# Assessment of Exposure to Radiofrequency Radiation from Wireless LANs at Two Isle of Man Schools

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## ABSTRACT

A survey of radiofrequency radiation produced by wireless local area networks (wireless LANs) and other radio transmitters has been carried out at two schools on the Isle of Man on behalf of the Department of Education. These schools were Castle Rushen High School, in Castletown and Rushen Primary School, near Port St Mary. Radio signal power densities were measured at a number of locations and the data were compared with exposure restrictions advised in guidelines, published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The most stringent *basic restrictions* on exposure are those advised by ICNIRP for the general public. These basic restrictions are complied with if the power density does not exceed the ICNIRP *reference level* for exposure of the general public.

The maximum exposure close to a wireless LAN base station was 2000 millionths (0.2%) of the ICNIRP public reference level, this being 60 cm from the Apple AirPort in the Library at Rushen Primary School. The exposure 60 cm from a laptop computer configured for wireless LAN was 22 millionths (0.0022%) of the reference level. Maximum exposures were also evaluated for signals from the microwave dish antennas at the two schools. Within the main beam of the 26 GHz dish at Castle Rushen High School this was 32 millionths (0.0032%) of the ICNIRP public reference level and for the 2.4 GHz dish at Rushen Primary School this was 68 millionths (0.0068%) of the public reference level in the Playground.

The total exposures due to all radio signals with frequencies between 30 MHz and 3 GHz were measured at two locations at both schools and these were dominated by signals from the wireless LANs. As a consequence, the total exposures were not significantly greater than the exposures due solely to the wireless LANs and microwave dishes.

All of the exposures measured at both Castle Rushen High School and Rushen Primary School were well below the ICNIRP guideline levels and are therefore considered not to be hazardous.

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# NON-TECHNICAL SUMMARY

The Department of Education has commissioned the installation of wireless local area networks (LANs) in about 30 primary and secondary schools on the Isle of Man. The networks require wireless LAN base stations (Apple AirPorts) at various locations within each school to direct radio wave signals to and from computer users throughout the school buildings. The base stations transmit radio waves intermittently with frequencies in the range 2.4 to 2.5 GHz. The schools are connected together and to the service provider (Domicilium) by point-to-point microwave links. These externally mounted microwave dish antennas operate at frequencies of either 2.4 or 26 GHz.

A survey of radio waves produced by wireless LAN base stations, microwave dishes and other radio transmitters has been carried out at Castle Rushen High School, in Castletown and Rushen Primary School, near Port St Mary on behalf of the Department of Education. Radio wave signals were measured at a number of locations and the results were compared with exposure restrictions advised in guidelines, published by the International Commission on Non-Ionizing Radiation Protection (ICNIRP).

The ICNIRP guidelines incorporate two levels of protection: one set of values for occupational exposure and another, more restrictive, set for the general public, which includes children. The guidelines are complied with if the radio wave exposure does not exceed these *reference levels*.

The maximum exposure close to a wireless LAN base station was 2000 millionths (0.2%) of the ICNIRP public reference level, this being 60 cm from the Apple AirPort in the Library at Rushen Primary School. The exposure 60 cm from a laptop computer configured for wireless LAN was 22 millionths (0.0022%) of the public reference level. Maximum exposures were also evaluated for signals from the microwave dish antennas at the two schools. Within the main beam of the 26 GHz dish at Castle Rushen High School this was 32 millionths (0.0032%) of the ICNIRP public reference level and on the line of the main beam of the 2.4 GHz dish at Rushen Primary School this was 68 millionths (0.0068%) of the public reference level in the Playground.

The total exposures due to all radio wave signals with frequencies between 30 MHz and 3 GHz were measured at two locations at both schools. Signals from distant mobile phone base stations and television broadcast transmitters were detected, however the greatest contributions to exposure were from the wireless LANs. As a consequence, the total exposures were not significantly greater than those due solely to the wireless LANs base stations and microwave dishes.

