

Current (and future) Exposure Scenarios and Assessments

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Non-ionizing Radiation and Children's Health
Exposure and Dosimetry

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Centre for Radiation, Chemical and Environmental Hazards
Radiation Protection Division




Independent Expert Group on Mobile Phones (2000)



Precautionary approach

- Adopt international guidelines
- Set up a research programme
- Audit of base stations
- Provision of information
- Measures to address concern

www.iegmp.org.uk



IEGMP Recommendation on Children's use of Phones

Concerns arising from studies at that time


- Effects on cognitive performance

Children may be more vulnerable

- Developing nervous system
- Greater RF absorption in the head
- Longer lifetime to accumulate exposure

Recommended

- Children should be discouraged from the non-essential use of mobile phones



Developments since the IEGMP Report

Scientific knowledge has advanced


- Exposure assessments and dosimetry
- Biological research
- Epidemiological research

Evolutions in mobile phone technology

- More phones and more base stations
- Advent of 3G (and 4G) networks
- Smart phones and more data services


Evolutions in data communications technology

- Wi-Fi computers/access points at home, work and school
- Smart meters for domestic gas, water and electricity use




Talk Plan

1. Background to Wi-Fi Project
2. Devices in Schools
3. Radiated Powers
4. SAR Modelling
5. Duty Factors
6. Conclusions



1) Background to Wi-Fi Project

- Context
- Scope



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Rapid Expansion of Wi-Fi use – Including in Schools



In 2007, 50% of UK primary schools and 82% of secondary schools made at least some use of wireless network technology



Background and Motives – Drivers for the Project



Expressions of public concern about Wi-Fi

- Media articles
- Enquiries received by HPA

Lack of quantitative information about exposures

- Comparison with exposure guidelines
- Context with regard to other sources

Existing precautionary advice to discourage non-essential use of mobile phones by children

- Chief Medical Officer
- HPA (NRPB)

HPA Project on WiFi Exposures



Announced on 12 October 2007

Scope

- Review of exposure literature and technical standards
- Measurements around selected Wi-Fi equipment
- Measurements with installed Wi-Fi systems
- Computer modelling of SARs produced in the body

Results of this study, and of other studies on radio signals and health, will be used as the basis for a wider health risk review

2) Wi-Fi Systems in Schools



- Types of equipment
- Technical aspects
- Devices for testing

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Devices in Schools



Up to 32 laptops can be used in a classroom,
Usually 1-2 access points in each classroom

Interactive whiteboards and hand held interactive slates often have wireless options enabled

Devices in Schools



ICT Suites



Laptop Trolleys



Technical Standards for WLAN IEEE 802.11



IEEE 802.11b

- Widely deployed, basic rate of Wi-Fi, 11 Mbps (4.3 Mbps throughput) at 2.4 GHz
- Recommended by some suppliers for teaching resources in large schools

IEEE 802.11a

- Primary standard for WLAN, max 54 Mbps (23 Mbps throughput) at 5 GHz
- Recommended by some suppliers for administration and teacher training

IEEE 802.11g

- 54 Mbps at 2.4 GHz
- Recommended by suppliers for teaching resources in both small & large schools

IEEE 802.11n

- High throughput (up to 600 Mbps using 4 channels) at both 2.4 and 5 GHz
- Deployment in schools has recently started

Overall there is no particular trend in the chosen wireless standards in UK schools

Specifications for Wi-Fi Devices in Europe



Name	Frequency Band	Max. Power (EIRP)	Conditions (UK)
A	2.4 – 2.4835 GHz	100 mW	Unlicensed
B	5.15 – 5.35 GHz	200 mW	Unlicensed (indoors)
C	5.470 – 5.725 GHz	1 W	Unlicensed
	5.725 – 5.825 GHz	4 W	Licensed

Channel numbers 1 to 14:

- 2.412 to 2.484 GHz in steps of 5 MHz (all channels available)

Channel numbers 36 to 64 (Band A):

- 5.180 to 5.320 GHz in steps of 5 MHz (only every fourth channel available)

Channel numbers 100 to 140 (Band B):

- 5.500 to 5.700 GHz in steps of 5 MHz (only every fourth channel available)

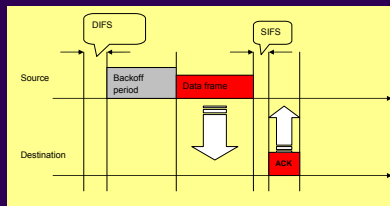
Channel numbers 149 to 165 (Band C):

- 5.745 to 5.825 GHz in steps of 5 MHz (only every fourth channel available)

