

Assessment of Human Exposure to Electromagnetic Radiation from Wireless Devices in Home and Office Environments

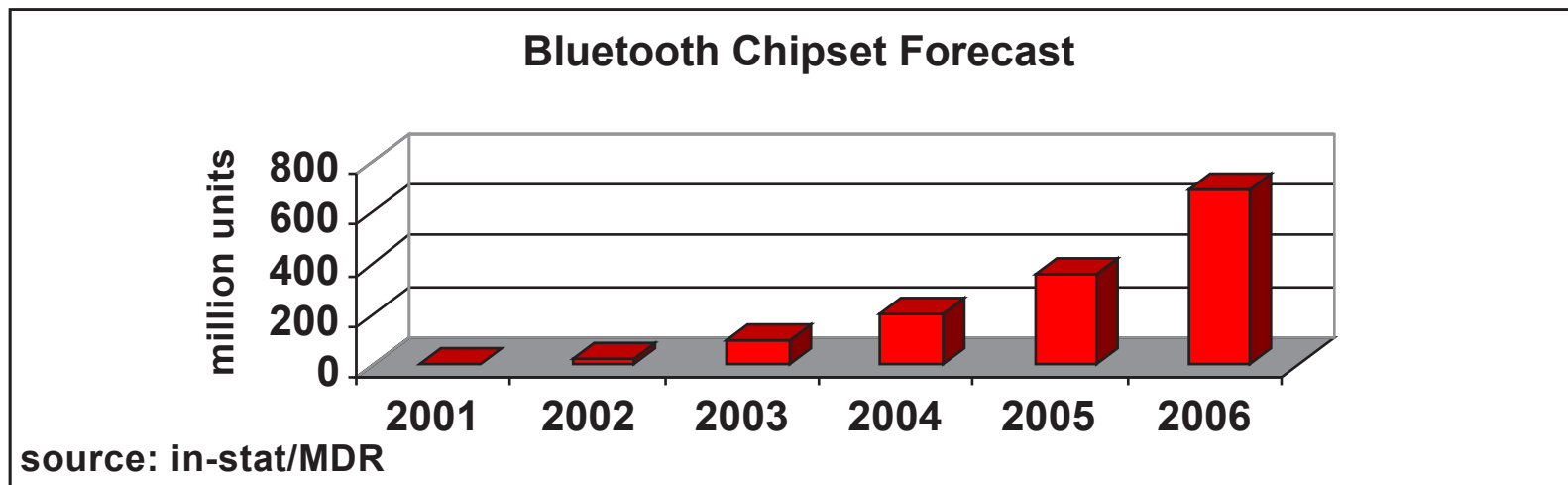
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Introduction

- several new wireless connectivity standards and technologies, e.g., DECT, Bluetooth, IEEE802.11.
- growing usage of these technologies within homes and offices
- request from public health agencies for information on the expected exposure from general mobile transmitters
- no systematic study on the expected exposure
- procedures for compliance testing unavailable



Objectives

- characterization and classification of the exposure from different communication systems applied in home and office environments
- evaluation of the exposure from these transmitters
- development of procedures for compliance testing of wireless devices used in home and office environments

Methods - Technology Review

- market survey to determine the most frequently used wireless communication technologies applied in home and office environments
- determination of the exposure relevant parameters of the considered device classes
 - DUT output power, RF range, ELF components
- theoretical evaluation
 - review of the underlying communication standards
 - review of DUT data sheets
- experimental evaluation
 - monitoring of the RF and ELF spectra of the DUT under different operational conditions
- selection of devices for further experimental evaluation on the basis of market surveys and review of exposure relevant parameters

Review of RF Exposure Relevant Parameters

Technology	RF range (MHz)	Peak output power (mW)
DECT	1880 ... 1900	250
Bluetooth	2402 ... 2480	100
802.11b	2400 ... 2483.5	100
802.11g	2400 ... 2483.5	100
802.11a	5250 ... 5350	200
802.11a	5470 ... 5725	1000
Wireless PC peripherals	27 ... 2400	up to 10
Baby surveillance	27 ... 2400	up to 500



Review of ELF Exposure Relevant Parameters

Technology	ELF spectral components (Hz)	Generated by
DECT	0.25, 6.25, 100, 100 ... 2400	hyper / multi / basic frames, TDMA
Bluetooth	0.78, 267 ... 800, 1600	standby, multi-slot transmission single-slot transmission
IEEE802.11b	~10, ~10 ... ~ 1500	beacon, TDD



