whether the body is present or not: it depends only of the source. The field inside the body is the total field, sum of the source field and of the induced field.

For the numerical simulation, the authors say that SAR was calculated with a plane wave of amplitude 1 V/m. Although the text is not explicit, this seems to be uniform amplitude and not a peak value as for the experimental investigation.

In Appendix A, the authors do not specify how the field amplitude varies as a function of height. Hence, it is difficult to evaluate the field to which the whole body is submitted.

The authors, however, specify the electric field at the height of the head, which is a most important factor.

CH Study

Results (2)(3)

CH study gives a negative answer to the question: do healthy adults experiment effects on well-being due to short-term exposure to UMTS signals with no carry-over effects?

Comment. This is not exactly the question answered by TNO study.

Differences between the two studies (1)(2)(3)

Exposed persons

The two studies consider two groups of persons.

TNO study

One group is composed of persons who had expressed health complains that they attributed to their sensitivity to electromagnetic fields. The other group is not.

CH study

One group is composed of persons that considered themselves as sensitive to electromagnetic fields, with complains or not. The other group is not.

Number

TNO study

Total number of persons is 72.

CH study

Total number of persons is 117.

Age

TNO study

Between 18 and 75 years.

CH study

Between 20 and 60 years.

Not accepted

TNO study

Nervous system diseases, epilepsy, claustrophobia, psychiatric treatment within six months before the start, use of psychoactive drugs within two weeks before, pacemaker, audio-equipment.

CH study

Previous head wounds, neurological or psychiatric illness, usual use of narcotics or psychoactive drugs within six weeks before, pacemaker, audio-equipment, smokers, people with complains about consequences of chronic illness, pregnancy, insomnia, average alcohol consumption of more than 10 glasses per week, caffeine takers of more than 450 mg caffeine per day (about 3 cups), long-distance flight of more than three time-zones within a month before.

Comment. The exposed populations are rather different; there is more homogeneity in CH study.

Exposure

TNO study

Two out of three different kinds of signals: GSM 900 MHz, GSM 1800 MHz, UMTS 2100 MHz, with equal distribution of each combination.

There are 36 persons per group; hence, each signal was used for 24 persons.

Each person was also submitted to a sham exposure.

Total is three different exposures per person.

Field amplitude is 0.7 V/m for each GSM signal and 1 V/m for UMTS.

CH study

No GSM exposure.

Exposure to UMTS 1 V/m and 10 V/m, and sham exposure as well.

Total is three different exposures per person.

Time intervals between exposures

TNO study

For each person, all exposures took place in one single day.

Exposure lasted long enough to complete the cognitive-function tests, about 20-25 minutes.

Time-interval between two sessions: about 20-25 minutes.

Each session could start 45 minutes after the start of the previous session.

CH study

Authors considered that the TNO procedure could induce carry-over effects.

This is why they used a time-interval of one week, with about the same time of the day for every person.

Duration of exposure was about 45 minutes.

List of questions**TNO study**

They used a list that was an adapted version of a series of questions made to investigate high blood pressure, with effects measured over a long period of time.

CH study

They used both the TNO list for comparison and another list.

Cognitive functions**TNO study**

The cognitive functions are tested by the TNO-developed Taskomat that comprises five different computer-controlled memory and reaction tests: reaction time, memory comparison, visual selective attention, double task, and filtration of irrelevant information.

The series of tests is done once in each session.

CH study

Out of the five TNO tests, only the visual selective attention is made.

Two other reaction-tests are added: a simple reaction test and a two-choice reaction test, and a memory test, respectively.

The series of tests is done twice in each session.

Statistical analysis**TNO study**

The data were analyzed using ANOVA (Analysis Of Variance). This takes all variables into account: exposure (sham, GSM900, GSM1800, UMTS), group (with and with no complains), session (first, second, third), ranking (18 different rankings possible), place of the person in ranking (36 in each of the two groups), forenoon or afternoon.

ANOVA assumes a normal distribution. This was not always the case. Hence, others methods were also used for analyzing the data (Wilcoxon, median test).

CH study

The analysis was made separately for the two groups, using linear mixed models. The variables are: exposure (sham, 1 V/m, 10 V/m) and time (week 1, 2, 3).

The series of tests for the exposure is taken as variable for the analysis of the cognitive functions.

Extreme results (larger than 4x the median deviation) are not taken into account.

When the data are not normally distributed, Wilcoxon is used.

Cognitive results**CH study**

No effect on the reaction speed was measured in any of the two groups.

No effect on the precision to perform a test was measured in any of the two groups.

References

- (1) Zwamborn APM, Vossen SHJA, Leersum BJIM, *et al.*, Effects of global communication system radiofrequency on well being and cognitive functions of human subjects with and without subjective complaints, *TNO Physics and Electronics Laboratory*, The Hague, FEL-03-C148, 2003, 89 pp.
- (2) Regel SJ, Negovetic S, Roosli M, *et al.*, *Environ. Health Perspec.*, 2006, 114, 1270-1275.
- (3) Gezondheidsraad, The Netherlands, UMTS en gezondheid, 062-3871, 13 October 2006, 17 pp.
- (4) Decat G, TNO Technical Report FEL-03-C148, About the Statistical and Electromagnetic Experimental Design, 25 May 2004, 1 p.
- (5) Vander Vorst A, TNO Technical Report FEL-03-C148, About the Electromagnetic Experimental Design, 8 May 2004, 1 p.

Annexe 6. Biological effects of modulated microwave radiation: the microwave hearing effect. Adang D. [12 avril 2007].

6.1. Description

The microwave hearing effect has been described in detail by J. Lin.

The phenomenon of an auditory sensation induced in humans and animals by exposure to microwaves is a well established effect [1][2]. This so called microwave hearing effect is related to the hearing by humans and laboratory animals of short pulses of modulated microwave exposure at high peak power. Depending on the pulse duration, pulse repetition frequency and the rate of energy absorption, high power microwave exposure can lead to rapid expansion of tissue in the head. The effect has been observed for radio frequency exposures across a wide range of frequencies (430-3000 MHz). It can arise, for example, at an incident energy-density threshold of 400 mJ/m² for pulses of duration less than 30 µs at 2.45 GHz, incident on the head of a human subject. And, it has been shown to occur at a Specific Absorption Ratio (SAR) threshold of 1.6 kW/kg for a single 10-µs-wide pulse of 2.45 GHz microwave energy impinging on the head [3]. A single microwave pulse can be perceived as an acoustic click or knocking sound and a train of microwave impulses to the head can be sensed as an audible tune, with a pitch corresponding to the pulse repetition rate. The auditory response is produced primarily by the energy delivered within the first 50 µs of the leading edge of each successive microwave pulse.

6.2. Mechanism

The hearing of microwave pulses is a unique exception to the airborne sound energy normally encountered in human auditory perception. The hearing apparatus responds to acoustic or sound pressure waves in the audible frequency range, but the hearing of microwave pulses involves electromagnetic waves, with frequencies from hundreds of megahertz to tens of gigahertz. Since electromagnetic waves are seen but not heard, the report of auditory perception of microwave pulses was at once astonishing and intriguing. Moreover, it stood in sharp contrast to the responses associated with continuous-wave microwave exposure. Initially, it had been interpreted to imply direct microwave interaction with the neurophysiologic system [4]. The scientific community now knows that the microwave auditory phenomenon does not arise from an interaction of microwave pulses directly with the auditory nerves of neurons along the auditory neurophysiological pathway of the central nervous system. Instead, the microwave pulse, upon absorption by soft tissues in the head, launches a thermoelastic wave of acoustic pressure that travels by bone conduction to the inner ear. There, it activates the cochlear receptors, via the same process involved for normal hearing.

The microwave auditory effect is the most widely accepted biological effect of human and animal microwave exposure – aside from tissue heating – with a known mechanism of interaction: the thermoelastic theory of the microwave-induced acoustic pressure waves in the head. However, there is little data regarding effects on the inner-ear hearing apparatus or the central nervous tissue from exposure to these microwave pulses. Any health effect that may attend exposure over a prolonged period or exposure to supra-threshold microwave pulses has not been investigated systematically. The possible health risks associated with mobile telecommunication devices used close to the human head, and in particular, the effects on the inner ear and hearing of users, have been recommended for further investigation by several scientific research groups.

6.3. Cochlear response

The cochlear response, a signature of mechanical disturbances in the cochlear hair cells, has been demonstrated in cats and guinea pigs subjected to microwave-pulse exposure [5]. These results confirmed that the microwave auditory effect is mediated by a physical transduction mechanism, initiated outside the inner ear, and involves mechanical displacement of biological tissues. Among the several transduction mechanisms suggested that involve mechanical displacement, thermoelastic expansion has emerged as the most effective mechanism. The pressure waves generated by thermoelastic stress in brain tissue are found to be one or three orders of magnitude greater than any other candidate mechanism. It has been shown that the minuscule (10⁻⁶°C) but rapid rise in temperature in the head of animals and humans as a result

of the absorption of pulsed microwave energy creates a thermoelastic expansion of tissue matter, which then launches an acoustic wave of pressure that travels to the cochlea, and is detected by the hair cells there [6].

