Exposure caused by wireless technologies used for short range indoor communication in homes and offices

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Background:

- Rapidly increasing number of short range wireless applications and devices

  ⇒ Only very little is known about the RF-exposure due to such devices

  ⇒ Extent of combined exposure from such devices when used simultaneously is of interest

- Identification of widespread applications / devices and assessment of exposures

Project Outline:

- Survey of wireless applications and devices used in homes and offices
- Selection of most relevant applications/technologies
- Characterization of the selected applications with respect to parameters relevant for exposure assessment
- Definition of optimized of measurement methods
- Exposure assessment by measurements on samples of devices or in selected installations of the applications/technologies under scope
- Numerical computations of exposure in real scenarios
- Numerical computations of combined exposure in generic scenarios under the assumption of extensive use of wireless applications in order to estimate worst case exposures

1. Survey and selection of applications:

- **WLAN** → IEEE 802.11b,g widely used (Access Points, PCMCIA Cards, USB Sticks, ...)
- **DECT** → widely used (simple cordless phones, professional cellular phone networks)
- **Bluetooth** → widely used (headsets, computer periphery)
- HomeRF/SWAP → pushed out by WLAN and Bluetooth
- **Wireless Mouse/Keyboard (other than Bluetooth)**
- WPANs acc. to IEEE 802.15 (Zigbee, Wireless Wire Fire) → new, not yet wide spread
- **Babyphones** → widely used (different frequency bands)
- **Wireless audio transmission systems** → widely used (headphones)
- **Wireless video transmission systems** → widely used (e.g. wireless webcams)
- Remote controlled door openers → widely used, not relevant regarding resulting exposure
- Wireless alarm systems → widely used, not relevant regarding resulting exposure
- **Remote controls of toys** → widely used

2. Exposure Assessment Methods:

- **Frequency selective measurements in real scenarios installations (WLAN- and DECT-installations):** Add3D-System with Spectrum Analyzer
- **Frequency selective measurements in anechoic chamber (emissions from selected devices at different distances):** PCD or LPDA with Spectrum Analyzer
- **SAR measurements (close near field exposure from Babyphones, WLAN- and Bluetooth-Devices):** *DASY 3* System (SPEAG) with linear axis probe positioning in a flat phantom
- **Numerical computations for close near field exposure:** *SEMCAD 1.8* (SPEAG)
- **Numerical computations for far field exposure:** *Wireless Insite 2.0* (REMCOM)

3. WLAN IEEE 802.11b,g in homes and offices

Main characteristics

- Operating Frequency Range: 2400 MHz – 2483 MHz
- Transmission Mode: **IEEE 802.11b**: *Direct Sequence Spread Spectrum (DSSS),*
  occupied bandwidth per WLAN channel ≈ 22 MHz

  IEEE 802.11g: *Orthogonal Frequency Division Multiplex (OFDM)*
  (52 carrier + 4 Pilot carrier)
  occupied bandwidth per WLAN channel ≈ 17 MHz
- Medium Access : CSMA/CA (*Carrier Sense Medium Access/Collision Avoidence*)

⇒ in every channel only one station can transmit at a given time

⇒ sychronization of stations by Beacon Signal (approx. 2.5 ms long RF-Burst transmitted every 100 ms by Access Point)

- Transmit Power (EIRP): max. 100 mW EIRP

WLAN IEEE 802.11b,g in homes and offices: Measurement methods

- Frequency selective measurements (antenna + spectrum analyzer)
- **RMS-Detector** necessary
  (peak detector would overestimate exposure due to stochastic signal characteristic of DSSS and OFDM)
- Resolution bandwidth (RBW) ≤ signal bandwidth
  ⇒ correction of measured amplitude necessary
- Problem of dynamic changes of emissions due to statistical characteristic of data traffic

Possible measurement modes:

LIVE with averaging: remaining variations up to approx. 4 -6dB (1 sec. avg), peak values not assessed

CHANNEL POWER with averaging: same as LIVE

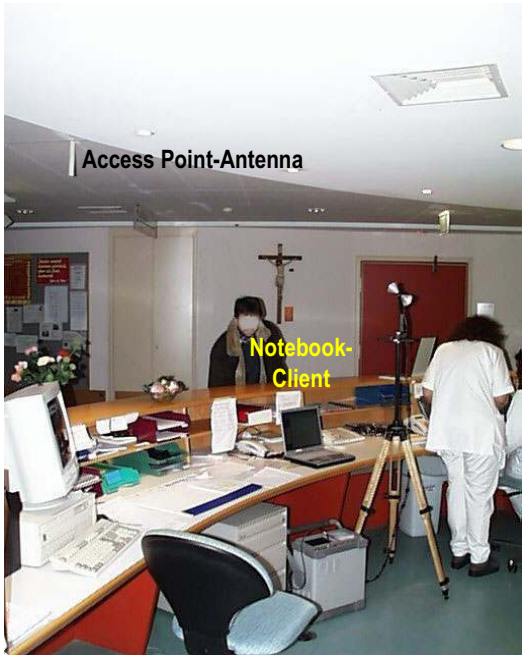
MAX-HOLD: measure for peak value, significant overestimation (up to 30 dB, depending on actual data traffic) of time averaged exposure