All of the exposures measured at both Castle Rushen High School and Rushen Primary School were well below the ICNIRP guideline levels and are therefore considered not to be hazardous. No further action is considered necessary, although it is suggested that the results of this work should be disseminated to the schools.

# CONTENTS

# 1 INTRODUCTION

The National Radiological Protection Board (NRPB) is an independent scientific organisation set up by the Radiological Protection Act 1970, as extended in 1974, with the responsibility to provide advice on the protection of people from radiation hazards. In 2002 it was announced that NRPB would form part of the Health Protection Agency (HPA) that was subsequently established in 2003. The incorporation of NRPB into the HPA is likely to occur in April 2005 and until then the two organisations are expected to work in close partnership. NRPB is able to provide technical services such as workplace monitoring and hazard assessments to determine compliance with electromagnetic field exposure guidelines. Staff from NRPB's Occupational Services Department carried out the work described in this report.

The Department of Education has commissioned the installation of wireless local area networks (LANs) in about 30 primary and secondary schools on the Isle of Man. Wireless LAN base stations installed at various locations within each school direct radio signals to and from computer users throughout the school buildings. The schools are connected together and to the service provider (Domicilium) by point-to-point microwave links using dish antennas. The Department of Education contracted NRPB to carry out an assessment of human exposure to the radiofrequency radiation produced by the wireless LANs at Castle Rushen High School, in Castletown and Rushen Primary School, near Port St Mary. The work included measurements of power density of the radio signals emitted by the wireless LAN base stations, microwave dish antennas and also from other radio transmitters operating in the 30 MHz to 3 GHz frequency range. The subsequent analysis included an assessment of the exposure at each location and a comparison of the relative contribution to the total exposure from the wireless LAN devices.

The measurements were carried out on 8, 9 and 10 December 2003 by the authors of this report.

An overview of the operation of wireless LANs and point-to-point microwave links is presented in the next section of this report. Other sources of radio waves that often contribute to people's exposures in the UK are also described briefly. The guidelines on exposure to electromagnetic fields issued by ICNIRP and NRPB's understanding of the current policy position in respect of adopting guidelines in the UK are summarised in Section 3. The equipment used to measure power density and the techniques employed during the survey are discussed in Section 4. The results of the survey are reported in Section 5, including an analysis to identify the most significant contributor to the total exposure at several locations. The overall conclusions of the assessment are given in Section 6.

# 2 DESCRIPTION OF SOURCES

## 2.1 Wireless LANs

The operation of the wireless LANs that have been installed at the schools is based on the 802.11b-1999 Standard for Information Technology published by the Institute of Electrical and Electronics Engineers (IEEE). The base stations (also known as access points or "hubs") for the networks are located throughout the schools and provide coverage for the majority of the school buildings. A network of laptop computers is served by a series of Apple AirPort base stations.

The frequency band 2.4 to 2.4835 GHz has been allocated to wireless LANs in the UK, in accordance with European Standard EN 300 328, published by the European Telecommunications Standards Institute (ETSI). The IEEE Standard specifies 13 channels within this band with centre frequencies ranging from 2.412 GHz to 2.472 GHz, and a channel spacing of 5 MHz. Each base station of a network and the computer terminals (known as clients) that it serves, all transmit on the same channel, though not at the same time. Time slots are allocated to different devices using the method of time division multiple access (TDMA).

The ETSI standard specifies a maximum effective radiated power of 100 mW for wireless LAN devices. The Apple AirPort base stations that have been installed throughout the schools are shown in Picture 1.

Laptop computers communicate with the base stations via antennas that are either inside the laptop ('Centrino Mobile Technology') or built into a 'Buffalo' card inserted into the PCMCIA port, as shown in Picture 2.