Wi-Fi Communications Protocols




- Multiple devices share the same frequency channel
- Emissions are in the form of short bursts
 - Tens of μ s to around 1 ms in duration



Laptops Selected for Testing

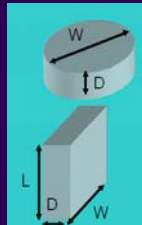


ID	Available Wi-Fi modes	Dimensions L x W x D	Available frequency channels		Settable power levels																							
			2.4 GHz	5 GHz																								
LT01	b/g	34 x 24 x 4	N/S	N/A	N/S	<table border="1"> <thead> <tr> <th>Ch.</th> <th>Freq. MHz</th> </tr> </thead> <tbody> <tr><td>1</td><td>2402</td></tr> <tr><td>6</td><td>2427</td></tr> <tr><td>11</td><td>2452</td></tr> <tr><td>36</td><td>5180</td></tr> <tr><td>48</td><td>5240</td></tr> <tr><td>64</td><td>5320</td></tr> <tr><td>100</td><td>5500</td></tr> <tr><td>140</td><td>5700</td></tr> <tr><td>149</td><td>5745</td></tr> <tr><td>165</td><td>5825</td></tr> </tbody> </table>	Ch.	Freq. MHz	1	2402	6	2427	11	2452	36	5180	48	5240	64	5320	100	5500	140	5700	149	5745	165	5825
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165	5825																											
LT02	b/g	36 x 27 x 4	N/S	N/A	N/S																							
LT03	b/g	36 x 27 x 4	1-13	N/A	25, 50, 75, 100%																							
LT04	a/b/g/n	37 x 27 x 4	1-11	36-48	1-5																							
LT05	a/b/g/n	37 x 28 x 4	1-11	36-48	1-5																							
LT06	b/g	34 x 25 x 4	1-14	N/A	N/S																							
LT07	a/b/g	32 x 24 x 4	1-11	36-48	1-6																							
LT08	a/b/g/n	30 x 25 x 4	1-11	36-48	1-5																							
LT09	a/b/g/n	33 x 23 x 3	1-14	36-64																								
				100-140																								
				149-165	25, 50, 75, 100%																							
LT10	a/b/g/n	33 x 25 x 4	1-11	36-48	1-5																							
LT11	a/b/g	28 x 17 x 5	1-14	36-64	25, 50, 75, 100%																							
				100-140																								
				149-165																								
LT12	b/g	23 x 17 x 4	N/S	N/A	N/S																							
LT13	b/g	23 x 12 x 3	N/S	N/A	N/S																							
LT14	a/b/g	40 x 23 x 5	1-11	36-48	1-5																							
LT15	b/g	28 x 24 x 4	1-13	N/A	1-6																							

Access Points Selected for Testing



ID	Available Wi-Fi modes	Dimensions L x W x D	Available frequency channels		Settable power levels
			2.4 GHz	5 GHz	
AP01	b/g/n	21 x 16 x 4	1-13	N/A	Not selectable
AP02	a/b/g	23 x 16 x 4	1-11	36-48	1-5 (each)
AP03	a/b/g/n	17 x 6	1-13	36-48	doubles
AP04	b/g/n	22 x 15 x 4	1-13	N/A	Any level to max
AP05	b/g/n	17 x 17 x 4	1-13	N/A	Not selectable
AP06	b/g	14 x 14 x 3	1-13	N/A	Not selectable
AP07	a/b/g	10 x 10 x 4	1-13	36-64	Not selectable
				100-140	Any level to max
				149-165	1-5 (each)
AP08	b/g	22 x 16 x 4	1-13	N/A	doubles
AP09	a/b/g/n	21 x 18 x 5	1-11	36-48	Not selectable
AP10	a/b/g	19 x 19 x 3	1-13	N/S	7 steps to max
AP12	a/b/g	17 x 5	1-13	N/A	Any level to max
AP13	b/g	23 x 18 x 4	1-13	36-48	Not selectable



- Mixture of internal patch antennas and external monopoles
- From zero to three antennas visible externally

3) Laboratory Measurements



- Technical Aspects
- Emissions

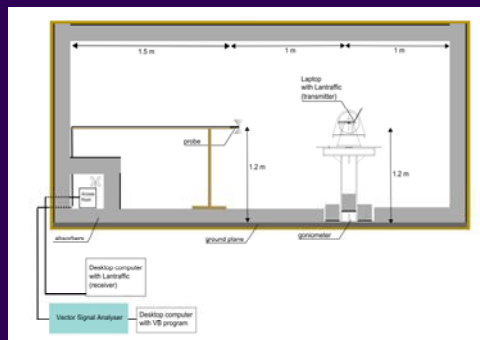
Experimental Facilities Built at HPA Chilton (CRCE)