6.4. **Experimental research**

The acceptance of the microwave-pulse-induced auditory effect is essentially based on two independent kinds of experimental research: discrimination response in behavioural tests and electrophysiological recordings [1]. Food-deprived rats trained to respond to an acoustic signal respond to microwave pulses at the same repetition frequency as the acoustic signal [7]. This is the strongest behavioural evidence that rats are sensitive to modulation frequency and that they interpret these stimuli similar to the manner in which they would sound. The rats were trained to make a nose-poking response to obtain food only during presentation of an acoustic cue (7.5 kHz acoustic pulse, 3 μ s wide, 10 pps). After the behaviour was conditioned to the acoustic stimulus, 900 MHz microwave pulses (peak power density of 150 kW/m², 10 μ s, 10 pps) were substituted for the acoustic stimulus. The rats demonstrated a continued ability to perform correctly (at 85 %-90 % level) on the discriminative task when presented with either the acoustic or the pulsed microwave cues.

Chou and Guy determined that: for pulses shorter than 30 μ s, microwave hearing depend on the energy pulse; for pulses between 50 and 500 μ s, microwave hearing depends on peak power [8]. Thermal expansion due to the absorption of electromagnetic energy can produce strains in the absorbing medium, leading to the production of a stress wave that propagates away from the heated region. Analysis showed that, for single long pulses, the induced stress wave is a function of peak power density; for shorter pulses, it is a function of the product of peak power density and pulse width (or energy per pulse) [9]. Foster and Finch [10] used a sensitive hydrophone to demonstrate that 2-to 27- μ s pulses of 2.45 GHz radiation produced in distilled water. They found that, for short pulses, the intensity of the pressure wave recorded within a band width corresponding to audible sound depends on energy per pulse. For longer pulses, the significant parameter is peak power.

Theoretical results indicate that there is an optimal microwave pulse width for the conversion of microwave to acoustic energy which varies with the size of the sphere (model of the human head). For a 7-cm radius sphere, the smallest optimal pulse width is 5 μ s [11].

6.5. **Cellular phone**

The SAR threshold of 1.6 kW/kg is about 1000 times higher than that allowable by the IEEE standards for cellular mobile telephones, which is 1.6 W/kg in 1 g of tissue. It has never been reported in the scientific literature that the microwave hearing effect has been provoked in the case of a cellular phone.

The above described auditory effect of microwaves is not known to cause any direct adverse health effect. On the other hand, it is obvious that in certain situations the onset of a sudden noise could distract or startle a person from performing a vital task so as to cause a dangerous situation. It is always important to prevent such nuisance.

6.6. **References**

- [1] J. Lin, "Auditory Perception of Pulsed Microwave Radiation," in O.M. Gandhi (ed.), *Biological Effects of Electromagnetic Fields*, Englewood Cliffs, NJ, Prentice-Hall, 1990, pp. 277-318.
- [2] A. Guy, C. Chou, J. Lin, and D. Christensen, "Microwave Induced Acoustic Effects in Mammalian Auditory Systems and Physical Materials," *Annals of New York Academy of Sciences*, 247, 1975, pp. 194-218.
- [3] J. Lin, "Hearing Microwaves: the Microwave Auditory Phenomenon", *Antennas and Propagation Magazine*, IEEE, 43 (6), 2001, pp. 166-168.
- [4] A. Frey and R. Messinger, "Human Perception of Illumination of Pulsed UHF EM Energy," *Science*, 181, 1973, pp. 356-358.
- [5] J. Lin, "Further Studies on the microwave Auditory Effect," *IEEE Transactions on Microwave Theory and Techniques*, MTT-25, 1977, pp. 936-941.
- [6] J. Lin, "On Microwave-Induced Hearing Sensation," *IEEE Transactions on Microwave Theory and Techniques*, MTT-25, 1977, pp. 605-613.

- [7] A. Johnson, D. Meyers, A. Guy, Lovely R. and R. Galambos, "Discriminative control in Appetitive Behavior by Pulsed Waves", *HEW Publ. FDA77-8010*, U.S. Department of Health, Education and Welfare, Rockville, MD, 1976, p. 238.
- [8] C-K. Chou and A. Guy, "Microwave-induced auditory responses in guinea pigs: relation of threshold and microwave-pulse duration", *Radio Sci.*, 14(6S), 1979, p.193.
- [9] L. Gournay, "Conversion of electromagnetic to acoustic energy by surface heating", *J. Acoust. Soc. Am.*, 40, 1966, p. 1322.
- [10] K. Foster and E. Finch, "Microwave hearing: evidence for thermoacoustic auditory stimulation by pulsed microwaves", *Science*, 185, 1974, p. 256.
- [11] J. Lin, "Microwave hearing sensation", *IEEE Trans. Microwave Theory Tech.*, 25, 1977, p. 605.

Annexe 7: Conditions for demodulating a microwave signal: Application to human body. Vander Vorst A. [septembre 2007].

*Demodulation consists in separating modulation **components** – the **signal** - from the carrier wave
This process recovers the **information** transported the wave*

Statement 1

A linear circuit does not demodulate a modulated wave

A linear circuit is composed of linear elements, series, parallel, or in combination

Proof

Superposition Principle applies to linear circuits

*The response of a linear circuit to the sum of several inputs
is equal to the sum of the individual responses of the circuit to each individual input, respectively*

Assumptions

1. Input is a voltage while response is a current
2. Input is a sum of 2 voltages at different frequencies, ω and $\omega - \Delta\omega$, respectively

Call R the response function of the circuit

Note: assuming R identical at the two different input frequencies is a simplification, because the response at these different input frequencies is most certainly not exactly the same at the two frequencies

Input is: $V = V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t$

Individual responses are:

$$I_1 = R V_1 \sin \omega t$$

$$I_2 = R V_2 \sin (\omega - \Delta\omega)t$$

Use Superposition Principle

Response is: $I = I_1 + I_2 = R [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t]$

Frequencies at input are ω and $\omega - \Delta\omega$

The same frequencies are in the response – with components not separated from each other

A linear circuit does not demodulate a modulated wave

* * *

Statement 2

A non-linear circuit demodulates a modulated wave

Proof

Superposition Principle is not valid anymore

Assumptions, same as for Statement 1

1. Consider a simple case of a non-linear circuit: a non-linear conductance - the inverse of a resistance
Hence, input is a voltage while response is a current

2. Input is a sum of 2 voltages at different frequencies, ω and $\omega - \Delta\omega$, respectively

Input is: $V = V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t$

The current I flowing through a non-linear conductance, as a result of a voltage across it, is:

$$I = aV + bV^2 + \dots (cV^3 + \dots)$$

Note: assuming $a, b, (c, \dots)$ identical at the different input frequencies is a simplification, because the response at different input frequencies is most certainly not exactly the same at the different frequencies

Response is equal to:

$$\begin{aligned} I &= a [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t] + b [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t]^2 + \dots \\ &= a [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t] \\ &\quad + b [V_1^2 \sin^2 \omega t + 2 V_1 V_2 \sin \omega t \sin (\omega - \Delta\omega)t + V_2^2 \sin^2 (\omega - \Delta\omega)t] \\ &\quad + \dots \\ &= a [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t] \\ &\quad + b \left\{ V_1^2 (1/2)(1 - \cos 2\omega t) + 2 V_1 V_2 (1/2)[\cos (\omega - \omega + \Delta\omega)t - \cos (\omega + \omega - \Delta\omega)t] \right. \\ &\quad \left. + V_2^2 (1/2)[1 - \cos 2(\omega - \Delta\omega)t] \right\} \\ &\quad + \dots \\ &= a [V_1 \sin \omega t + V_2 \sin (\omega - \Delta\omega)t] \\ &\quad + b \left\{ V_1^2 (1/2)(1 - \cos 2\omega t) + 2 V_1 V_2 (1/2)(\cos \Delta\omega t - \cos [(2\omega - \Delta\omega)t] \right. \\ &\quad \left. + V_2^2 (1/2)[1 - \cos 2(\omega - \Delta\omega)t] \right\} \\ &\quad + \dots \end{aligned}$$

Input frequency components are $\omega - \Delta\omega$ and ω , respectively

Response frequency components are $0, \Delta\omega, \omega - \Delta\omega, \omega, 2\omega - \Delta\omega,$ and $2(\omega - \Delta\omega), \dots$ respectively

If $\Delta\omega$ is a very small frequency

component at frequency 0 is a DC-component

component at $\Delta\omega$ is a very low frequency component - ELF

components at $\omega - \Delta\omega$ and ω are very close to ω

components at $2\omega - \Delta\omega, 2(\omega - \Delta\omega),$ and 2ω are very close to 2ω

It is proven that non-linearity $bV^2 + \dots$ separates frequency components, hence demodulates

Non-linear terms demodulate DC-component and ELF component $\Delta\omega$

* * *

Can a living body demodulate DC- and ELF-components contained in a microwave signal?**Only one condition** has to be met: **the living body must exhibit non-linearity***preferably in volume close to skin (3 skin depths at 900 MHz are about 4.5 cm)*

Non-linearity should be:

either a constitutive part of the layers composing the body

e.g. conductivity of muscle tissue, ...

or in boundary conditions at interfaces separating different elements

*e.g. skin-muscle, skin-bone, bone-muscle, ...***The good question: is there such non-linearity present in the human body?**A **very general argument** is in observing that all the senses of the human being are non linear*non linearity is most probably present everywhere***Would such demodulation produce ELF components in the body at an appreciable level?**

No idea!

Could this level produce a measurable effect, for instance be a cause of discomfort?

No idea!!

Could it be pathogenic?

No idea!!!

