Wi-Fi in schools

Azadeh Peyman and Simon Mann of the Health Protection Agency's Physical Dosimetry Department report progress in the assessment of exposure to electromagnetic fields from wireless computer networks (Wi-Fi) in schools.

During the last few years, the use of wireless local area networks (WLAN) has increased rapidly, offering flexibility and mobility to the users. This has made the technology popular amongst a wide range of users, including the education sector. According to the British Educational Communications and Technology Agency (BECTA, 2007), 50 per cent of primary schools and 82 per cent of secondary schools reported making at least some use of wireless network technology. Also, in 23 per cent of primary schools and 22 per cent of secondary schools, either all or a substantial portion of their network was wireless.

Children in a primary school using Wi-Fi equipped laptops **Photo:** HPA

In WLAN, the most popular technology often used for the wireless portion of the network is known as Wi-Fi. Through the use of this technology devices and computers are connected to the Local Area Network (LAN) wirelessly, eliminating or reducing the need for wired Ethernet. In such set-ups all devices must be equipped with antennas that transmit and receive radio waves in order to allow wireless connection. Terminal devices such as laptop computers are known as 'clients' and the point of entry to the wired network is referred to as an 'access point', usually located within a few tens of metres and in the same building. People using Wi-Fi, or those in the proximity of Wi-Fi equipment, are exposed to the radio signals emitted from it and will absorb some of the transmitted energy in their bodies.

The output power of Wi-Fi equipment is restricted to a maximum of 100 mW in Europe at the most popular 2.4 GHz (gigahertz) frequency band. Currently, there are no expectations that exposure to radiowaves from Wi-Fi sources will exceed guideline levels from the International Commission on Non-Ionizing Radiation Protection (ICNIRP), as recommended by the Agency for use in the UK.

Nevertheless, this is a rapidly developing area of technology. Given the existing precautionary advice from the chief medical officer and from the Agency (as the successor to NRPB) to discourage non-essential use of mobile phones by children, it is important to quantify the exposure from Wi-Fi equipment, as used by pupils, and consider how the exposures from Wi-Fi compare with those from mobile phones and other commonly used radio equipment.

For this reason, the Board of the Agency announced on 12 October 2007 that it would carry out a systematic programme of research into wireless local area networks (WLANs) and their use. The project was initiated within the framework of the agency's R&D development fund and planned over two years.

Project's objectives

The project's objectives are summarised as follows:

- review of technical standards and wireless equipment used in UK schools
- procurement and setting up of Wi-Fi test facilities
- procurement of a selection of Wi-Fi terminals (laptops and other devices) and access points for testing
- laboratory measurements of the electromagnetic field strengths around the selected devices during transmission and calculations of radiated powers
- measurements of the proportion of the time that individual Wi-Fi computers transmit during typical school lessons
- computer modelling of the specific energy absorption rate (SAR) produced in the body when using Wi-Fi equipment under various scenarios
- health risk review drawing on the above exposure measurements and modelling.

The majority of the experimental work in the project was planned as laboratory-based because it is possible to do more carefully controlled measurements on the equipment used in schools if the measurements are made in a laboratory environment. However, it is planned to make some measurements in schools, because it is difficult to simulate in the laboratory a real classroom network and the data traffic generated by pupils.

During the course of the Wi-Fi project, the Agency held several discussions with organisations such as BECTA, which have a detailed knowledge of the range of equipment used in schools and how it is configured. The Department for Children Schools and Families (DCSF) and the Department of Health (DH) were also involved in discussions with the Agency while the project was being set up. A link to the industry was also sought through the Wi-Fi Alliance (WFA) to clarify and confirm the technical characteristics of Wi-Fi equipment in schools.

WLAN technology

WLAN technologies operating in certain frequency bands near 2.4 and 5 GHz are 'licence exempt', and the bandwidth is shared between users. The widespread growth of WLANs makes for a market comprised of several competing technologies. It is therefore the role of standardisation bodies to ensure product compatibility and reliability among the various manufacturers.