⇒ approach: MAX-HOLD measurements and scaling according to expected data traffic

- For **close near field exposure** (e.g. Notebook with WLAN card on the upper legs): **SAR measurements** during defined data transmission (constant crest factor)

WLAN IEEE 802.11b,g exposure assessment on typical workplaces:

Nurse support point in a Hospital

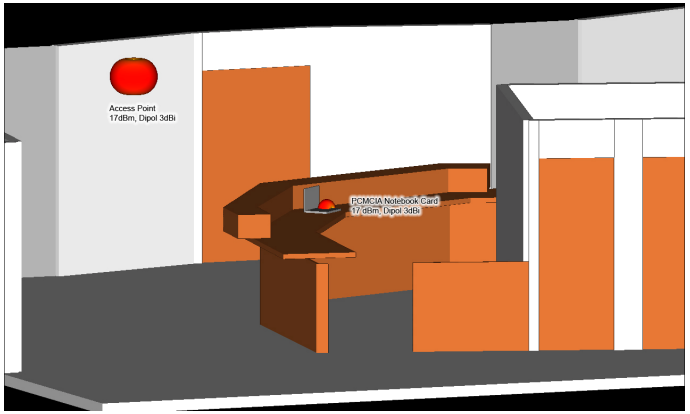


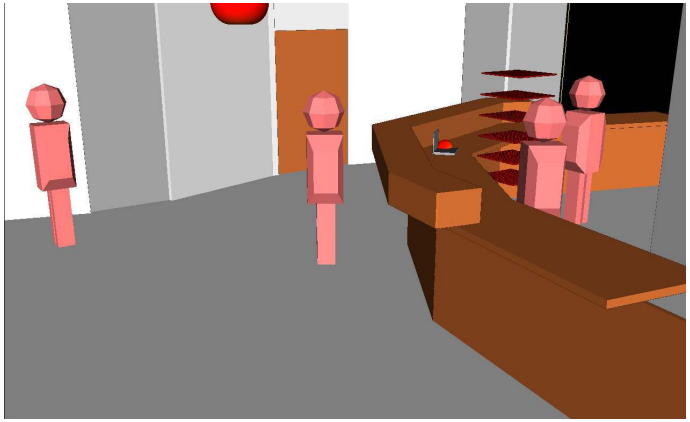
Office workplace

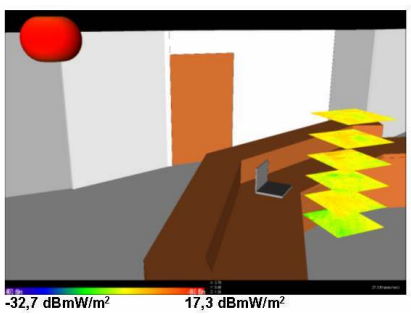
real life conditions, no control over additional clients

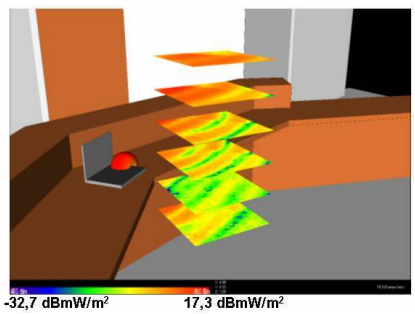
WLAN IEEE 802.11b,g exposure assessment on typical workplaces:

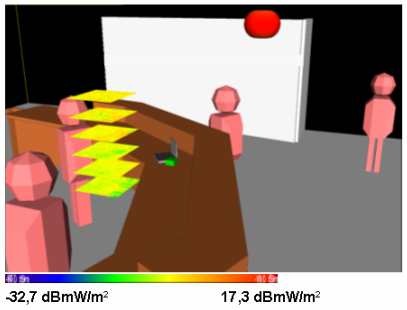
Nurse support point in a Hospital (Wireless Insite Computations)