**Picture 1 Two Apple AirPort base stations at Rushen Primary School**


**Picture 2 Laptop computers configured for wireless LAN with Centrino Mobile Technology (left) and a Buffalo card in the PCMCIA port (right)**

## 2.2 Microwave dish antennas

The schools are connected together and to the service provider by point-to-point microwave links using dish antennas mounted high on external walls of the buildings. There were two 2.4 GHz 'Radio Waves Parabolic Subscriber Antennas' and one 26 GHz 'Andrews' dish antenna at Castle Rushen High School. Similarly, there were two 2.4 GHz Radio Waves antennas at Rushen Primary School. Table 1 gives the characteristics of these two types of dish antenna.

**Table 1 Characteristics of the microwave dish antennas at the two Manx schools**

| Dish type | Dish size (mm) | Transmit frequency (GHz) | Beam width (°) | Gain (dBi) | Radiated power | |
|---|---|---|---|---|---|---|
| | | | | | (dBm) | (mW) |
| Radio Waves SP2-2.4 | 600 | 2.4 to 2.5 | 28 | 14 | 12 | 16 |
| Andrews VHLP2-240 | 600 | 26.3 | 1.2 | 41.1 | 15 | 32 |

The general principle of beam formation is illustrated in Figure 1. The nature of point-to-point communication involving microwave dish antennas is such that the beams are not directed towards the ground or at buildings, as they must have a clear line of sight to the receiving antenna at the distant site. As a consequence of this and the very low radiated powers (see Table 1) the exposures at ground level produced by signals from microwave dish antennas will be a small fraction of the guideline levels.

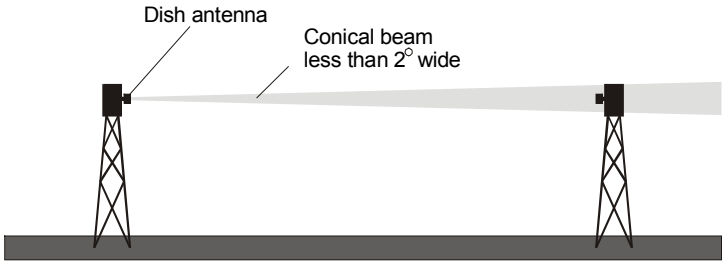



**Figure 1 Pair of dish antennas used for a point-to-point microwave link**

## 2.3 Other environmental radio transmitters

In addition to the signals from the wireless LANs and microwave dish antennas that were of primary interest to the survey, radio signals were measured from a variety of other transmitters in the environment. The measured frequencies of these signals gave an indication of their likely purpose through references such as the radio spectrum allocation tables published by the Office of Communications (Ofcom formerly the Radiocommunications Agency) (http://www.ofcom.org.uk/static/archive/ra/topics/spectrum-strat/uk-fat/uk-fat2002.htm) and various technical standards.

Broadcast radio and television signals can be measured wherever the receiving equipment can be used. VHF FM signals are broadcast in the 88–108 MHz frequency band and UHF television signals are broadcast in the 470–860 MHz band. The main broadcast television transmitter for the South of the Island is at Port St Mary (grid reference SC206678).

Base stations for mobile phone networks using the Global System for Mobile Telecommunications (GSM) technical standard transmit frequencies in the bands 935–960 MHz (GSM900) and 1805–1880 MHz (GSM1800). Those using the third generation (3G) Universal Mobile Telecommunications System (UMTS) transmit frequencies in the bands 2010–2025 MHz and 2110–2170 MHz.

Other signals often measured in the environment are those for wide-area paging and a variety of analogue professional radio systems operating in the VHF and UHF bands up to 470 MHz. Digital professional radio is currently being deployed using the Terrestrial Trunked Radio (TETRA) system operating at around 400 MHz.

# 3 GUIDELINES ON EXPOSURE TO ELECTROMAGNETIC FIELDS

In 1993 NRPB published guidelines on restrictions on human exposure to static and time-varying electromagnetic fields and radiation (NRPB 1993). Since that time there has been a considerable amount of research published and, importantly, the International Commission on Non-Ionizing Radiation Protection (ICNIRP) has published exposure guidelines covering the same frequency range (ICNIRP 1998a,b). ICNIRP is an independent scientific organisation responsible for providing guidance and advice on the health hazards of exposure to non-ionising radiation.