Technical standards

The most widely used technical standards are produced by the US-based Institute of Electrical and Electronic Engineers (IEEE). The IEEE802.11x family of standards specifies the technical configuration of Wi-Fi technology. The original 802.11 specified the standard for WLANs, providing for 1 Mbps (megabits per second) and 2 Mbps data rates. However, to address the need for supporting higher data transmission rates, the IEEE introduced 802.11b for rates of up to 11 Mbps in the 2.4 GHz band. Standards 802.11a, 802.11g and 802.11n were later developed to attain higher data rates (up to 74 Mbps) and exploit the 5 GHz band to avoid overcrowding in the 2.4 GHz frequency band.

Regulatory standards

In Europe, the European Telecommunications Standards Institute (ETSI) plays the role of harmonising the equipment in terms of compliance with regulatory requirements in relation to the use of the radio spectrum. For example, ETSI's harmonised standard EN 300 328 limits the maximum power for any system operating in the 2.4 GHz band to 100 mW.

At national level, Ofcom (the Office of Communications) requires compliance to the Interface Requirement (IR) which limits the maximum transmit power at the frequency band of 2.4 to 100 mW and stipulates that devices operating in band of 5 GHz may only be operated indoors and must have a maximum of 200 mW (IR 2005 and 2006).

Exposure to WLAN sources

The parameters that can affect the exposure of people to WLAN sources include distance, operation frequency, output power and antenna configuration.

Distance: while not intimately related to the particular source, the fact that the antennas inside laptops are small (a few cm diameter) in relation to the distance from laptop to the user in usual situations means that exposure reduces very rapidly with increasing distance, broadly according to the inverse square law.

Frequency: radio waves become less penetrating into body tissues as frequency increases. The electric field component of a wave penetrating into the body reduces to 36 per cent of its initial value after a distance known as the skin depth. The skin depths of tissues with low water content such as fat and bone are greater than those with lower water content such as muscle and skin.

Output power: power absorption in body tissues is proportional to the output power of a device for a given exposure scenario. As mentioned before, in Europe, the output power is defined in terms of the maximum equivalent isotropic radiated power (EIRP) and is limited to 100 mW in the 2.4 GHz band and 200 mW in the 5 GHz band (indoor).

Antenna configurations: ideally WLAN antennas would radiate their power equally in all directions but real antennas tend to radiate preferentially in certain directions and have nulls in certain other directions. From the perspective of exposure of a laptop user, the extent to which the antennas direct the radiated power towards the user is a key factor. In addition, the international exposure guidelines from ICNIRP are based on power absorption in the body tissues averaged over 6 minutes. Since WLAN devices transmit brief pulses (bursts) and the *duty factor* - the ratio of the pulse duration to the pulse period of transmission - of Access Points is usually low, the time-averaged exposure should be far below that produced by a continuous source operating at the same peak power level.

WLAN in UK schools

WLAN standards in schools

According to BECTA (2007), the most widely used standard in schools was 802.11g, where two-thirds of primary and 80 per cent of secondary schools had equipment operating at this level. Either in combination or exclusively, a third of primary and 46 per cent of secondary schools provided 802.11b. Some schools were also

Children in a primary school using Wi-Fi equipped laptops **Photo:** HPA

A typical ICT suite in a primary school equipped with laptop trolleys **Photo:** HPA beginning to make use of the 802.11n standard. Discussions with suppliers of educational resources revealed no particular trend in the chosen wireless standards in schools.

Wireless devices in schools

Discussions with BECTA and the Wi-Fi Alliance as well as some of the major suppliers of educational resources to the schools revealed that laptops are the most popular wireless devices used in schools, where up to 32 can be used in a single classroom simultaneously.

Increasingly, primary schools are making the use of 'notebuses', which consist of a trolley (bus) with 8 or more laptops and with the access point installed inside the bus.

Most laptops are now equipped with built-in WLAN devices, where the antennas are usually mounted above or around the screen. There are typically up to three antennas in each device, but they don't operate at the same time, and switch from one to another. In order to establish a wireless connection, access points are used in the classrooms and the number of access points depends on the size and structure of the building. A typical small primary school can have four or five access points while in larger schools the network can consist of up to 100 access points.

Interactive white boards are also increasingly used in schools with educational software to cover the curriculum. The option of Wi-Fi connectivity is available for most of the interactive whiteboards. Other wireless devices popular in schools are thin clients, wireless slates and tablet PCs, as well as wireless microphones. Some schools have obtained wireless voting systems to improve the marking and evaluation of the lessons. The widespread use of wireless location and asset tracking systems in schools is also predicted. Wireless CCTV systems are also becoming popular in schools.