- Anechoic chamber (3.6 m × 2.4 m × 2.4 m)
- Angular positioner
- Access point
- Receiving antenna
- Signal analyser
- Wi-Fi traffic generator
- Software acquires electric field strength
 - Angular distribution
 - Function of distance



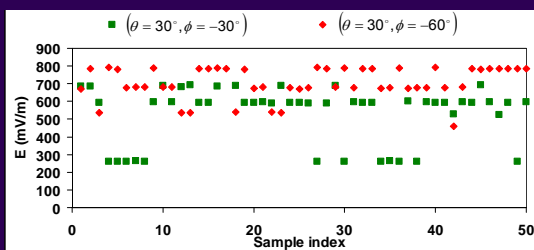
Elevation of Layout Inside Anechoic Chamber



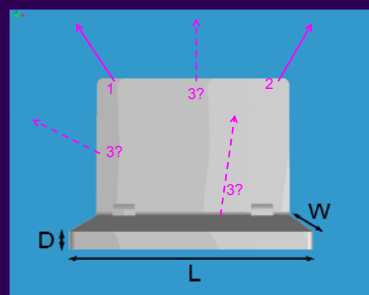
Effect of Switched Antenna Diversity



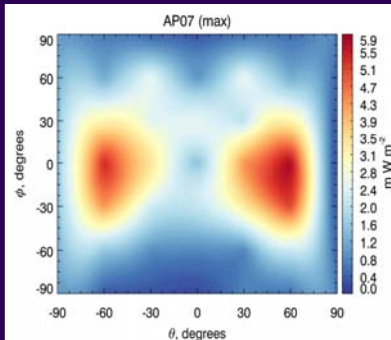
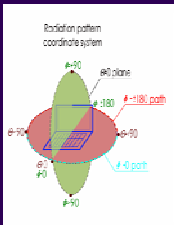
- Field strength measured during 50 captured bursts at each position
- Two (or sometimes three) different levels found



Typical Antenna Locations in Laptops



Angular Distribution of Power Density



Spherically Integrated Radiated Powers in mW



Laptop	Frequency Band	
	2.4 GHz	5 GHz
LT01	9	
LT02	17	
LT03	15	
LT04	12	9
LT05	5	4
LT06	11	
LT07	11	16
LT08	9	5
LT09	16	1
LT10	10	6
LT11	9	13
LT12	15	
LT13	8	
LT14	11	4
LT15	8	

Access Point	Frequency Band	
	2.4 GHz	5 GHz
AP01	20	
AP02	24	9
AP03	28	29
AP04	8	
AP05	6	
AP06	5	
AP07	12	29
AP08	9	
AP09	3	3
AP10	10	25
AP12	7	7
AP13	8	

Access point powers integrated over a hemisphere

Summary of Laboratory Measurements



- Laboratory measurements have been carried out with examples of Wi-Fi devices used in UK schools.
- The spherically-integrated radiated power (IRP) ranged from 5 to 17 mW for 15 laptops in the 2.45 GHz band and from 1 to 16 mW for eight laptops in the 5 GHz band.
- For practical reasons and because access points are generally wall-mounted with beams directed into the rooms, their powers were integrated over a hemisphere. These ranged from 3 to 28 mW for 12 access points at 2.4 GHz and from 3 to 29 mW for six access points at 5 GHz

Payman A, Khalid M, Calderon C, Addison D, Mee T, Maslanyj M, Mann S (2011). Assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools; results of laboratory measurements. Health Physics, 100(6), 594-612.

4) Calculations of SAR



- Exposure Scenarios
- Localised SARs

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Wi-Fi Exposure Scenarios and SAR



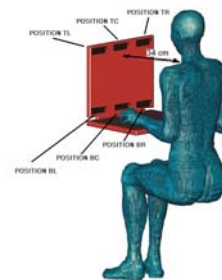
FDTD calculations have been performed at 2.4 and 5 GHz using a voxel model of a 10 year old child

- Scaled from the NORMAN adult phantom
- Posture adjusted to a seating position

The study presented whole-body and peak localised specific energy absorption rates (SAR) from a variety of exposure conditions

- Plane wave exposure
- Exposure from dipole antennas in the near-field
- Exposure from antennas on a model laptop computer

Antenna positions on the laptop



Wi-Fi Exposure Scenarios and SAR

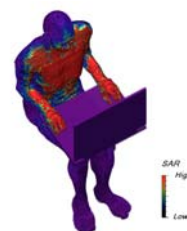


In all situations studied, the SAR values calculated were considerably below basic restrictions