Personal conclusions

Analog microwave signals have not raised emotions or hypersensitivity symptoms in human beings.

Numerical signals have.

Numerical signals contain ELF components.

I consider as an interesting research assumption to investigate the possibility of direct demodulation of modulated microwaves by components of the human being.



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 Government) [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 (FIELD COP 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 ($E^2_{\text{peak}}/\sqrt{2}$) 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/m ²)	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:

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

with :

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

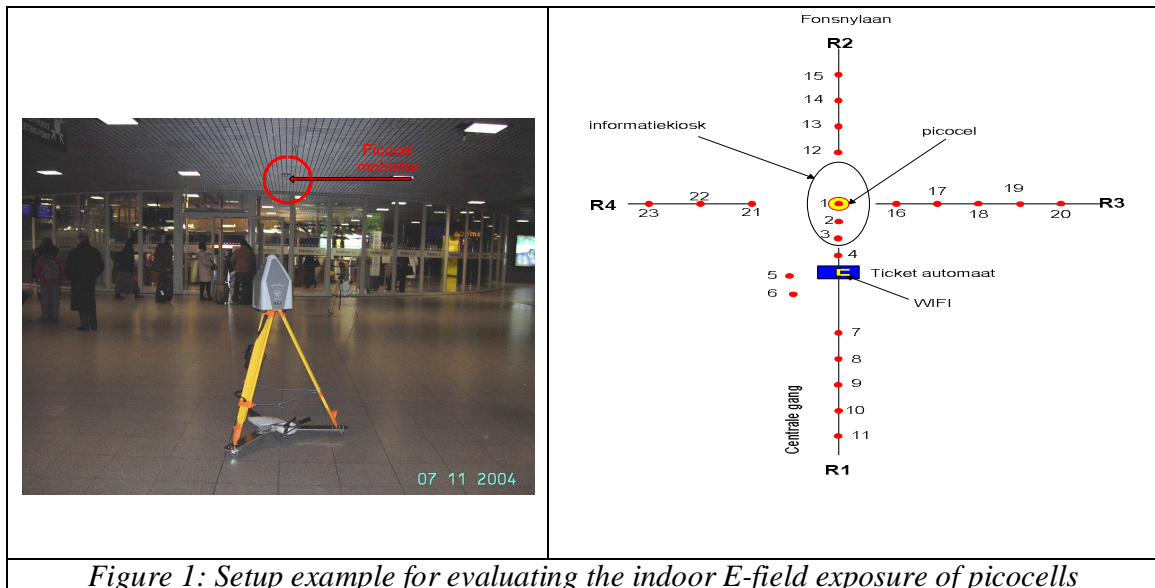
E^2_{i-ref} = square of the reference E-field level at frequency i

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.



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.

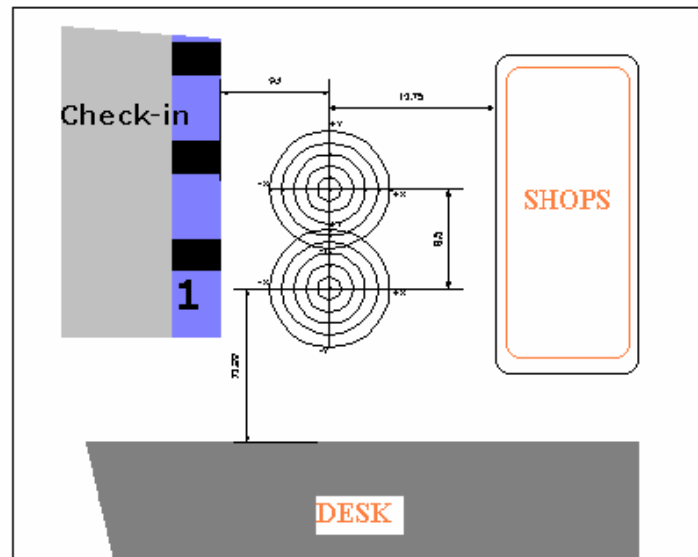


Figure 2: Measurement scheme in the departure hall

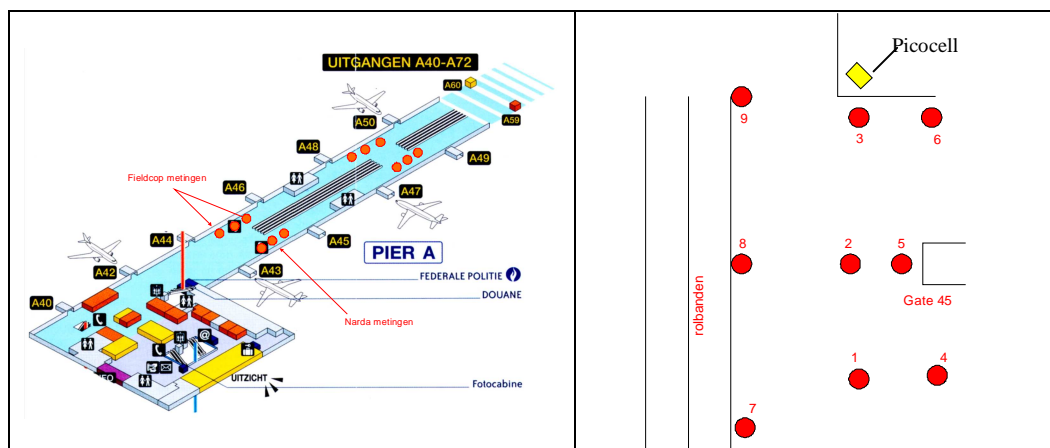


Figure 3: Measurement scheme in the PIER A for evaluating the E-field distribution in the waiting rooms at the different gates

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.

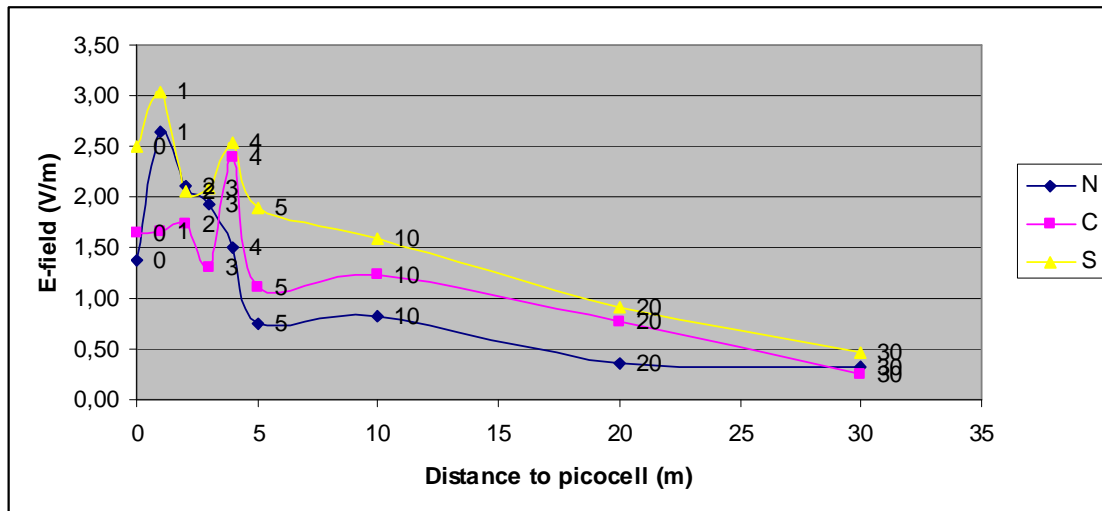


Figure 5: E-field versus distance in the Brussels railway stations North (N), Central (C) and South (S)

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.