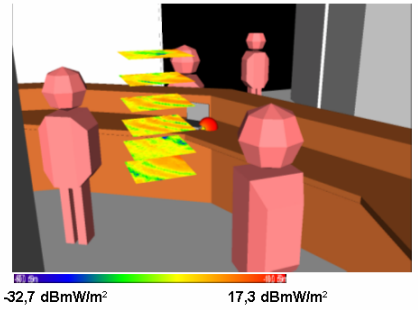








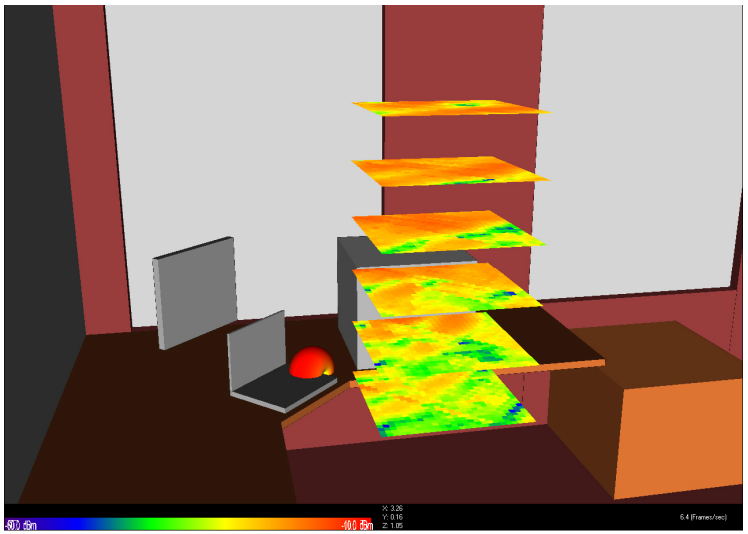




Burst peak contributions from Access Point and Client

WLAN IEEE 802.11b,g exposure assessment on typical workplaces:

Office Workplace (Wireless Insite Computations)



-32,7 dBmW/m² **17,3 dBmW/m²**

Combined exposure from Access Point and Client

WLAN IEEE 802.11b,g exposure assessment on typical workplaces:

Results Summary Far field exposure due to WLAN on typical workplaces

Spatial and temporal peak values: **5.8 – 55 mW/m²**

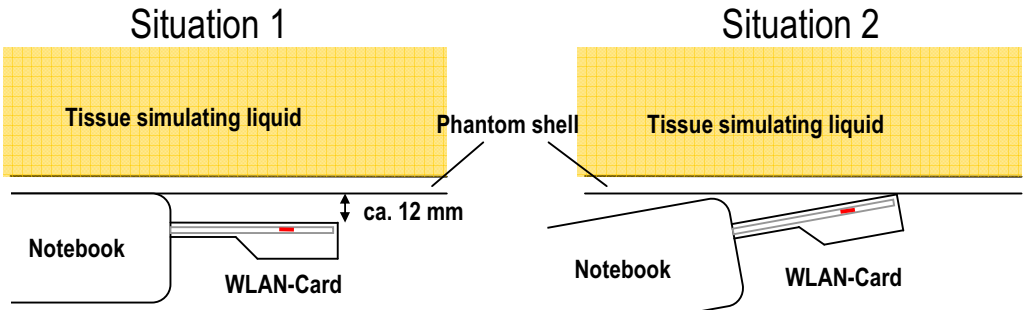
Spatially (over body dimensions) and time averaged exposure: **0.14 - 0.29 mW/m²**

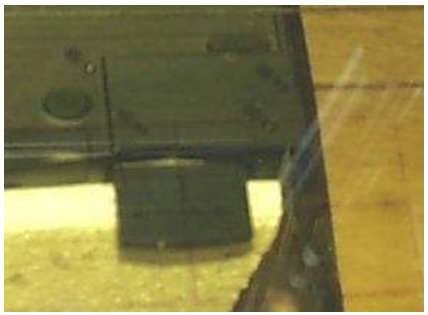
Corresponding to **0.0014% - 0.0029%** of current ICNIRP limit (10000 mW/m²)

Agreement between measurement and computations (regarding spatial average): within 7 dB (computation overestimated measurements)

WLAN IEEE 802.11b,g close near field exposure:

SAR measurements with PCMCIA card





	max SAR_{10g}
Situation 1	0,034 W/kg
Situation 2	0,052 W/kg

Belkin Wireless Notebook Network Card, F5D7010

SAR is strongly depending on the specific device.

Other authors (e.g. Kühn et al. 2005) reported SARs (10g) up to 0.81 W/kg close to access point antennas

3. DECT Main Characteristics (1)

- Frequency range: 1880 MHz – 1900 MHz
- Medium Access Method: FDMA/TDMA (10 Channels, spacing 1.7 MHz)
- Duplex Method: TDD (12 slots uplink, 12 slots downlink per Channel)
- Burst Transmit Power: 250 mW
- Modulation GFSK
- **Automatic Dynamic Frequency Control (ADFC)**
- No Transmit Power Control
- Applications: - Cordless phones for homes (usually 1 BS + 6 max. MS)



- Professional cellular network
  with several BS and up to several hundred MS

DECT Main Characteristics (2)

- Average transmit power (due to duplex- / framing-structure):

  Base Station: 250 mW / 24 = approx. 10 mW per active call

  Mobile Station: 250 mW / 24 = approx. 10 mW

  → Emissions strongly dependent on the number of active calls (dynamic variations in practice)

- Without active calls:

  Base Station: Beacon transmission (83 µs lasting burst, every 10 ms) → approx. 2 mW average