Recently, following a thorough review of the current scientific knowledge on the effects of EMFs and an extensive consultation exercise the Board of NRPB has recommended the adoption in the UK of the ICNIRP guidelines (NRPB 2004). The Board recognises the need to adopt a cautious approach in the interpretation of scientific knowledge and the benefits of common international guidelines. The full statement by NRPB is included in Appendix A to this report.

The recommendations made by NRPB and the guidelines published by ICNIRP represent scientific advice, however it is for policy makers to determine how the guidelines should be adopted. This section begins by explaining the framework of the guidelines and the applicable exposure restrictions. It then summarises the current UK position, as understood by NRPB and concludes with a brief review of European product safety directives applicable to wireless LAN devices.

## 3.1 Basis of ICNIRP guidelines

The survey carried out for the Department of Education was concerned only with exposure to electromagnetic fields with frequencies greater than 10 MHz. The established adverse effects of exposure to such fields arise at levels of exposure where appreciable heating of the body tissues is able to occur due to the absorption of the energy carried by radio waves. Heating can occur, either in parts of the body due to localised absorption of energy, or more generally throughout the body. Consequently, the ICNIRP guidelines specify *basic restrictions* to cover both situations and they must all be complied with to ensure compliance with the guidelines. The basic restrictions are expressed in terms of the specific absorption rate (SAR) of energy.

The ICNIRP guidelines incorporate two tiers of protection: one set of values for occupational exposure and another, more restrictive, set for general public exposure.

## 3.2 Reference levels

SARs are not easily measurable in living people, therefore the ICNIRP guidelines specify *reference levels* in terms of field strengths and power densities. These are derived so that the basic restrictions cannot be exceeded under certain conservative exposure conditions. If a reference level is exceeded, then a more detailed investigation of the resultant SAR distribution in the body is necessary.

Coupling of the body to an electromagnetic field varies with frequency and it is strongest at frequencies around 40–80 MHz. In this frequency range, the wavelength of the electromagnetic field is comparable in size to that of the body dimensions so that resonance occurs, as with an antenna. The reference levels are therefore most restrictive in this part of the spectrum. A graph showing the variation of the reference levels with frequency is shown in Figure 2. The reference level for general public exposure is five times below the occupational reference level, reflecting the difference between the basic restrictions. The ICNIRP reference levels that apply at the frequencies used by the wireless LANs and microwave dishes are given in Table 2.