Laboratory measurements

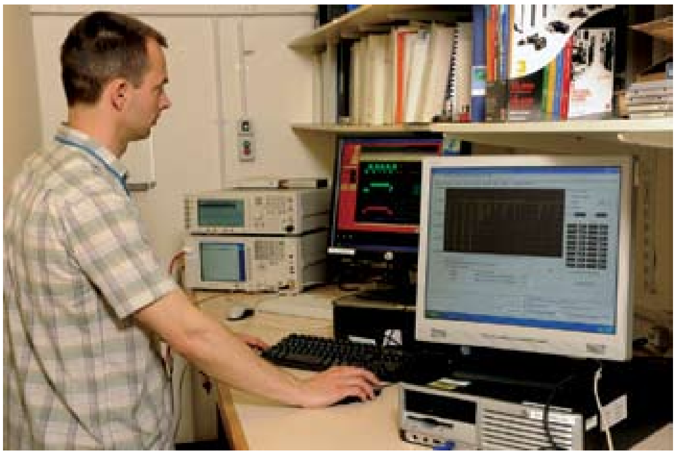
Due to the popularity of laptops in classrooms and the fact that the majority of Wi-Fi exposure would come from these devices because they are generally nearer to children than the access points, it was decided that the experimental measurements would begin with laptops.

As part of the procurement strategy, a few suppliers were identified from a list of companies in BECTA's Infrastructure Services Framework. Fifteen laptops were chosen from among the most popular models used by the education sector in the UK.

The objective of the laboratory measurements was to establish the radiation pattern, i.e. the angular distribution of electric field strength around each laptop, and identify the angles at which the field was a maximum. The electric field strength at these angles was then measured as a function of distance. The measurements were carried out within an anechoic chamber lined internally with radiofrequency absorber material, and with a purpose-built manual positioning system.

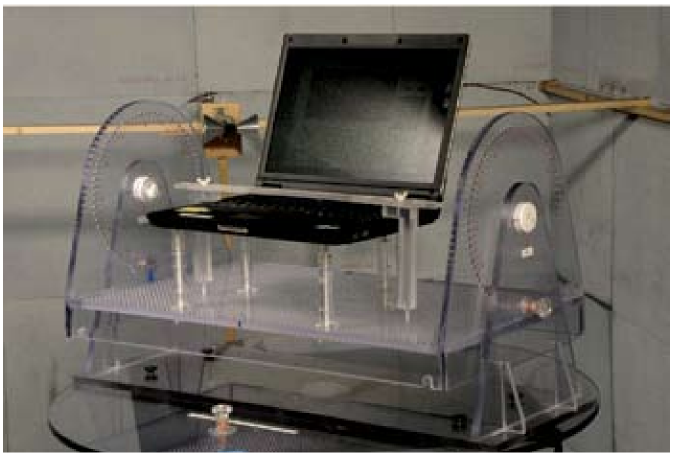
Dedicated software (LanTraffic) was used to generate and monitor the Wi-Fi signal from the laptops, set to transmit at roughly 22 Mbps, the maximum sustained rate that could be reliably maintained using the IEEE 802.11g standard. The screen of the laptops was opened to an angle of 115 degrees, a typical angle in which users operate their devices.

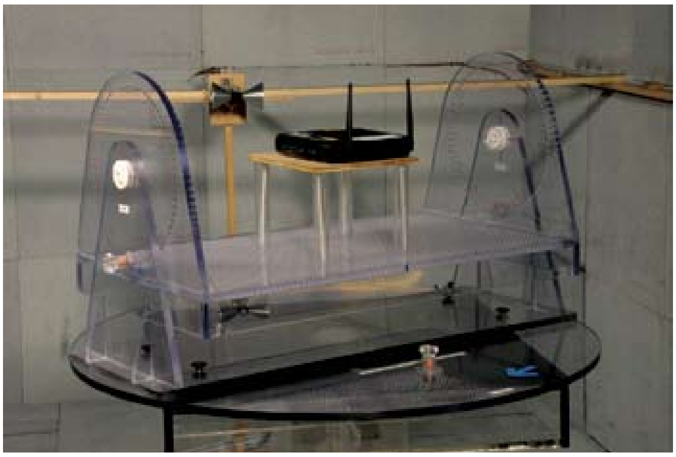
To analyse the transmitted Wi-Fi signals, a signal analyser was used with a bandwidth of 25 MHz allowing the detection of the whole WLAN signal. Unlike spectrum analysers, which have bandwidth less than that of Wi-Fi signals (typically a maximum of 5 MHz), the signal analyser instrument captures individual Wi-Fi bursts in the time domain and demodulates them to identify the burst power, and many other parameters. For this work, the power of 50 bursts was measured at each position and then analysed in terms of the statistical distribution.