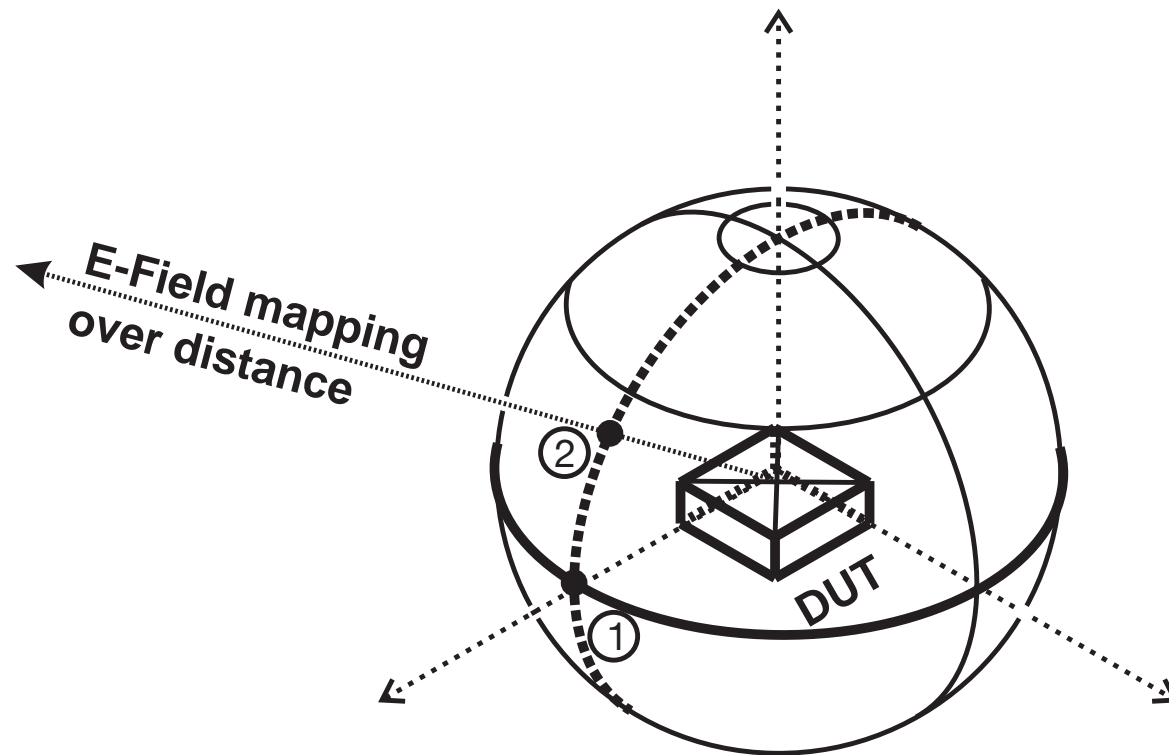
Devices Selected for Experimental Investigation

- DECT
 - 5 telephone devices
- IEEE 802.11b
 - 3 access points
- Bluetooth
 - 2 USB dongle devices
 - 2 headset devices
- Baby surveillance devices
 - 3 devices (40, 446, 863 MHz)
- Wireless PC peripherals
 - 2 wireless mice (27, 40 MHz)
 - 1 wireless keyboard (27 MHz)



Methods for Experimental Evaluation in Free Space

- Experimental determination of the DUT's radiation main beam
 - circular scans at a constant distance around the DUT
 - determination of the E-field maximum
- E-field mapping up to a distance of 2.5m



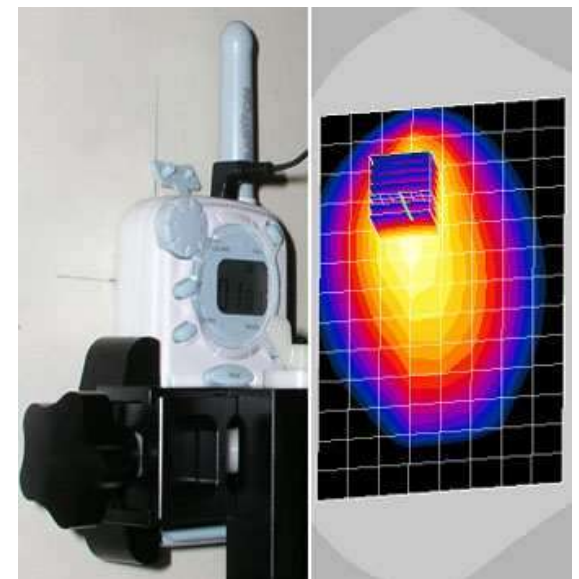
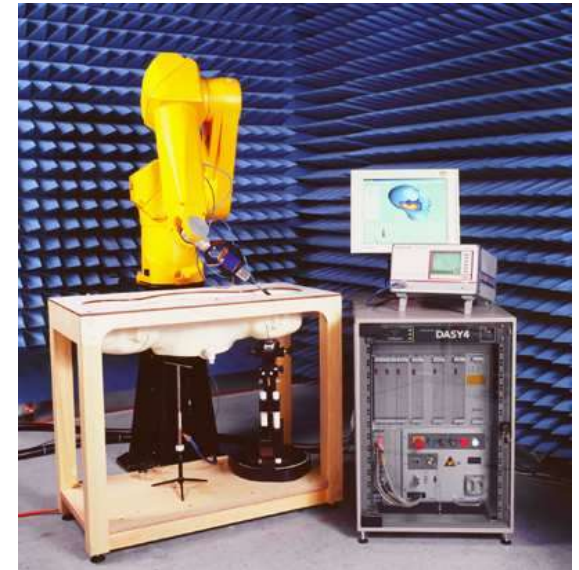
Equipment for Exposure Evaluation in Free Space