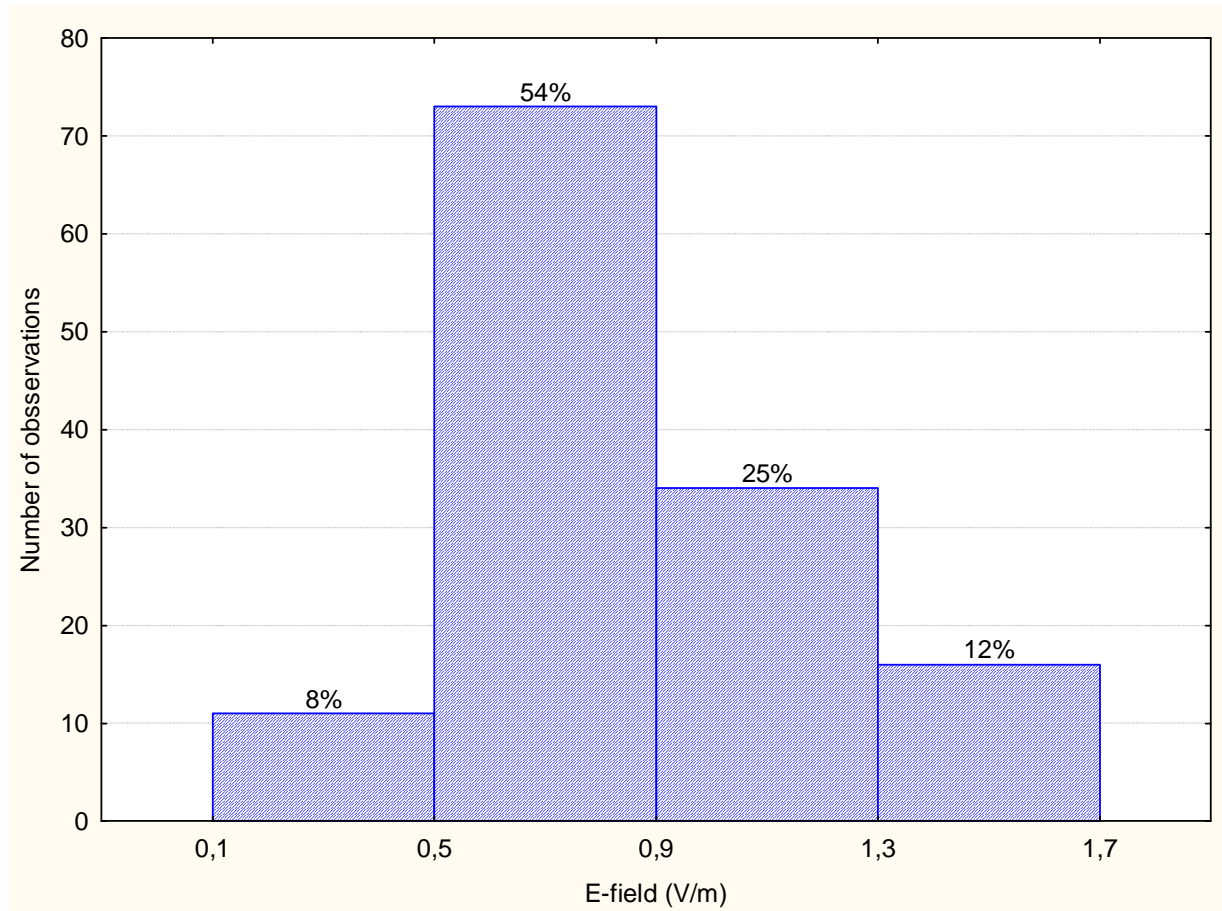


Figure 6: Histogram of RMS E-field

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.

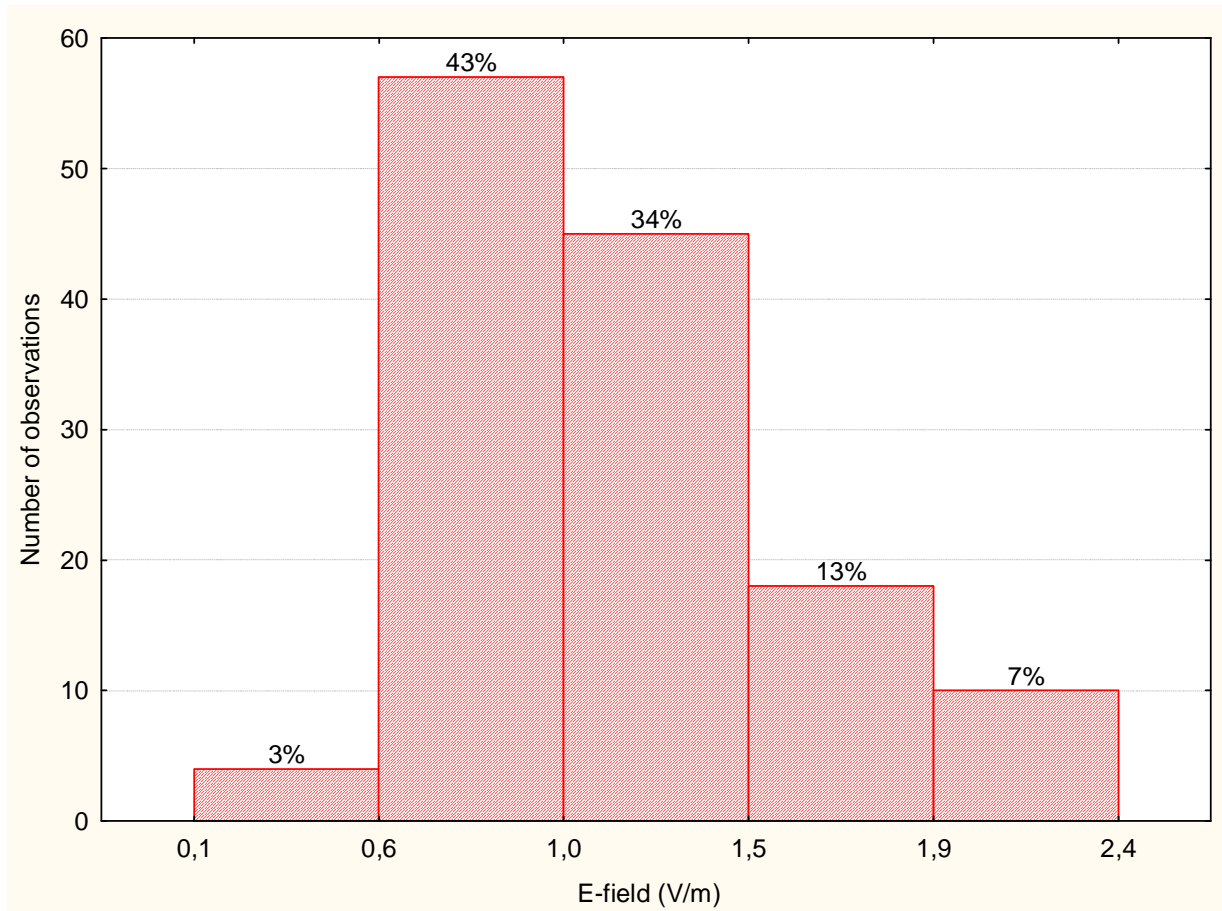


Figure 7: Histogram of the peak E-field

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.

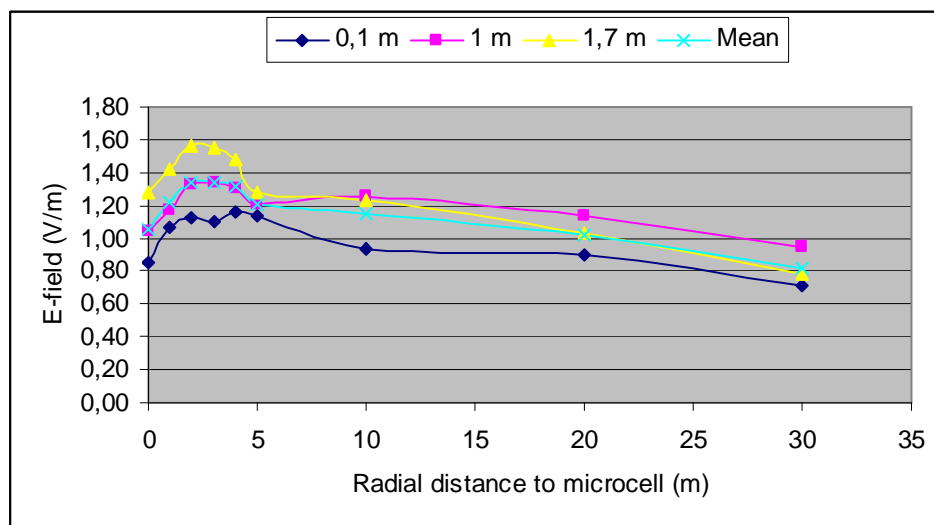


Figure 8: Relation between E-field strength, measurement height and radial distance to microcell

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.

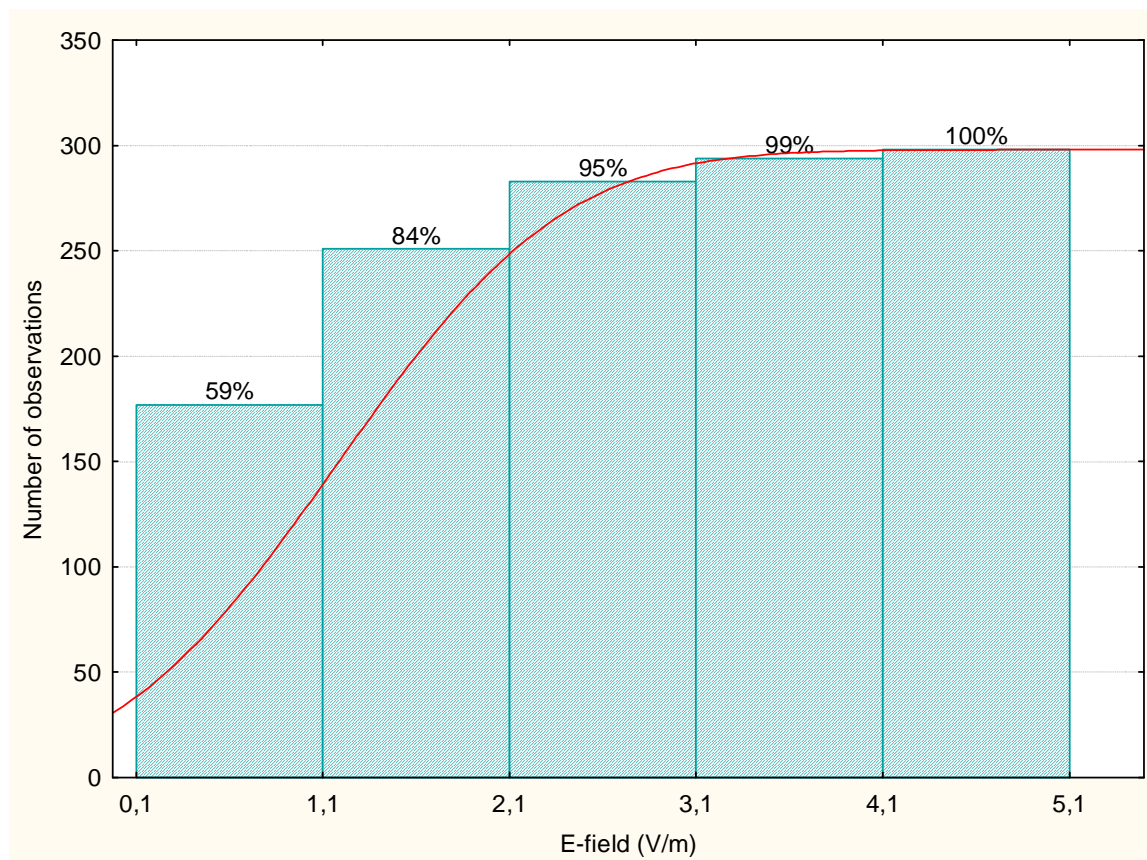


Figure 9: Cumulative distribution of the E-field strength in the shopping streets

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 μ T.