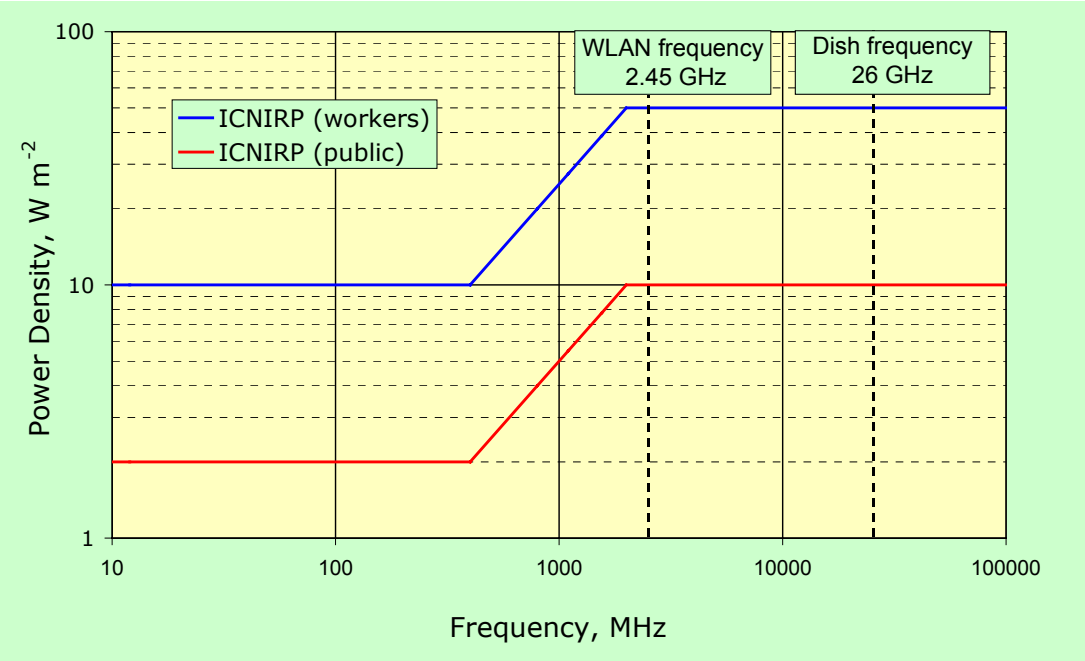



**Figure 2 ICNIRP reference levels for power density at frequencies between 10 MHz and 100 GHz**

**TABLE 2 ICNIRP reference levels for power density that apply at frequencies in the range 2–300 GHz.**

| Scope | Power density (W $m^{-2}$) |
|---|---|
| Occupational | 50 |
| General public | 10 |

## 3.3 Adoption of guidelines

Currently there is no specific legislation in the UK relating to human exposure to electromagnetic fields. However the Council of the European Union has published a recommendation on the limitation of exposure of the general public to electromagnetic fields on 12 July 1999 (CEU 1999) and this document incorporates the ICNIRP guideline values for general public exposure.

Furthermore, on 7 April 2004 the Council of the European Union adopted a Directive aimed at protecting workers from the adverse effects of exposure to electromagnetic fields (CEU 2003). The Directive gives priority to reducing risks at source, through preventative measures related to workstation design, work equipment design, procedure and methods. It attributes responsibility to employers for assessing exposure levels, adopting preventative measures and arranging for information and training for their workers. The Directive incorporates the ICNIRP guideline values for occupational exposure. The expectation is that the Directive will be transposed into UK regulations in 2008. More information on this subject may be obtained from the Health and Safety Executive's web site at http://www.hse.gov.uk/radiation/nonionising/issues.htm.

At present in the UK, the HSE expects employers to follow NRPB advice on EMFs as evidence that they have carried out their duties under the Health and Safety at Work etc Act 1974 and the Management of Health and Safety at Work Regulations 1999. Regulation 3 of the MHSWR99 requires employers to make a suitable and sufficient assessment of risks to health and safety. However, in the light of the above mentioned European Directive, HSE recommends that employers start preparing as soon as possible to comply with this forthcoming law.

## 3.4 European product safety directives

Wireless LAN devices bearing the CE mark should satisfy the essential requirements of the Radio and Telecommunications Terminal Equipment Directive (1999/5/EC). This directive extends the objectives with respect to safety requirements contained in the Low Voltage Directive (73/23/EEC) in order to apply to all apparatus, with no voltage limit applying (see Article 3, Point 1a). In the Low Voltage Directive it is stated that measures of a technical nature should be prescribed in order to ensure that temperatures, arcs or radiation which would cause a danger are not produced (see Point 1 in Article 2 and Annex I, Part 2b). The text of these directives can be accessed through the following web page: http://europa.eu.int/comm/enterprise/newapproach/standardization/harmstds/reflist.html.

The European Commission has issued a Standardisation Mandate to European electrical standards bodies for them to develop technical standards to enable a presumption of conformity of products with the above Directive Articles. The standards bodies are asked to take into account the basic restrictions and reference levels in the Council Recommendation. The text of the Mandate is accessible through the following web page: http://europa.eu.int/comm/

enterprise/electr_equipment/lv/mandate.htm. The European Committee for Electrotechnical Standardization (CENELEC) has produced a generic product standard to demonstrate the compliance of electronic and electrical apparatus with the basic restrictions. The generic standard (BS EN 50392) has been published in the UK by the British Standards Institution (BSI).