- Semi-anechoic chamber or open area test site for well-defined, comparable field conditions
- Field probes (f: 27MHz - 6GHz)
 - miniature isotropic E-field probes (near field)
 - ADD3d isotropic antenna (far field)
- Spectrum analyzer for frequency-selective measurements
- Data acquisition unit for broadband diode based field probes



Methods and Equipment for Dosimetric Evaluation

- dosimetric assessment system, e.g., DASY4
- ES3DV6, EX3DV6
- flat and SAM phantoms
- head tissue simulating liquids (f: 27MHz - 6 GHz)

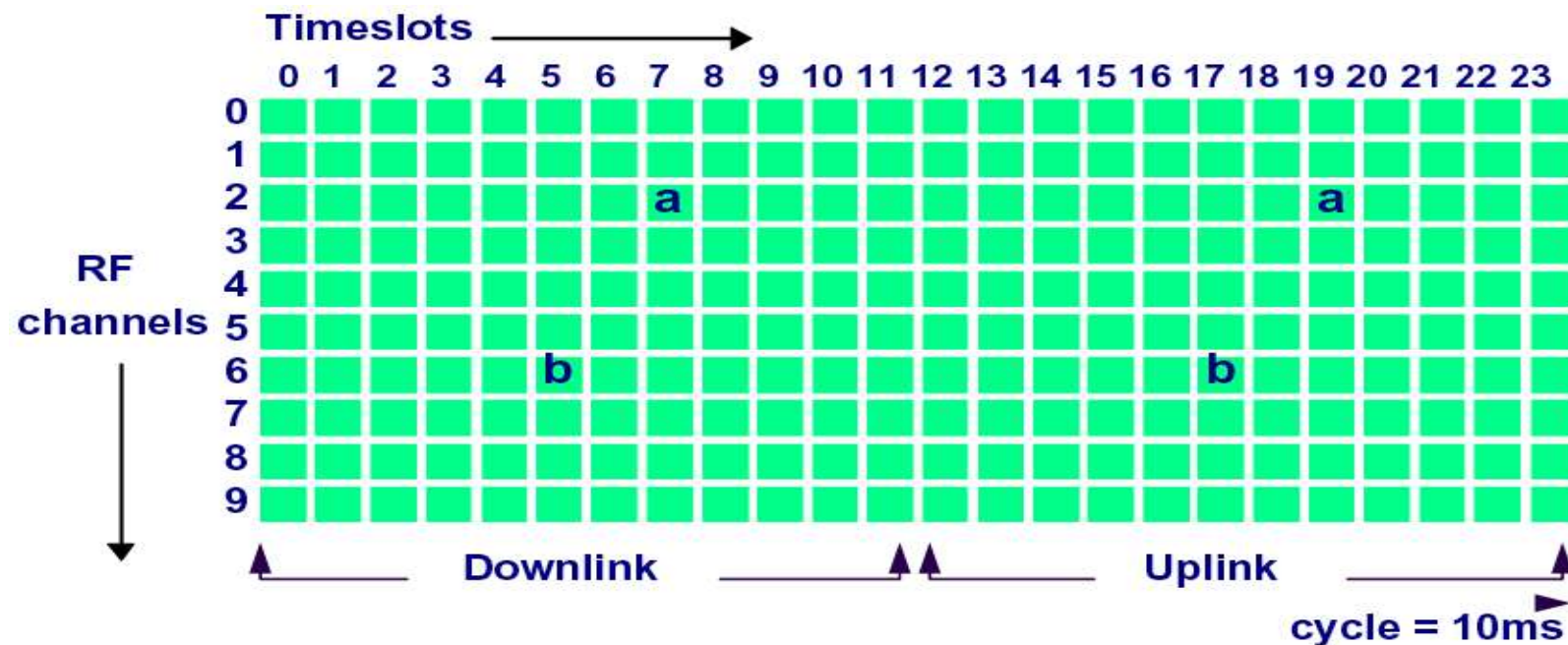


Test Condition of Device

- well-defined time-averaged P_{out} (with respect to max time-averaged P_{out})
to-consider: 1) static or adaptive power control
2) time domain channel access dependence
 - medium access control method
 - time domain duplex
 - transmitted data rate
- covering frequency dependencies
- worst-case exposure position for dosimetric evaluation
to-consider: 1) typical operational positions can be defined
 - applicable test standard exists, e.g., telephone handset
 - no applicable test standard exists, e.g., Bluetooth headset2) no typical operational positions can be defined