  Mobile Station: **no RF- transmission at all**

DECT Measurement methods

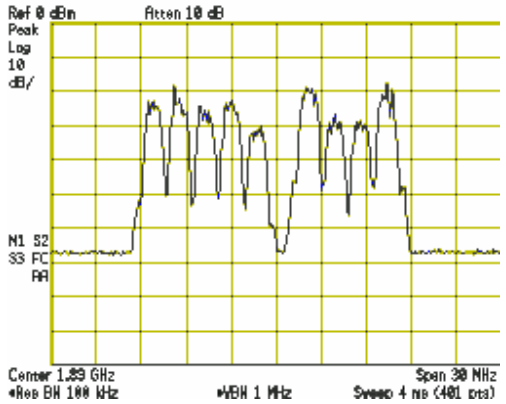
- Frequency selective measurements (antenna + spectrum analyzer)
- **Problem of ADFC and dynamic changes of emissions depending on call traffic**

Possible measurement modes:

LIVE with averaging: remaining variations up to approx. 12 dB, peak values not assessed

CHANNEL POWER with averaging: same as LIVE

MAX-HOLD: measure for peak value,
arbitrarily high overestimations
of actual exposure possible,
depending on actual call traffic



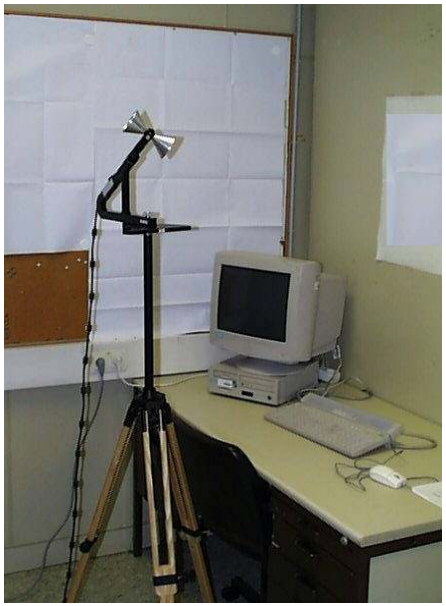
MAX-HOLD (1 Minute)
with a single active call

⇒ approach: **CHANNEL POWER** measurements over the entire DECT frequency band for average exposure and **MAXHOLD** measurements for peak exposure

DECT exposure assessment on typical workplaces

Professional DECT-Installation with more than 250 Mobile Stations:

Example workplace 1



Distance to closest BS approx. 10 m

Measurements in heights bewteen 85 cm – 185 cm

CHANNEL POWER meas.
(800 ms AVG, Observation time 20 s)

MAX-HOLD meas.
(Observation time 20 s)

Example workplace 2

Distance to closest BS approx. 5 m

real life conditions, no control over mobile stations

DECT exposure assessment on typical workplaces:

Results Summary Far field exposure due to a professional DECT installation on typical workplaces

- Spatial and temporal peak values (MAX HOLD): **3.2 – 25.7 mW/m²**
- Spatially (over body dimensions) and time averaged exposure: **0.007 - 0.03 mW/m²**
- Corresponding to approx. **0.00007% - 0.0003%** of current ICNIRP limit (9400 – 9500 mW/m²)
- Remaining **variations** during CHANNEL POWER measurements (800 ms avg / 20 sec. observation time): **±2 dB … ± 6dB**

DECT exposure assessment on cordless phones for homes:

Measurements in anechoic chamber at different distances during phone call between mobiles

Immissionen durch DECT-Geräte						
Gerätetyp	**Hersteller**	**Frequenz [MHz]**	**Sendeleistung [mW]**	**E (1m) [V/m]**	**E (3m) [V/m]**	**Reference Value according to ICNIRP [V/m]**
Gigaset A140 Basisstation	Siemens	1880 - 1900	max. 250 mittel 20	max. 3,61 mittel 1,03	max. 1,28 mittel 0,36	59,6 - 59,9
Gigaset A140 Mobilteil	Siemens		max. 250 mittel 10	max. 1,24 mittel 0,25	max. 0,44 mittel 0,09	
211 Duo Basisstation	Philips		max. 250 mittel 20	max. 2,69 mittel 0,76	max. 1,50 mittel 0,42	
211 Duo Mobilteil	Philips		max. 250 mittel 10	max. 1,93 mittel 0,39	max. 0,77 mittel 0,15	

4. Bluetooth Main Characteristics

- Frequency range: 2400 MHz – 2483 MHz (79 Channels, spacing 1 MHz)
- Medium Access Method: Master Slave
- Modulation GFSK
- 3 transmit power (EIRP) classes:

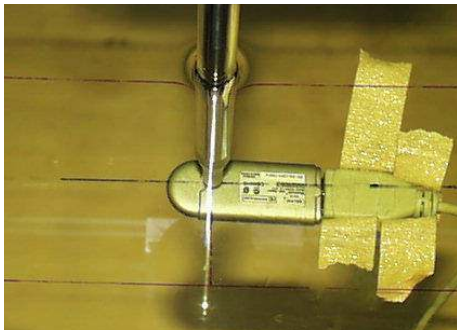
Class	Max. power (EIRP)	Power control
I	100 mW	yes
II	2,5 mW	optional
III	1 mW	optional

- Applications: - headsets for mobile phones (class II or III), PCMCIA cards, wireless computer periphery, ..