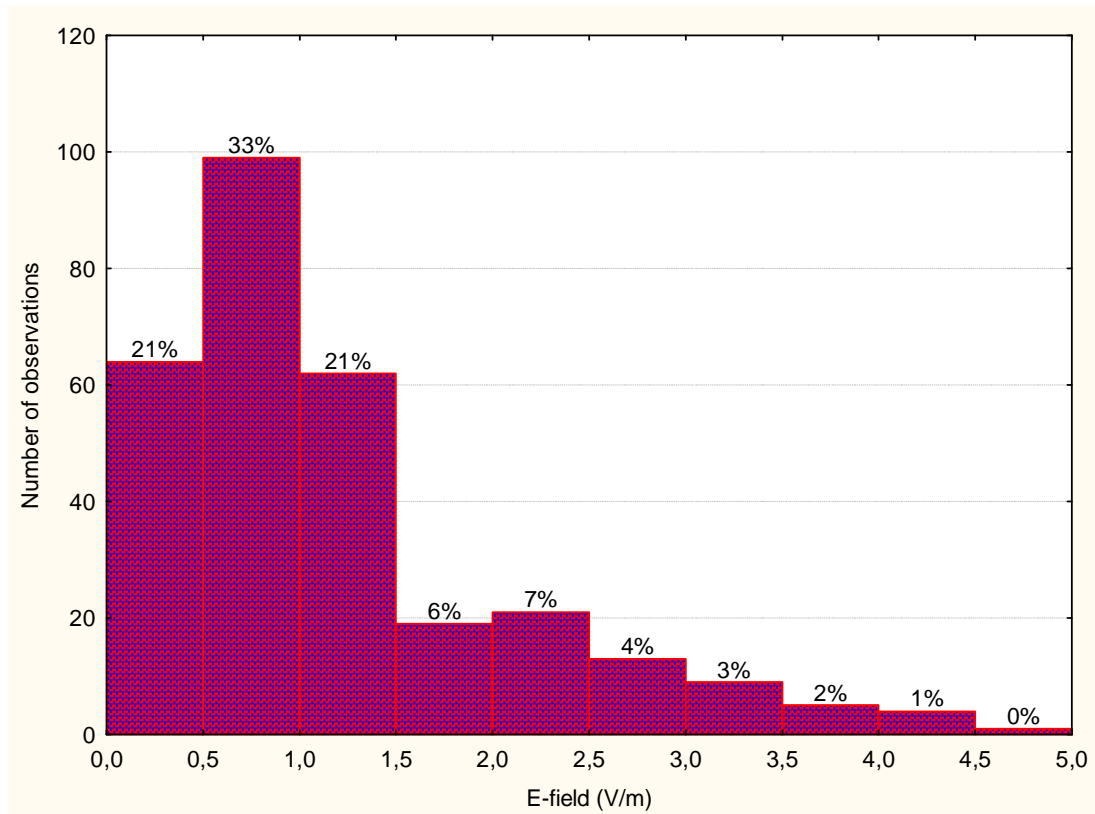


Figure 10: Distribution histogram of the RF-exposure in the shopping streets (worst case situation)

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).

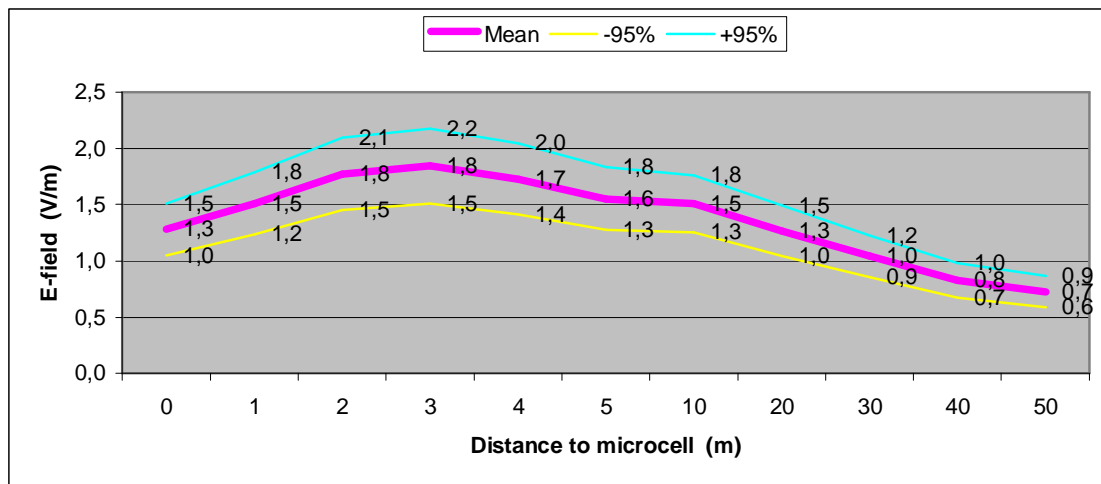


Figure 11: average RF-exposure recorded in 30 randomly selected streets

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 B. (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 Staatsblad 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 D. (12/04/ 2007) Summary for the working group modulation: Biological effects of modulated microwave radiation: the microwave hearing effect
- [6] Vanderstraeten J. (18/05/2007) Summary for the working group modulation: Effets biologiques des *ELF-amplitude modulated microwaves*

Algemene verspreiding

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Elektrisch veld van DECT basisstation en handset

Gilbert Decat en Leo Deckx

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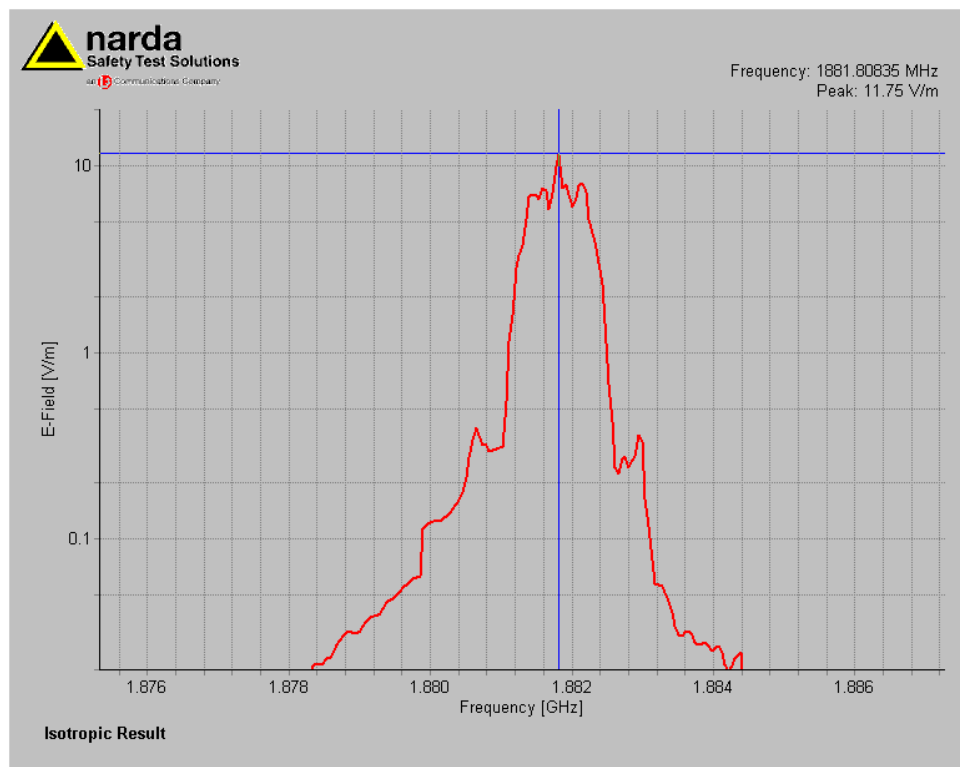
1 SPECIFICATIE VAN HET DECT SIGNAAL

De set waarvan de sterkte van het elektrisch veld (E-veld) gemeten werd was een DECTGIGSET A240 (Siemens) met volgende specificaties:

- Centrale frequentie: 1880 – 1900 MHz
- Max vermogen 250 mW
- Puls bij 100 Hz of om de 10 msec. een piek (zie frequentieanalyse signaal) van 0,4 msec.
- Gemiddeld vermogen 10 mW

2 SPECTRUM VAN HET DECT-SIGNAAL

Error! Reference source not found. toont de piekwaarde van het E-veld (11,75 V/m) bij 1881,808 MHz van het elektrisch veld dat tijdens het telefoneren tegen het basisstation gemeten werd.