- For a typical Wi-Fi exposure configuration using an inverted F antenna operating at 100 mW, a duty factor of 0.1, the maximum peak localised SAR was found to be 3.99 mW kg^{-1} in the torso region
- At 2.4 GHz, using a power of 100 mW and a duty factor of 1, the highest localised SAR value in the head was calculated as 5.7 mW kg^{-1} . This represents less than 1% of the SAR previously calculated in the head for a typical mobile phone exposure condition

Findlay RP and Dimbylow PJ (2010). SAR in a child voxel phantom from exposure to wireless computer networks (Wi-Fi). Physics in Medicine and Biology, 55(15).

SAR Intensity Plot



Irradiation of NORMAN from the front, using an inverted-F antenna mounted on a laptop, under isolated conditions at 2.4 GHz

5) Duty Factors

- Signal quality/strength
- Measurement methods
- Monitoring networks in schools

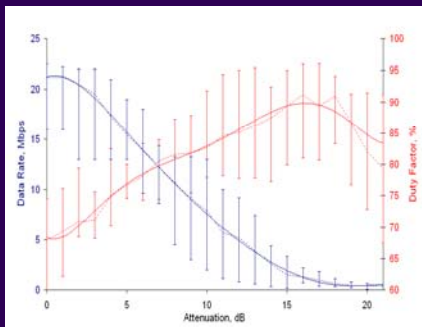
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Data Rates Provided by IEEE802.11 Devices

Availability	Data rate, Mb s ⁻¹	Modulation		
		Type	Variant	Coding
801.11	1	DSSS	BPSK	
	2	DSSS	QPSK	
802.11b/g	5.5	DSSS	CCK	
	11	DSSS	CCK	
802.11a/g	6	OFDM	BPSK	1/2
	9	OFDM	BPSK	3/4
	12	OFDM	QPSK	1/2
	18	OFDM	QPSK	3/4
	24	OFDM	16QAM	1/2
	36	OFDM	16QAM	3/4
	48	OFDM	64QAM	2/3
	54	OFDM	64QAM	3/4

Duty Factor Dependencies

- Data rate
- Modulation scheme
- Packet structure
- Signal attenuation
- Other conditions



Monitoring of Duty Factors in Schools' Networks

Packet capture software

- Laptop brought into classroom
- Wireshark software used with AirPCap adaptor
- Identifies source IP address from captured bursts

Transmit time accumulators

- Small sensors taped near/over transmitting antennas
- Gated counter evaluates cumulative transmit time

Transmit Time Accumulators



Summary of Duty Factor Results


- Data gathered for 135 laptops and access points associated with 7 school networks
- During a 30 min sampling period
 - Laptops transmitted up to 17 sec, giving duty factors of less than 1%
 - Access points transmitted up to 280 sec, implying duty factors of less than 12%
 - Baseline duty factor of access points is around 1% due to beacon pulses (10 per second of ~1 ms duration)
- Time averaged powers of devices, especially laptops, are much less than the burst powers measured in the laboratory

7) Conclusions




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Summary



- Transmitted powers from the measured laptops were up to around 20 mW, but duty factors of around 1%, imply time-averaged powers of up to 200 μW
- Computer modelling with this time-averaged power suggests maximum localised SARs of around
 - 80 $\mu\text{W kg}^{-1}$ in the torso
 - 10 $\mu\text{W kg}^{-1}$ in the head
- Transmitted powers from the measured access points were up to 30 mW when integrated over a hemisphere
 - Potentially up to 60 mW in total

Conclusion




- Results consistent with HPA's present position that exposures are
 - well within exposure guidelines and
 - less than from mobile phones

Health Risk Review

- These results are being shared with AGNIR for consideration in its presently ongoing review of RF exposures and health


HPA Position on Wi-Fi



- The frequencies used are broadly the same as those from other RF applications such as FM radio, TV and mobile phones
- There is no consistent evidence to date that Wi-Fi and WLANs adversely affect the health of the general population
- Results so far show RF exposures are likely to be well within internationally accepted (ICNIRP) guidelines
- Based on current knowledge and experience, exposures from Wi-Fi are lower than those from mobile phones
- There is no reason why Wi-Fi should not continue to be used in schools. However with any new technology it is a sensible precautionary approach, as happened with mobile phones, to keep the situation under ongoing review

<http://www.hpa.org.uk/HPA/Topics/Radiation/UnderstandingRadiation/UnderstandingRadiationTopics/ElectromagneticFields/WiFi>

Thank You



Any questions.....

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