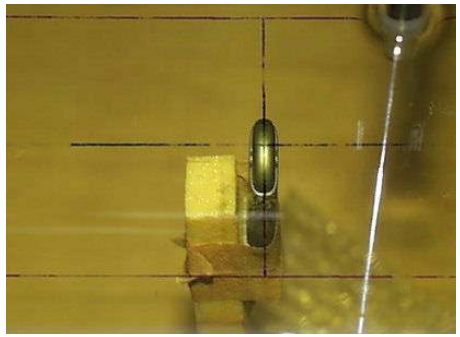
Bluetooth close near field exposure:

SAR measurements with Bluetooth USB Stick

Situation 1



Situation 2



Belkin Bluetooth Stick
Modell F8T001
(Class I)

	max SAR_{10g}
Situation 1	0,087 W/kg
Situation 2	0,024 W/kg

SAR is strongly depending on the specific device.

Other authors (e.g. Kühn et al. 2005) reported SARs (10g) up to 0.47 W/kg close to a class I Bluetooth device

5. Further applications used in homes

5.1 Babyphones

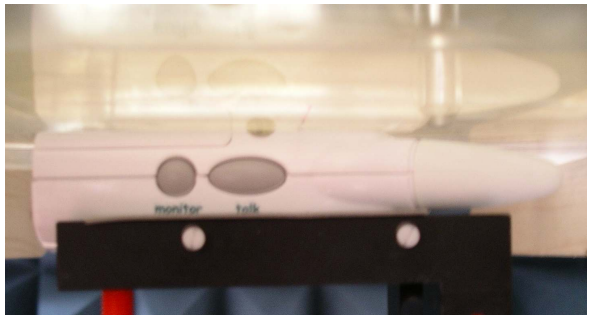
Several frequency bands and transmit powers

Babyphones						
Device	**Manufacturer**	**Frequenc y [MHz]**	**Specified power [mW]**	**E (1m) V/m**	**E (3m) V/m**	**Reference Value according to ICNIRP [V/m]**
BM30	Vivanco	40,68	max. 10	**0,04**	**0,03**	28,0
BM1000	Vivanco	446	max. 500	**1,086**	**0,412**	29,0
BM800	Vivanco	864,7	max. 10	**0,447**	**0,139**	40,4
Babystar	Bob Home	2450	k.A.	**0,397**	**0,109**	61,0

Babyphones: SAR assessment with 500 mW Babyphone

Situation 1

Situation 2



SAR caused by Babyphone ***Vivanco BM1000*** 446 MHz, 500 mW	
	max. SAR $_{10g}$ [W/kg]
Situation 1	0,133
Situation 2	0,074

5.2 Wireless Stereo Headphones (fixed station)

Wireless stereo headphones – fixed station						
Device	**Manufact**	**Frequency [MHz]**	**Specified power [mW]**	**E (1m) V/m**	**E (3m) V/m**	**Reference Value according to ICNIRP [V/m]**
K105 UHF	AKG	864	k.A.	**0,14**	**0,04**	40,4
SBC HC8440	Philips	864	max. 10	**0,35**	**0,10**	

5.3 Wireless WebCam

Wireless WebCam						
Device	**Manufact**	**Frequency [MHz]**	**Specified power [mW]**	**E (1m) V/m**	**E (3m) V/m**	**Reference Value according to ICNIRP [V/m]**
QuickCam	Logitech	2450	k.A.	**0,30**	**0,11**	61,0

5.4 Wireless Video Transmission System

Wireless Video Transmission						
Device	**Manufact**	**Frequency [MHz]**	**Specified power [mW]**	**E (1m) V/m**	**E (3m) V/m**	**Reference Value according to ICNIRP [V/m]**
MD 4687	Tevion	2450	k.A.	**1,66**	**0,47**	61,0