# 4 MEASURING EQUIPMENT AND SURVEYING TECHNIQUES

Measurements of power density were made using narrowband instrumentation and portable broadband measurement instrumentation. The two types of instrumentation and the methods employed in their use are described below.

## 4.1 Narrowband instrumentation

Sensitive equipment was required for measuring the weak radio signals that were found at the locations surveyed at the two schools. The system employed for this purpose consisted of a spectrum analyser connected to one of a choice of antennas via a coaxial cable. This set-up allowed measurements to be made over a range of frequencies using a narrow bandwidth, which made possible the detection of power densities considerably below 1 $\mu$W m$^{-2}$. The data collected by the spectrum analyser were transferred to a laptop computer and stored for subsequent analysis.

### 4.1.1 Antennas

Four broadband antennas were employed in conjunction with the spectrum analyser for measuring electric field strength over different frequency ranges. The antennas were mounted on lightweight tripods providing stable support but permitting their orientation to be varied by hand. Calibration data were available for each antenna in the form of antenna factors evaluated for a number of discrete frequencies. The antennas are listed in Table 3 together with the range of frequencies specified for each model.

**TABLE 3 Antennas used for radiofrequency measurements**

| Manufacturer | Model | Serial number | Type | Frequency range |
|---|---|---|---|---|
| Schaffner-Chase | VBA6106A | 1288 | Biconical | 30–300 MHz |
| Schaffner-Chase | UPA6108 | 1123 | Log-periodic | 300–1000 MHz |
| EMCO | 3115 | 0002-6069 | Ridgeguide | 1–18 GHz |
| EMCO | 3116 | 2103 | Ridgeguide | 18-40 GHz |

### 4.1.2 Spectrum analyser

A Hewlett Packard E4407B spectrum analyser (s/n US39440965) was used to display the frequency and amplitude (in millivolts) of each detected radio signal. The amplitude was converted to power density taking into account the antenna calibrations and losses in the connecting cable.

### 4.1.3 Surveying method for wireless LAN and microwave dish signals

The propagation of radio waves inside buildings is complex due to shielding and shadowing by various objects, reflections from walls and ceilings and re-radiation from conducting structures that are excited by the radio waves. These effects cause the direction and polarisation of radio waves to be unpredictable at a given location and variable over small regions of space. The power density can also be non-uniform over similarly small regions. For these reasons the receiving antenna used for the measurements was positioned as far away as possible from conducting and other perturbing structures at each of the measurement locations. The orientation of the antenna was varied in order to achieve optimal coupling with the electric field at each measurement location.

The power density due to wireless LANs varies considerably over time at any given location depending on whether the base station, one of the clients or no part of the system is transmitting. The modulation method used by wireless LANs also causes the measured power density to vary during a period of transmission. It is appropriate in a hazard assessment to record the maximum power density in order to calculate a worst-case *signal exposure quotient*.

The technique employed for the assessment of the wireless LANs and microwave dishes is a published instrument test application (Mill 2000) involving the measurement of digital signal power. The span of the spectrum analyser was set to fully encompass the signal of interest and the analyser was swept for several minutes with the maximum hold function enabled. The resultant trace was recorded for subsequent analysis of the average signal power density across all sweep increments. This was then corrected according to the method, for the measurement span and resolution bandwidth, to give an estimate of the worst-case power density.

### 4.1.4 Surveying method for other environmental radio signals

A description of the techniques used for performing surveys of environmental levels of radiofrequency radiation has been given in an NRPB report (Mann *et al*. 2000), hence only a brief summary will follow. The intention in measuring signals other than those associated with the wireless LANs and microwave dishes was to record the maximum field strength from every signal in order to calculate a worst-case exposure quotient at each measurement location. The display screen of the spectrum analyser was set to 'maximum hold' in order to record the peak amplitude of each signal during the accumulation time and to facilitate the capture of any intermittent or transient signals. The duration of each measurement was at least one minute. During this time the orientation of the

antenna in use was varied to achieve maximum coupling with radio signals emanating from different directions and having different polarisations.