Test Conditions - DECT

- frequency division channel is automatically chosen
- time division duplex is applied
- telephone call uses one time division slot
- usually no power control integrated



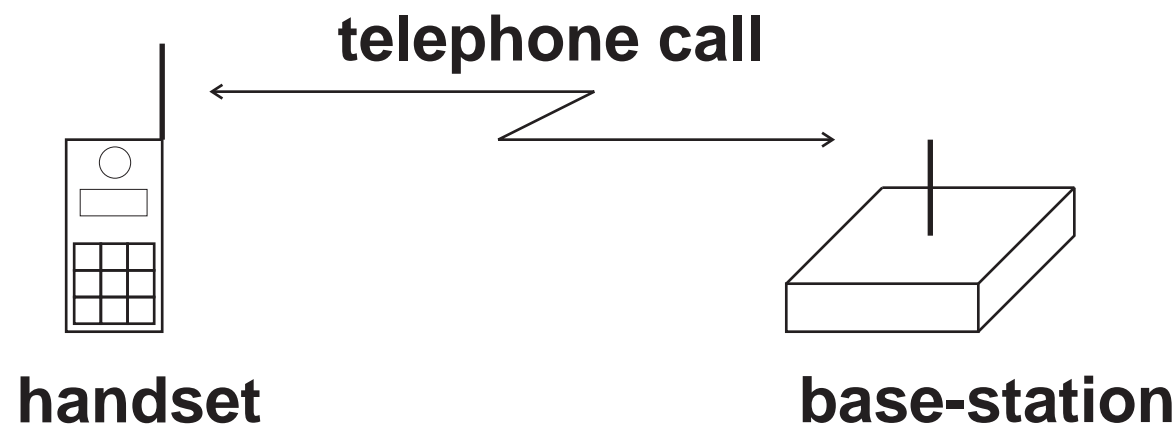
Test Conditions - DECT

Handset

- one active telephone call
- SAM head (dosimetry only)

Base-Station

- one active telephone call and extrapolation to maximum
- flat phantom (dosimetry only)



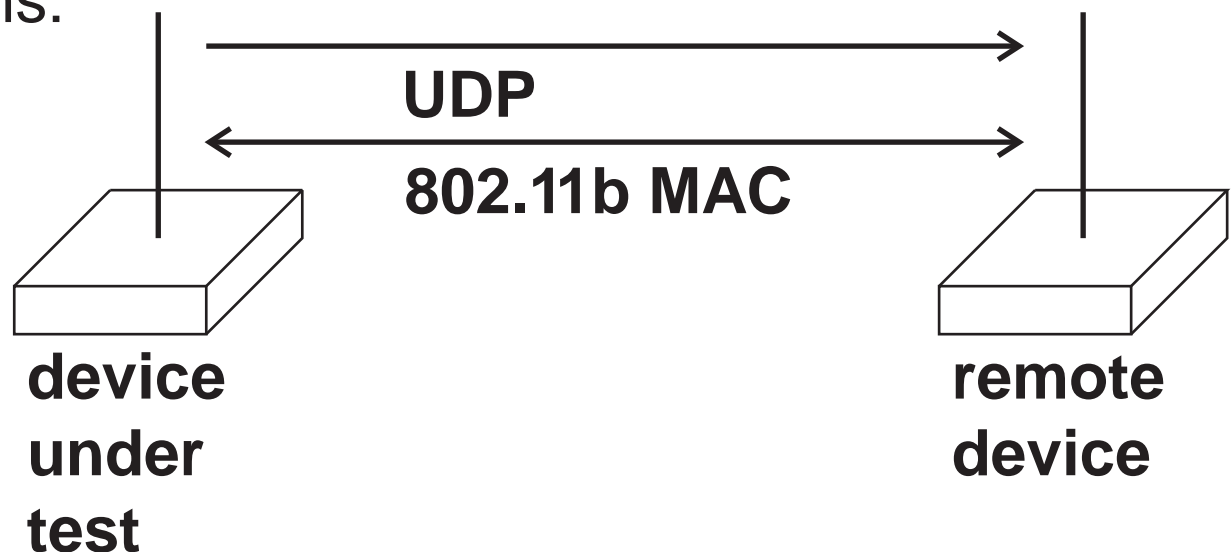
Test Conditions - IEEE802.11b

- one RF channel occupies 22 MHz of the 80 MHz band
- fixed peak output power
- channel access mechanism and data rate determine P_{avg}
 - channel access mechanism determines minimum crest factor
 - CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance)
 - CSMA/CA + RTS/CTS (Ready to Send / Clear to Send)
 - MSDU size determines actual crest factor:

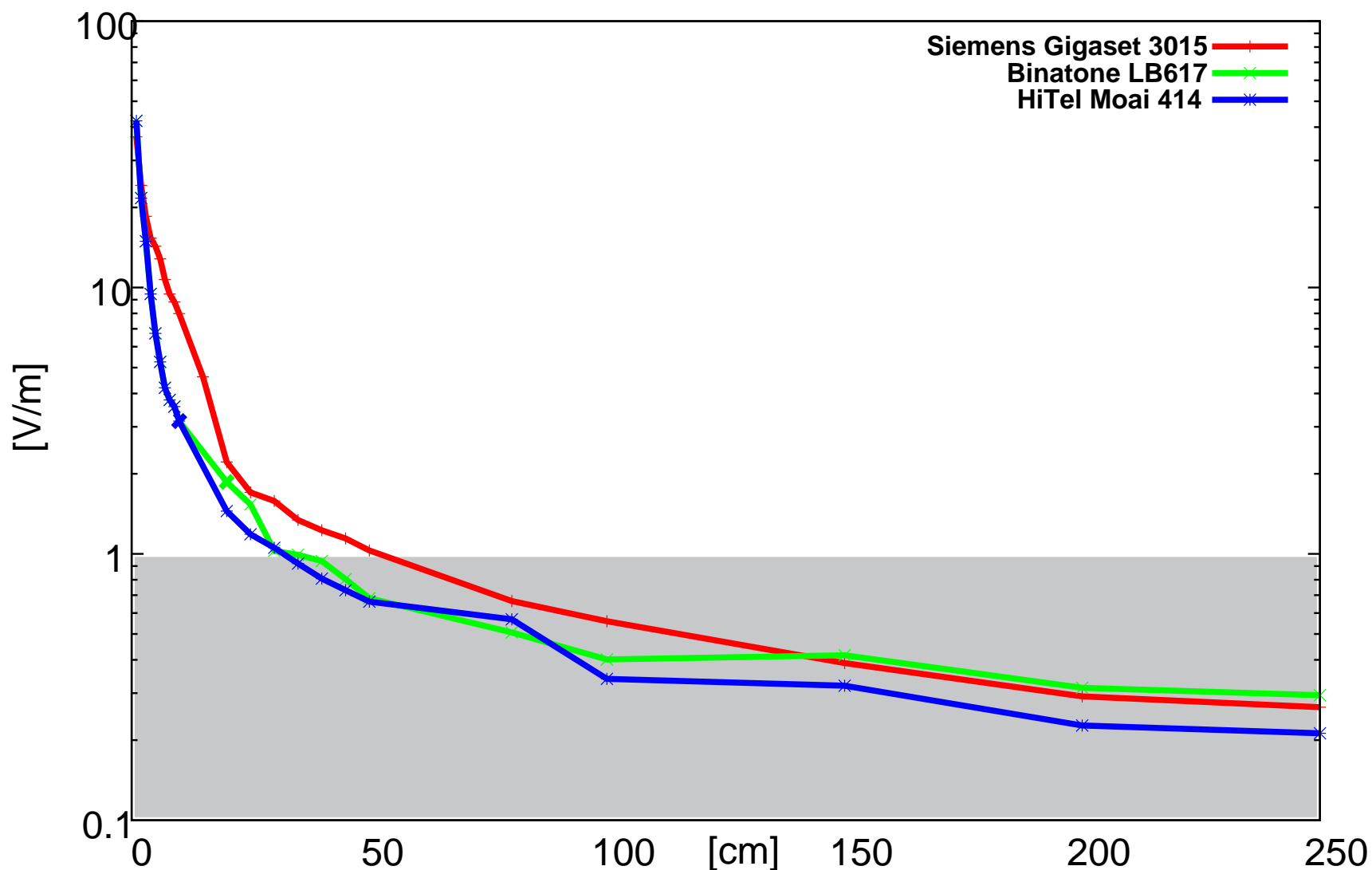
$$cf_{CSMA/CA} = \frac{673 + 8/11 \cdot MSDU}{309 + 8/11 \cdot MSDU} \cdot \frac{\mu s}{\mu s}$$