Wi-Fi transmission set up and signal analyser control for field measurements around laptops and access points, EMF laboratory, HPA Chilton site **Photo:** HPA

The manual positioning system rotates in azimuth and elevation directions in 30° steps **Photo:** HPA





Setup for assessing the electric field distribution around a laptop, EMF laboratory, HPA Chilton site **Photo:** HPA

Electric field measurement around an access point, EMF laboratory, HPA Chilton site **Photo:** HPA

To establish the radiation pattern, the electric field strength at 1 m distance from the laptop was measured by an ARC Seibersdorf miniature biconical antenna in horizontal and vertical polarisations for azimuth and elevation rotations in 30° steps for each laptop on the manual positioning system (168 positions in total). The measured electric field data were then analysed and the angles of maximum radiation were identified. The manual positioning system was then set up at these maximum angles and the electric field strength was measured in 10 cm steps from 0.5 m to 1.9 m for each laptop.

The results of laboratory measurements have so far showed that, for a given position, the power level fluctuated between two (and sometimes three) distinct levels because of the use of switched diversity with several antennas within each laptop. Overall, similar radiation pattern measurements for all 15 laptops have been observed with a minimum in the direction from the front of the laptop (towards the torso of the user). Generally, two angular maxima were observed that were symmetrically opposed across a vertical plane bisecting the screen and keyboard. All 15 laptops tested had electric field strength values indicating they had output powers well below the 100 mW (EIRP) limit. The highest recorded EIRP was 57 mW.

Further work

The second phase of laboratory measurements includes the assessment of the electric field strength around access points operating at 2.4 GHz. In addition, measurements will be carried out on a selection of laptops and access points operating in the 5 GHz band.

Further work will then involve the modelling of Wi-Fi equipment and its internal RF structures (antennas) in order to assess the localised specific energy absorption rates (SARs) in children. In addition, measurements of radiated powers and transmit time proportions in schools are planned. Finally, an overall health risk review will be carried out.

Dr. Azadeh Peyman is a senior radiation protection scientist in the Physical Dosimetry Department at the Agency's Radiation Protection Division. She has extensive research experience on the interaction mechanisms of electromagnetic fields with biological tissues. Her current research includes the assessment of exposure of people to electromagnetic fields. Before joining the HPA, she worked as a consultant for Microwave Consultants Ltd., where she researched the dielectric properties of biological tissues, which contributed substantially to the debate on the extent to which children's exposure to electromagnetic fields may be different from adults.

Dr. Simon Mann is head of the Physical Dosimetry Department at the Agency's Radiation Protection Division. In 15 years with the Agency and its predecessors he has specialised in electromagnetic field exposure assessments. He has a strong interest in improving epidemiological studies through better exposure assessments and has worked on occupational exposure to radio frequency fields and public exposure to radio signals from mobile phones and their associated base stations. Dr Mann is a member of ICNIRP's Standing Committee III (Physics and Engineering), a UK delegate in the European technical standards process for electromagnetic fields, and leads for the Agency in the WHO's international EMF Project.

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REFERENCES

Wireless Technology in Schools 2007 C3 Education for The National Education Research Panel (NERP)

ICNIRP (1998) Guidelines for Limiting Exposure to Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)

Advice on Limiting Exposure to Electromagnetic Fields (0-300 GHz), 2004 Documents of the NRPB: Volume 15 , No. 2

UK Interface Requirement (2005) UK Radio Interface Requirement for Wideband Transmission Systems operating in the 2.4 GHz ISM Band and **Using Wide Band Modulation Techniques** 98/34/EC Notification number: 2006/420/UK.

UK Interface Requirement (2006) Wireless Access Systems (WAS) including RLANs operating in the 5150-5725 MHz band 98/34/EC Notification number: 2006/421/UK