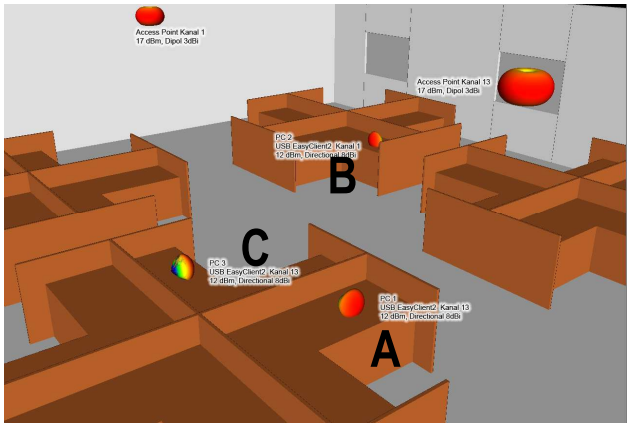
5.5 Remote Controls for Toys

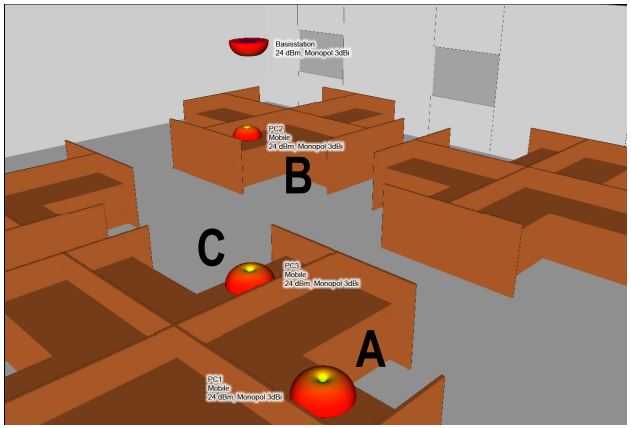
Remote Controls for Toys							
Device	**Manufact**	**Freq. [MHz]**	**Specified power [mW]**	**max E / max H [V/m] / [mA/m]**			**E / H -Reference Value according to ICNIRP [V/m] / [mA/m]**
				20 cm	**1 m**	**3 m**	
27050	Dickie Spielzeug	27	not spec.	4,5 / 5,1	0,5 / 1,1	0,15 / 0,25	28 / 73
693004	Artin Europe	27	not spec.	2,6 / 4,2	0,4 / 0,8	0,05 / 0,15	
Tyco RC	Mattel	27	not spec.	3,4 / 4,6	0,4 / 0,9	0,10 / 0,12	

6. Estimation of combined exposures

6.1 Generic Office Model („Call Center“ using WLAN and DECT)

- 3 workplaces (A,B,C), each of them equipped with a WLAN Clients and a DECT MS
- 2 WLAN Access Point and 1 DECT BS on the ceiling





Source	Frequency	Transmit Power	Antenna
WLAN Access Points	2412 MHz / 2472 MHz	17 dBm	Dipole, 3dBi
WLAN-Clients	2412 MHz / 2472 MHz	12 dBm	Patch, 8 dBi
DECT-Mobile Station	1890 MHz	24 dBm	Monopole, 3 dBi
DECT Base Station	1890 MHz	24 dBm	Monopole, 3 dBi

Generic Office Model – Results (1)

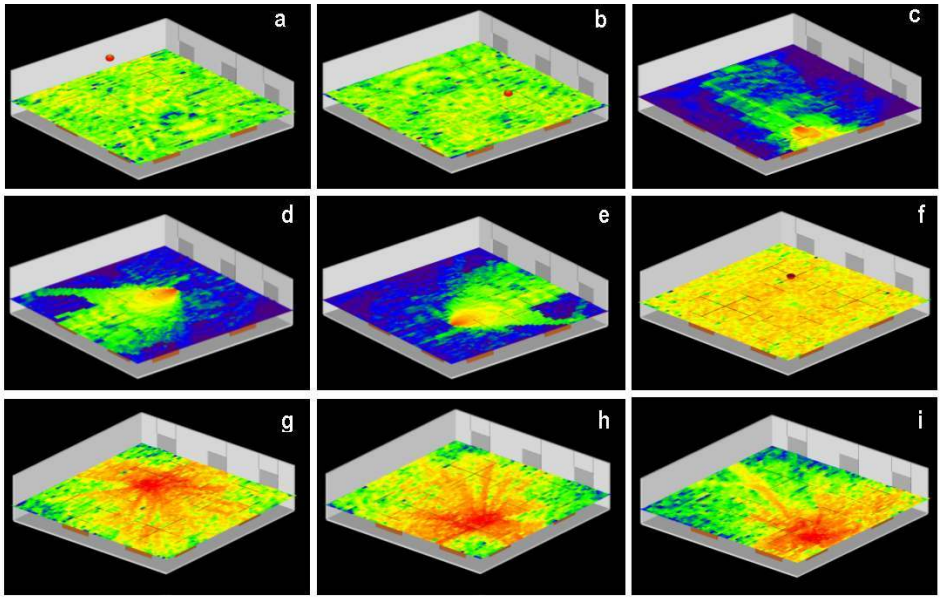
Combined exposures at workplaces for different realistic (static) WLAN and DECT traffic situations (spatially and time averaged)

In terms of
percent of the current ICNIRP limit:

Workplace A: **0.018% - 0.036%**

Workplace B: **0.038% - 0.061%**

Workplace C: **0.027% - 0.055%**



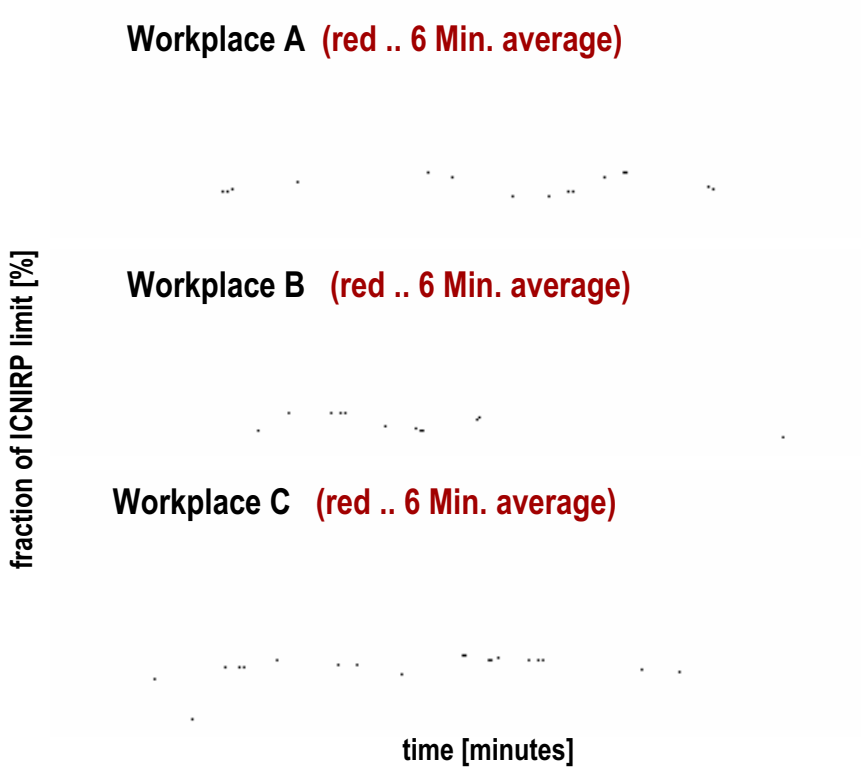
Contribution of different sources 100 cm above floor (burst peak values)

Generic Office Model – Results (2)

Combined exposures at workplaces for dynamically changing WLAN and DECT traffic, based on statistical models.

Statistical Parameters for WLAN Systems				
	Number of accesses per 2 hours	Start time of access	Transferred data per access	Datarate during access
Clients	Pseudo random normally distributed mean: 50 std.deviation.: 20	Pseudo random normal distributed mean: 0+1Std. std.deviation.: 30min	Pseudo random normally distributed mean: 2MB std.deviation.: 500kB	Pseudo random normally distributed mean: 2MBps std.dev..: 1MBps max.: 5 MBps min.: 0.5 MBps
Access Points	Derived from clients' data			

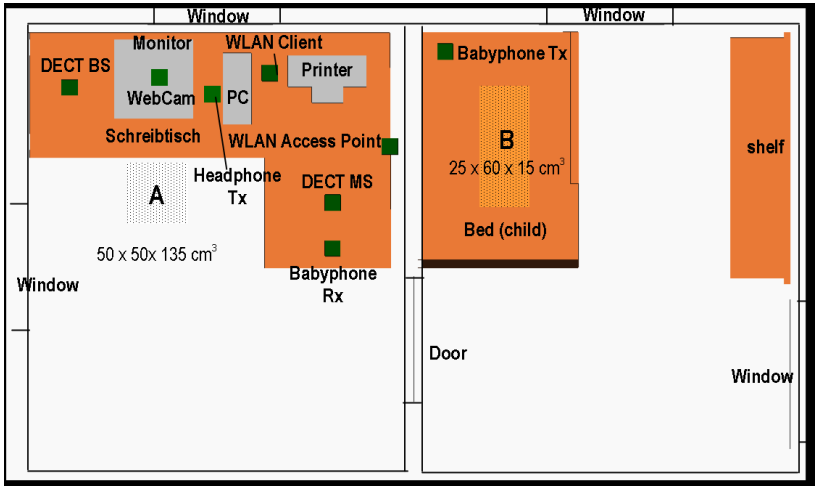
Statistical Parameters for the DECT System				
	Number of calls per 2 hours	Start time of calls	Duration of calls	Used frequency channel
Mobile Stations	Pseudo random normally distributed mean: 40 std.deviation.: 10	Pseudo random normal distributed mean: 0+1Std. std.deviation.: 30min	Pseudo random normal distributed mean: 3 min. std.deviation.: 2 min.	Equally distributed between DECT-Channels 1 to 10
Basestation	Derived from mobile stations' call traffic			

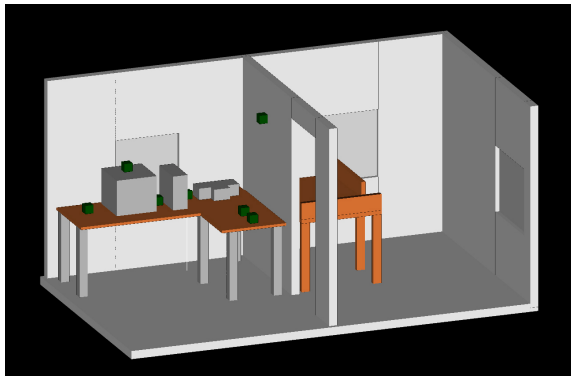


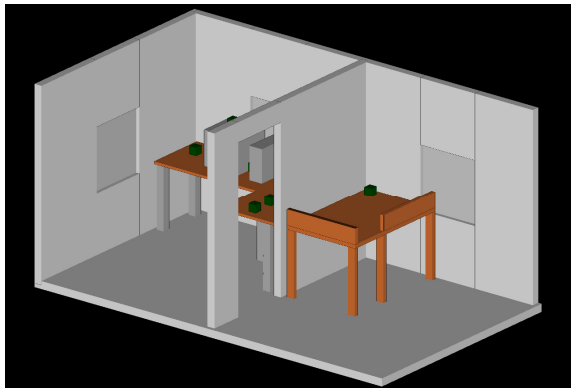
6.2 Generic Home Model

(with WLAN-, DECT-, Babyphone-, Wireless stereo headphone- and Wireless webcam-usage)