Test Conditions - IEEE802.11b - Test Parameters

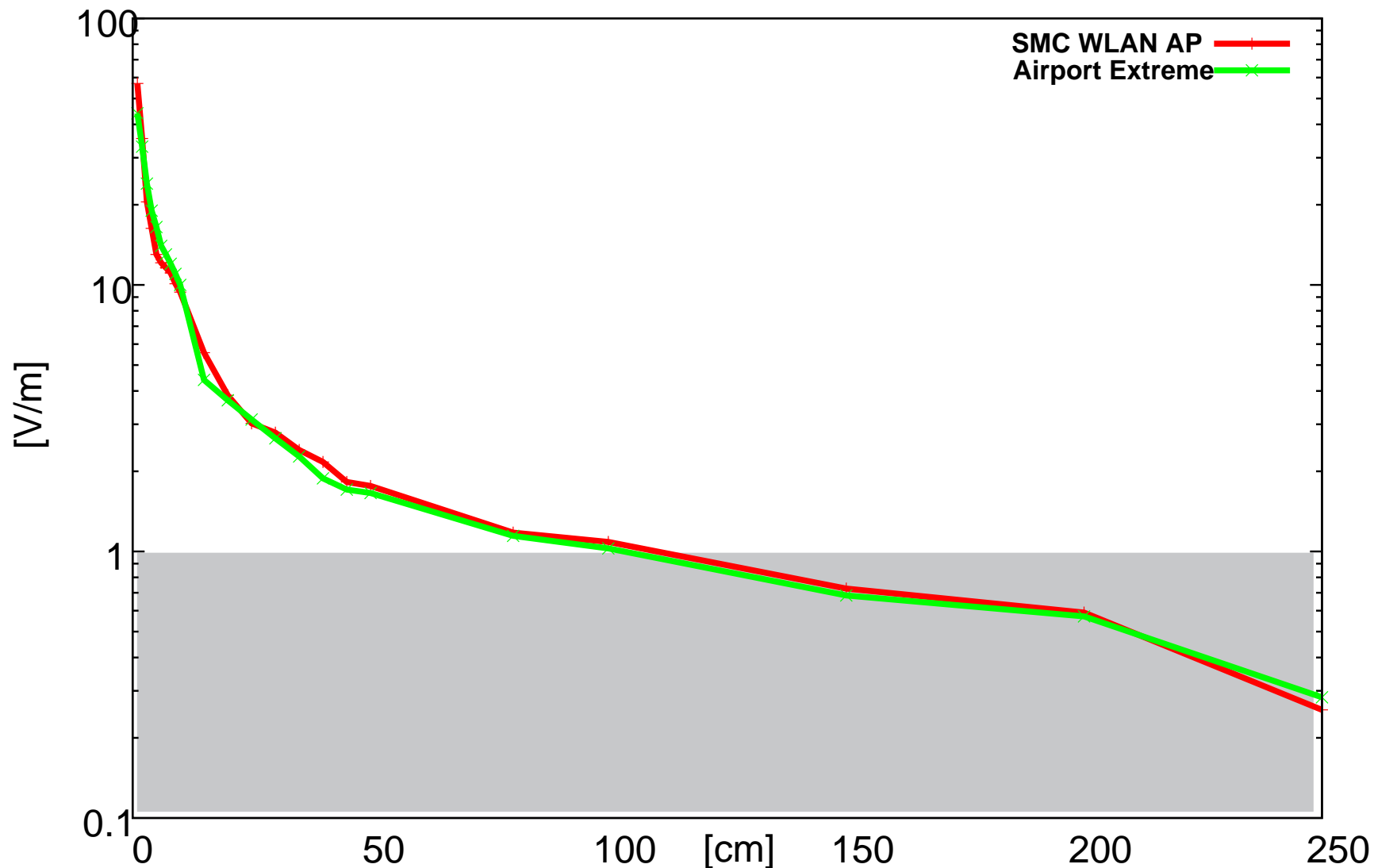
- three test channels (1, 7, 13) cover nearly the entire band
- channel access mechanism with lowest crest factor
 - CSMA/CA: $cf_{min} = 1.26$
 - CSMA/CA + RTS/CTS: $cf_{min} = 1.38$
- maximum output data rate:
 - unidirectional transmission (e.g. use of UDP)
 - UDP payload = 1472 byte
- dosimetric test positions:
 - phantom flat section
 - phantom head for WLAN handsets