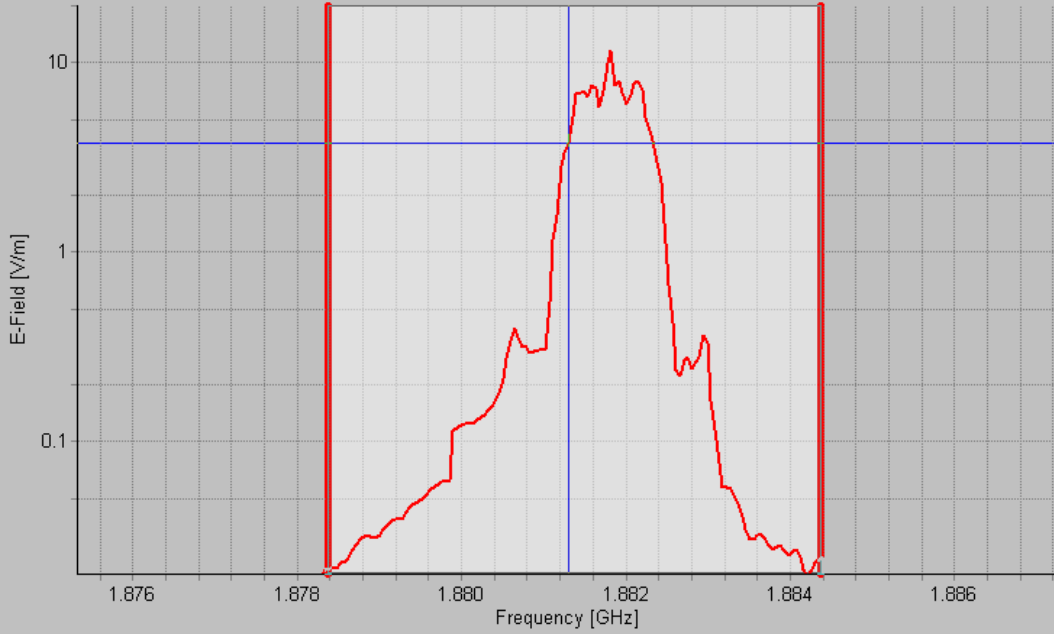


Figuur 1: Piekveldsterkte van DECT-sigitaal

Figuur 2 toont de sterkte van het E-veld (22,97 V/m) van de geïntegreerde frequentie van het DECT-sigitaal dat tijdens het telefoneren tegen het basisstation gemeten werd.

Frequency: 1881.30312 MHz
Value: 3.761 V/m

Integration Minimum Frequency: 1878.37344 MHz
Integration Maximum Frequency: 1884.37344 MHz
Integration Result: 22.97 V/m



Isotropic Result

Figuur 2: E-veld van de geïntegreerde frequentie

3 MEETRESULTATEN

Tabel 1 toont de sterkte van het elektrische veld (E-veld) dat door middel van de Fieldcop op verschillende afstanden van het DECT basisstation gemeten werd tijdens het niet en wel telefoneren met de handset.

Tabel 1: E- veld van het DECT basisstation tijdens het telefoneren en niet-telefoneren

Meetafstand tot basisstation [m]	E-veld (V/m)					
	Tijdens het niet-telefoneren			Tijdens het telefoneren		
	Min.	Max.	RMS (6 min)	Min.	Max.	RMS (6 min)
0	0,03	35,08	2,604	0,03	43,78	8,375
0.5	0,0	10,92	0,90			
1	0,0	3,43	0,28			
2	0,03	2,11	0,2			

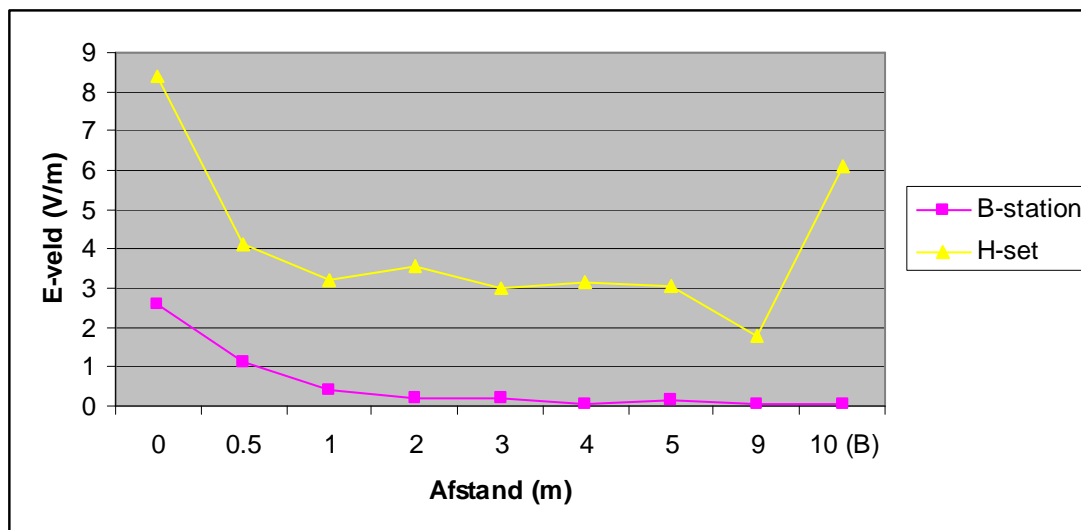
Tabel 2 toont de sterkte van het E-veld dat door middel van de Fieldcop op verschillende afstanden van de handset gemeten werd tijdens het niet en wel telefoneren met de handset.

Merk op dat in tabel 1 de afstand van het basisstation tot de meetsonde wordt gegeven, terwijl in tabel 2 de afstand tussen de handset en het basisstation gegeven wordt. In tabel 2 gaat het om de evaluatie van de veldsterkte aan het oor tijdens het telefoneren op verschillende afstanden van het basisstation terwijl het in tabel 1 gaat om de evaluatie van het de blootstelling aan het E-veld i.f.v. de afstand tot het basisstation wanneer niet en wel getelefoneerd wordt.

Tabel 2: Elektrisch veld door handset geproduceerd aan het oor tijdens het telefoneren en niet-telefoneren

Afstand tussen handset en basisstation [m]	Elektrisch veld (V/m)					
	Van basisstation tijdens het niet-telefoneren			Van handset tijdens het telefoneren		
	Min.	Max.	RMS (6 min)	Min.	Max.	RMS (6 min)
0	0,03	35,08	2,604	0,03	43,78	8,375
0.5	0,03	21,52	1.124	0,03	40,00	4,138
1	0,03	5,00	0,418	0,03	40,50	3,181
2	0,03	4,22	0,215	0,03	39,67	3,578
3	0,03	2,65	0,194	0,03	37,36	2,994
4	0,00	1,53	0,076	0,03	39,33	3,147
5	0,03	4,20	0,157	0,03	37,00	3,039
9	0,03	0,34	0,039	0,03	34,06	1,773
10 buiten	0,03	0,05	0,034	0,03	35,52	6,112

Figuur 3 illustreert enerzijds het verloop van de effectieve waarde (rms) van het E-veld i.f.v. de afstand tot het basisstation en anderzijds van het E-veld aan het oor op verschillende afstanden tussen de handset en basisstation.



Figuur 3: E-veld(rms) van basisstation (B-station) en handset tijdens telefoneren

Voor wat het basisstation betreft leiden we uit tabel 2 en figuur 3 af dat het E-veld tijdens het bellen afneemt in functie tot het basisstation. Betreffende de handset kunnen we stellen dat wanneer de handset tijdens het telefoneren op het basisstation staat (afstand 0 m) de gemeten veldsterkte bestaat uit de som van de grootte van het E-veld dat respectievelijk door het

basisstation en de handset uitgezonden wordt. Vanaf een afstand van 0,5 m tot 5 m tussen het basisstation en de handset is het E-veld aan het oor tijdens het bellen betrekkelijk constant. Bij 9 m valt het E-veld om onverklaarbare redenen tot minder dan 2 V/m maar wanneer buiten gemeten wordt (afstand tussen station en handset 10 m) stijgt het E-veld omwille van het grotere vermogen dat door de handset moet ontwikkeld worden om het basisstation te bereiken tot 6 V/m.