## 4.2 Portable broadband instrumentation

A portable broadband survey instrument was used to measure power density close to several items of wireless LAN hardware at the two schools. The instrument consisted of a Narda 8712 survey meter (s/n 20007) connected to one of two isotropic electric field probes, also manufactured by Narda Safety Test Solutions. The probes are listed in Table 4 together with the range of frequencies specified for each model. The dynamic range of the instrument was 0.1–200 W $m^{-2}$. The probe was held at arms length and care was taken to maintain a spacing of about 5 cm between the probe and item under examination.

**TABLE 4 Portable probes used for radiofrequency measurements**

| Manufacturer | Model | Serial number | Type | Frequency range |
|---|---|---|---|---|
| Narda | 8761D | 05009 | E field probe | 300 kHz - 3 GHz |
| Narda | 8721D | 08022 | E field probe | 300 MHz - 50 GHz |

# 5 MEASUREMENT RESULTS

This section describes the locations where measurements were made at Castle Rushen High School and Rushen Primary School. The resulting data are compared with the ICNIRP reference levels and are also analysed to determine the relative contributions of radio waves from different categories of radio transmitter to people's total exposure at four of the survey locations.

## 5.1 Survey locations

### 5.1.1 Castle Rushen High School

Castle Rushen High School occupies a fairly modern extended building with a complex layout comprising of both single storey and double storey buildings. Plans of the ground floor and first floor of the school are shown in Figures 3 and 4 respectively. The figures show the measurement locations and the locations of some of the Apple AirPort base stations and microwave dishes. The measurement locations are more fully described in Table 5 along with the day on which the measurements were made.