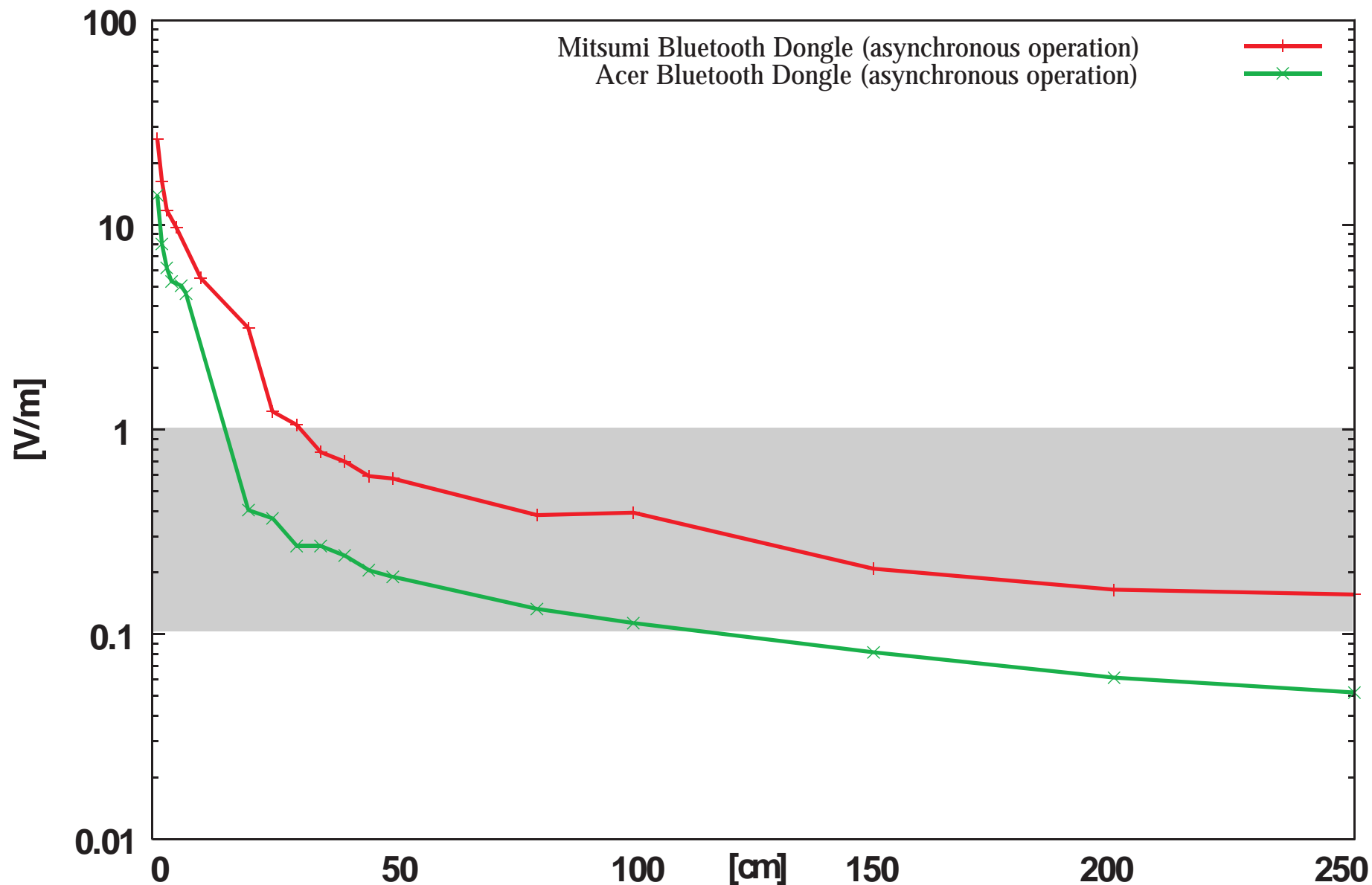
Results - Incident E-Field from DECT Fixed Part



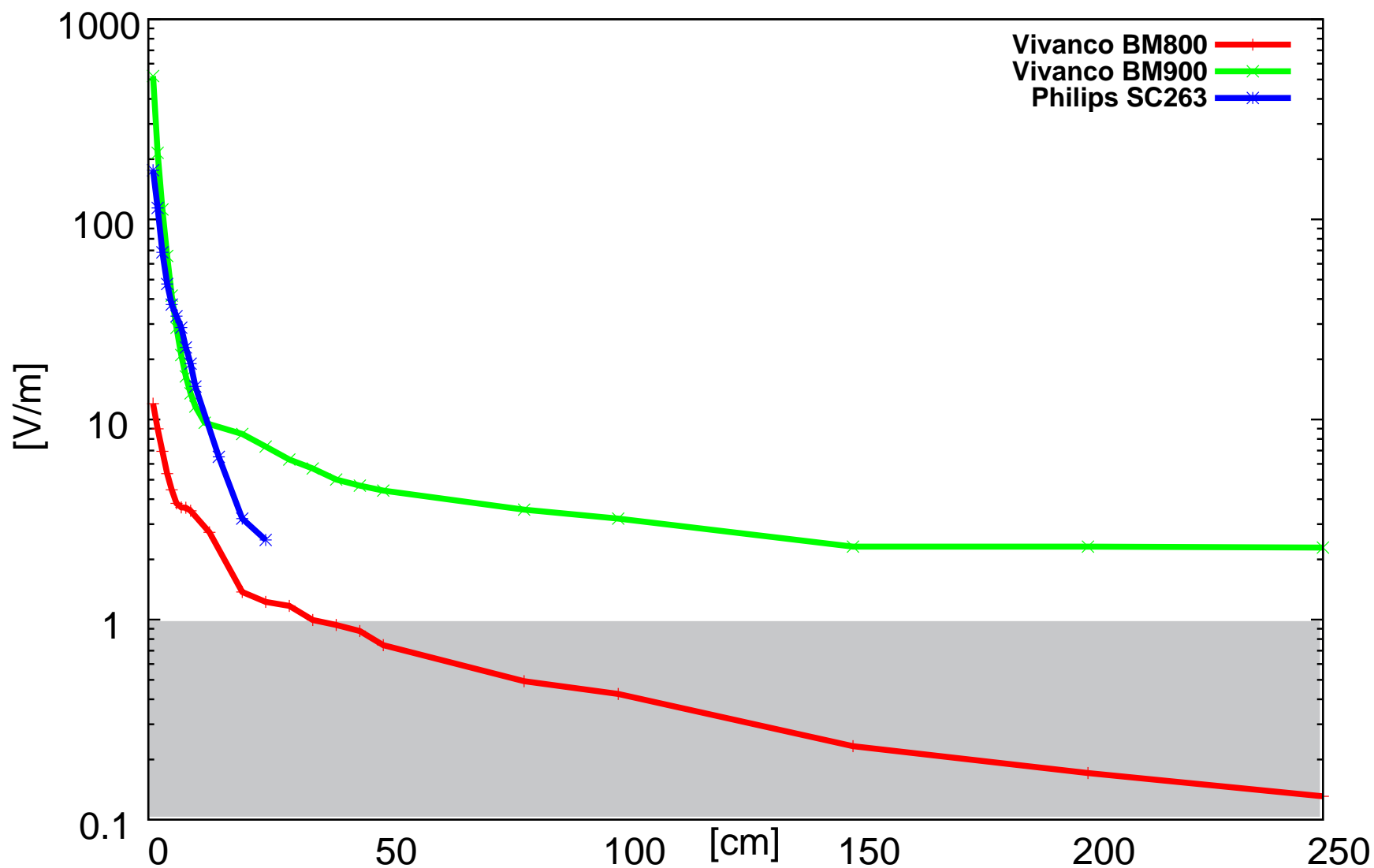
Results - Incident E-Field from IEEE802.11b