4 MEETRESULTATEN VERSUS BELGISCHE NORM

Tabel 3 toont de blootstellingslimieten waarmee de meetresultaten vergeleken worden;

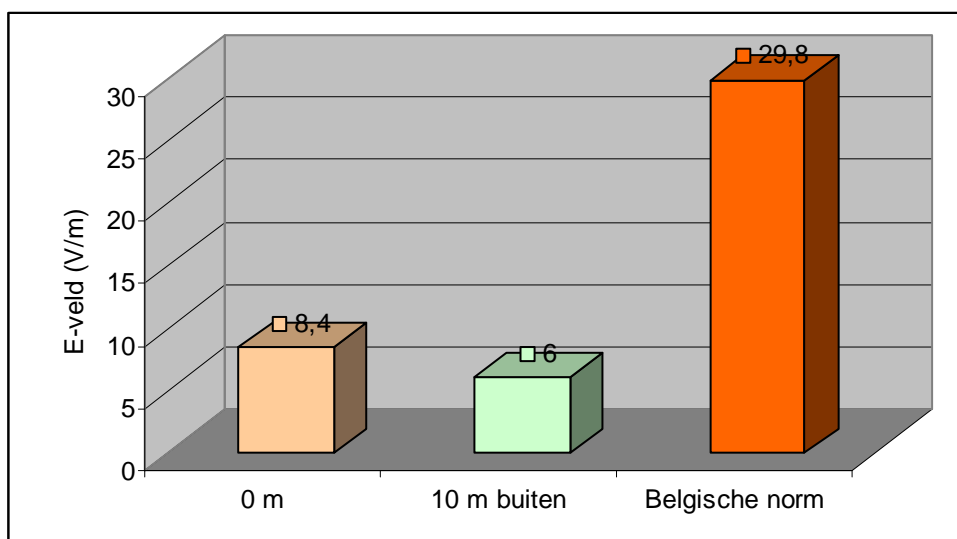
Tabel 3: Belgische blootstellingsnorm voor EMV-en tussen 10 MHz en 10 GHz

Frequentie	Elektrisch veld (RMS) (V/m)
10 MHz tot 400 MHz	13,7
400 MHz tot 2 GHz	$0,686 \cdot f^{1/2}$
2 GHz tot 10 GHz	30,7

** f wordt uitgedrukt in MHz*

Bij toepassing van $0,686 \cdot f^{1/2}$ bij een DECT frequentie van 1882 MHz (zie figuur 1) is de RMS normwaarde waarmee de gemeten sterkten van het E-veld moeten vergeleken worden 29,76 V/m

Figuur 4 illustreert de vergelijking van de Belgische norm met de sterkste rms-velden (zie tabel 2 en figuur 3) die aan het oor gemeten werden.



Figuur 4: Vergelijking grootste rsm-waarden met Belgische norm

5 BESLUIT

Uit figuur 4 kan besloten worden dat de sterkste rms-waarden die in deze meetcampagne gemeten werden substantieel kleiner zijn dan de limietwaarde die in de Belgische norm aanbevolen wordt in het frequentiegebied van 400 MHz tot 2 GHz. Volgens de interpretatie van de huidige norm zou de blootstelling aan het DECT-sigitaal geen gezondheidsrisico's inhouden. Deze uitspraak is alleen gebaseerd op de vergelijking tussen de norm en de effectieve waarde (rms) uitgemiddeld over 6 minuten en houdt geen rekening met de maximale veldsterkte die groter kan zijn dan de rms-waarde van de norm.

BIJLAGE: GRAFIESCHE VOORSTELLING VAN MEETRESULTATEN

De volgende reeks grafieken geven een inzicht van het E-veld dat onder verschillende omstandigheden in de centrale frequentieband van 1895 MHz met een bandbreedte van 30 van het DECT-signaal gemeten werd.

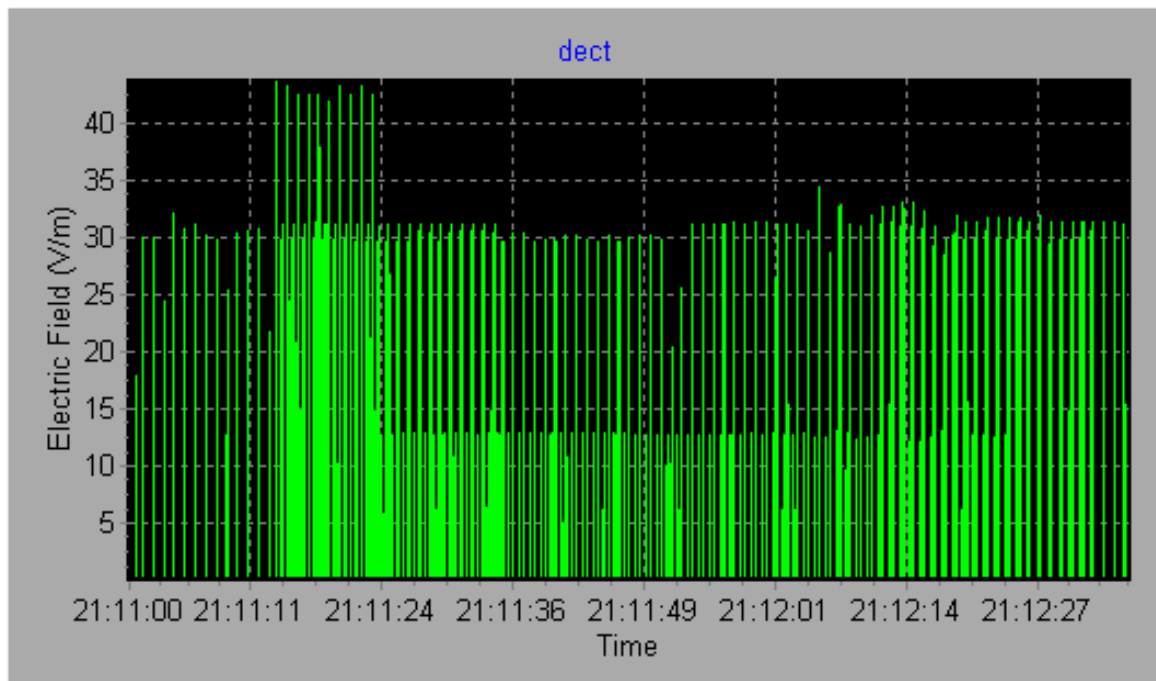
Meting 1

Base station tegen fieldcop.

Base station wordt opgebeld gedurende 1 min. Handset niet opgenomen.

Maximale waarde : 43,78 V/m

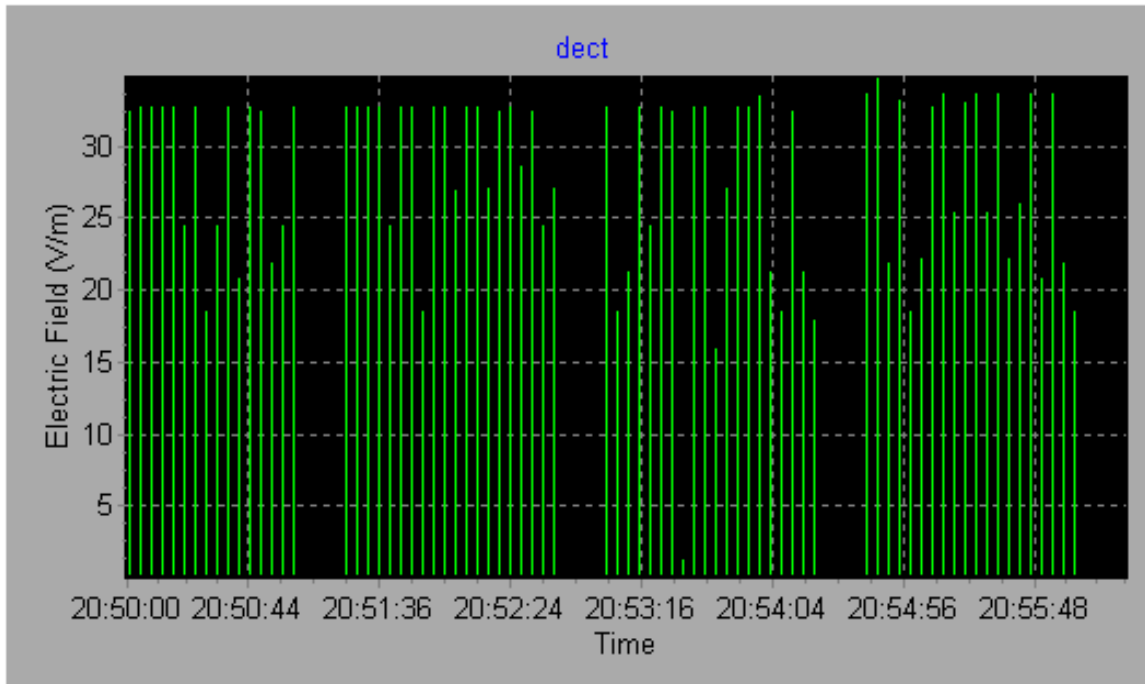
Minimale waarde: 0.03 V/m



Meting 2

Base station tegen fieldcop.
Base station wordt niet opgebeld
6 min. Handset niet opgenomen.

Maximale waarde : 35,08 V/m
Minimale waarde: 0.00 V/m



Meting 3

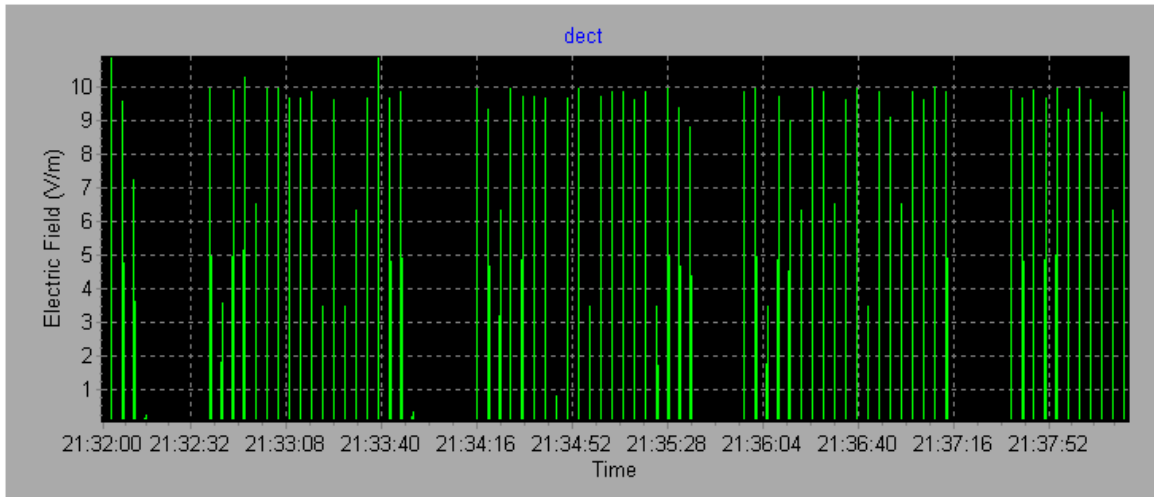
Base station 0,5 m verwijderd van fieldcop.