- Exposures at workplaces in front of desk (A) and in the bed of a child (B)







Source	Frequency	Transmit power	Antenna
Babyphone	446 MHz	20 / 27 dBm	Monopol, 3 dBi
DECT-Mobile Station	1890 MHz	24 dBm	Monopol, 3 dBi
DECT Base Station	1890 MHz	24 dBm	Monopol, 3dBi
WLAN Access Point	2462 MHz	17 dBm	Monopol, 3dBi
WLAN-Client	2462 MHz	12 dBm	Patch, 8 dBi
WebCam	2,45 MHz	7 dBm	Monopol, 3 dBi
Stereo-Headphone	860 MHz	7 dBm	Monopol, 3 dBi

Generic Home Model – Results

Combined exposures in front of the desk (A) and in the bed (B) for

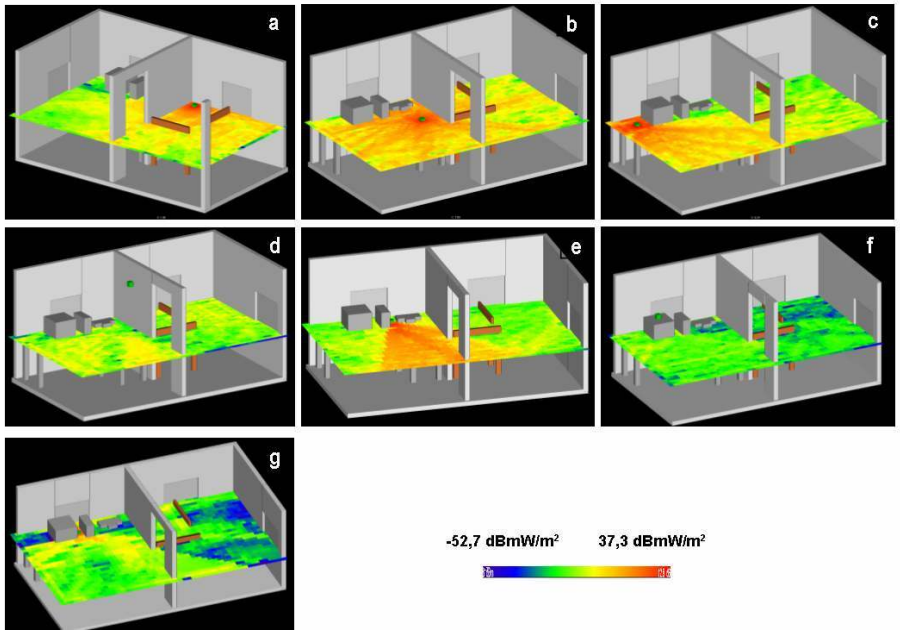
- different realistic (static) WLAN and DECT traffic situations
- different transmit powers of Babyphone
- cont. Trans. Headphone-Tx and WebCam

In terms of
percent of the current ICNIRP limit:

Desk (A): **0.017%* - 0.38%** (0.06%)*****

Bed (B): **0.012%* - 5.86%** (0.27%)*****

* without babyphone
** with 500 mW babyphone
*** with 20 mW babyphone



Contribution of different sources 100 cm above floor (burst peak values)

Conclusions:

- Typical exposures (in the far field) of DECT-, WLAN- and Bluetooth devices can be expected well below approximately 0.1% of the current reference values according to ICNIRP.
- In some cases close near field exposure by WLAN- and Bluetooth class I devices can cause spatial peak SARs in the order of the current limits for localized exposure, however in most cases and under normal use conditions these values are 1-2 orders of magnitude below the limits
- The maximum electric field strengths measured in 1 m and 3 m distance to the considered Babyphones and DECT devices, wireless headphone transmitters, as well Webcams and wireless video transmission systems were found to be well below the current ICNIRP reference values. Depending on the device type the maximum time averaged electric field strengths were found to be in the range of 0.04% - 3.7% (1 m) and 0.015% - 1.4% (3 m) of the above mentioned reference levels, respectively. At distances very close to the transmitters higher field strengths may occur. In such situations SAR measurements are recommended for testing compliance with the basic restrictions of safety standards.

Acknowledgements:

- COMNET Computer-Netzwerke
- Austriamicrosystems

THANK YOU FOR YOUR ATTENTION !