Results - Incident E-Field from Bluetooth



Results - Baby Surveillance Devices



Results - Incident E-Field from Wireless Peripherals

Device	E-field (V/m) at distance		
	1 cm	5cm	10 cm
Logitech keyboard	26.0	5.7	1.5
Gyraton mouse	200.0	8.3	1.5

Results - Finger Exposure

Position	E-field (V/m)
Thumb	5.5-6.5
Little finger	5
Trigger finger	2.0-2.5
Mouse tip	2

Results - Peak Spatial SAR

DECT

Device	maximum SAR	
	1g [mW/g]	10g [mW/g]
Ascom Avena	0.023	0.019
Siemens 2000C	0.019	0.013
Siemens 3015	0.087	0.052
Swisscom R106	0.047	0.027

IEEE802.11b

Device	maximum SAR	
	1g [mW/g]	10g [mW/g]
SMC Access Point	1.93	0.81
Airport Extreme Comp	0.11	0.06
Airport Express	0.52	0.19



Results - Peak Spatial SAR

Bluetooth

Device	maximum SAR	
	1g [mW/g]	10g [mW/g]
Mitsumi Dongle (Class 1)	1.31	0.466
Acer Dongle (Class 2)	0.02	0.0092
SE HDH-300 (Class 3)	<0.005	<0.005
Nokia HDW-2 (Class 3)	0.009	<0.005



Baby Surveillance

Device	maximum SAR	
	1g [mW/g]	10g [mW/g]
Vivanco BM 900	0.115	0.077
Vivanco BM 800	0.012	0.01



Wireless PC Peripherals

below measurement uncertainty: < 0.005 mW/g

Results - Summary

Device class	test frequency range [MHz]	max. 10g SAR [W/kg]	max. E-field [V/m] (20 cm)	max. E-field [V/m] (100 cm)	ICNIRP limit [V/m]	ONIR* limit [V/m]
Baby surveillance	40 - 863	0.077	8.5	3.2	29	4
DECT**	1880 - 1900	0.055	11.5	2.9	60	6
WLAN	2400 - 2484	0.81	3.9	1.1	61	6
Bluetooth	2402 - 2480	0.49	3.1	1	61	6
PC peripherals	27 - 40	0.005	<1.5	<1.5	28	4

*ONIR limits for fixed transmitters with ERP of >6W

** Extrapolated maximum for asymmetric transmission mode

Conclusions

- Worst-case peak spatial SAR values are close to the limits for the public or uncontrolled environments, e.g., IEEE802.11b and Bluetooth Class I.
- Maximum incident field exposures at 1m can significantly exceed those of base stations (typically 0.1 - 1 V/m). At very close distances the derived or reference exposure limits are violated.
- The most reliable procedure for exposure evaluation and demonstration of compliance is dosimetric evaluation under worst-case conditions.

Acknowledgment

- Support of the Swiss Federal Office for Health