Base station wordt niet opgebeld

6 min. Handset niet opgenomen.

Maximale waarde : 10.08 V/m

Minimale waarde: 0.00 V/m



Meting 4

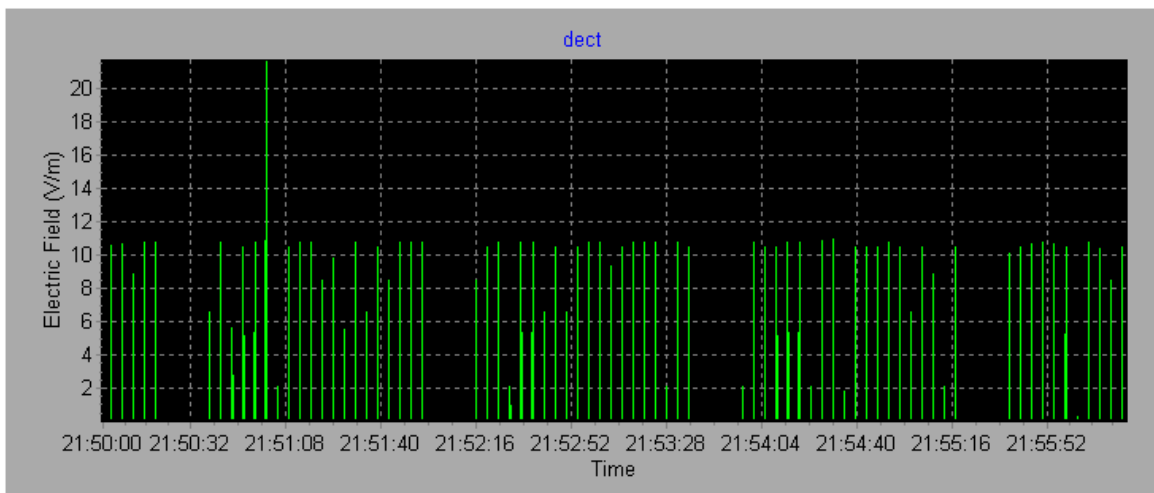
Base station 0,5 m verwijderd van fieldcop.

Base station wordt niet opgebeld

6 min. Handset 6 m verwijderd van base station

Maximale waarde : 21,68 V/m

Minimale waarde: 0.03 V/m



Meting 5

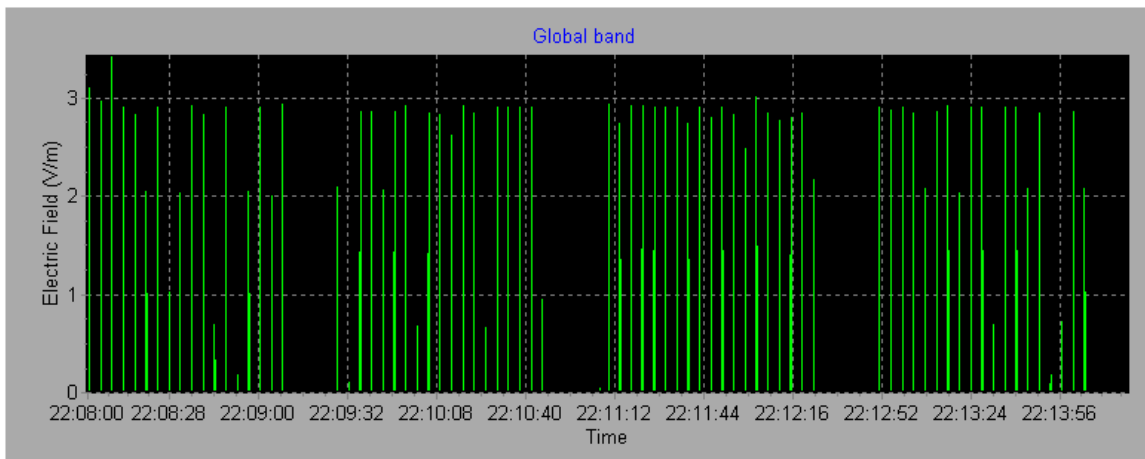
Base station 1 m verwijderd van fieldcop.

Base station wordt niet opgebeld

6 min. Handset niet opgenomen.

Maximale waarde : 3,43 V/m

Minimale waarde: 0.00 V/m



Meting 6

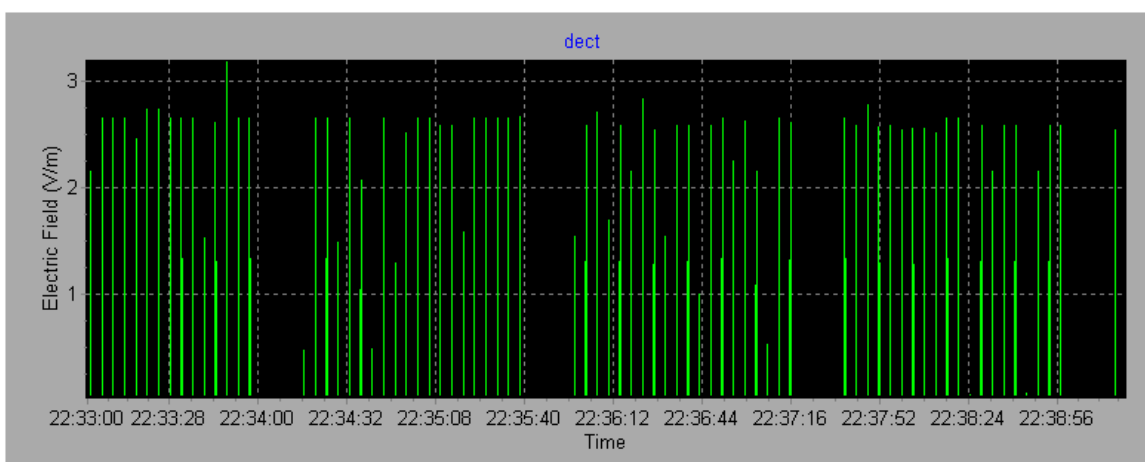
Base station 1 m verwijderd van fieldcop.

Base station wordt niet opgebeld

6 min. Handset 6 m verwijderd van base station

Maximale waarde : 3,19 V/m

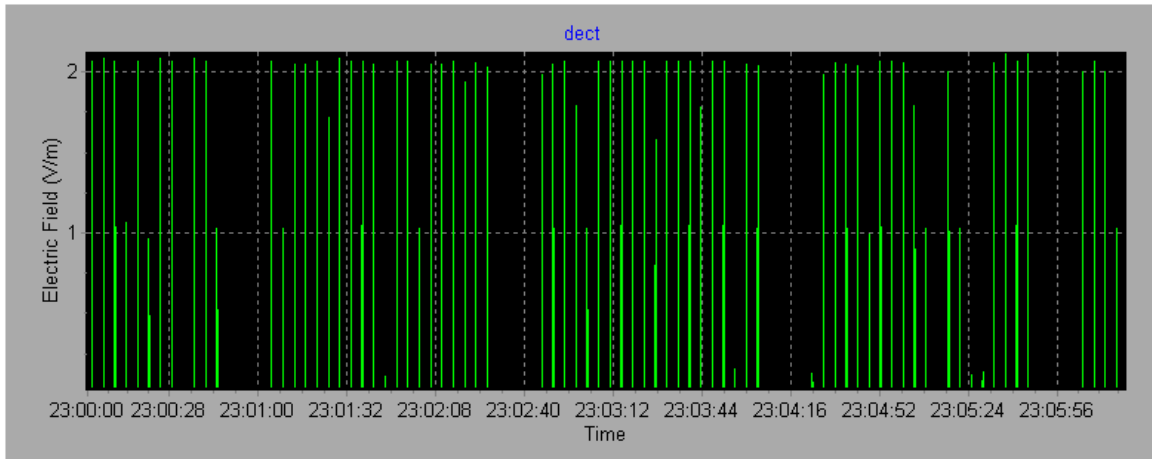
Minimale waarde: 0.03 V/m



Meting 7

Base station 2 m verwijderd van fieldcop.
Base station wordt niet opgebeld
6 min. Handset niet opgenomen.

Maximale waarde 2,11 V/m
Minimale waarde: 0.03 V/m



Meting 8

Basestation 2 m verwijderd van fieldcop.
Basestation wordt niet opgebeld
6 min. Handset 6 m verwijderd van base station

Maximale waarde : 3,19 V/m
Minimale waarde: 0.03 V/m