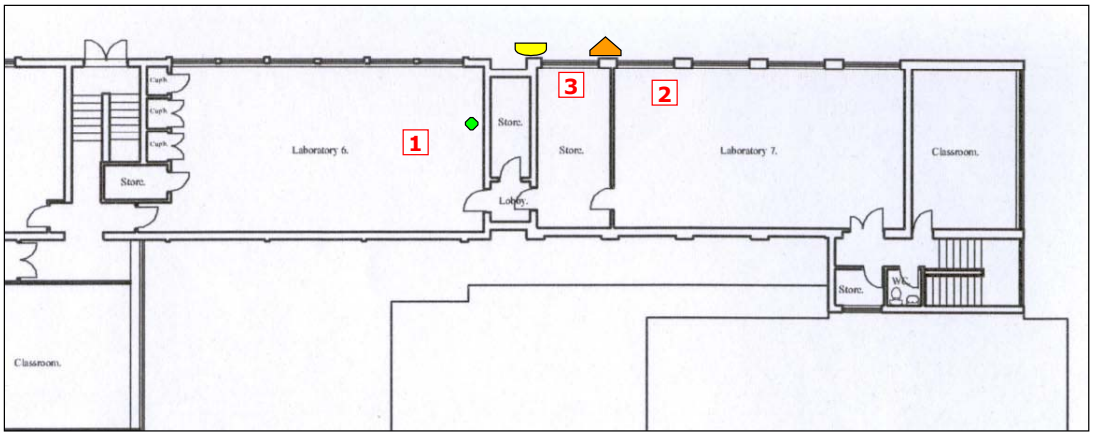



**Figure 3 First floor measurement locations and wireless LAN hardware at Castle Rushen High School**

**1** **Measurement location**

**Apple Airport**

**2.4 GHz microwave dish**

**26 GHz microwave dish**

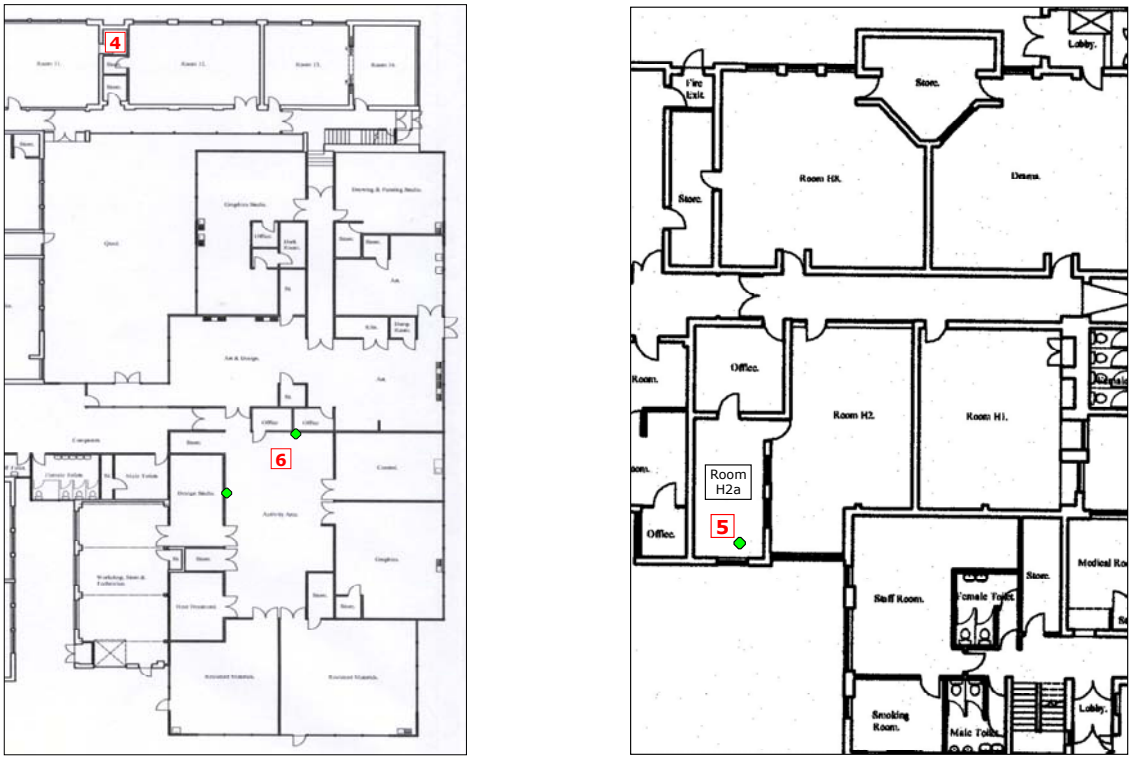



**Figure 4 Ground floor measurement locations and wireless LAN base stations at Castle Rushen High School**

**Table 5 Measurement locations at Castle Rushen High School**

| Day | Location | Location number | Position |
|---|---|---|---|
| 1 | Laboratory 6 | 1.1 | Close to Apple AirPort to LHS of blackboard |
| 3 | Laboratory 7 | 2.1 | Front of classroom facing 2.4 GHz dish outside |
| 3 | | 2.2 | Front of classroom facing laptop running Centrino on front bench |
| 1 | Preparation Room between Labs 6 and 7 | 3.1 | Outside window facing 26 GHz dish |
| 3 | | 3.2 | Outside window facing 26 GHz dish |
| 1 | Storeroom between Classrooms 11 and 12 | 4.1 | Close to microwave signal generator and feeder cable |
| 1 | Room H2a (rear portion) | 5.1 | Close to Apple AirPort on top of patch panel cabinet |
| 1 | | 5.2 | Seated position in front of patch panel cabinet |
| 1 | | 5.3 | Central position close to laptop running Buffalo card |
| 3 | Design Technology | 6.1 | Outside teacher's office, central position between two Apple AirPorts |
| 3 | | 6.2 | Outside teacher's office, close to white Apple AirPort on table |
| 3 | | 6.3 | Outside teacher's office, close to grey Apple AirPort on shelf |

### 5.1.2 Rushen Primary School

Rushen Primary School comprises of an old two-winged school building with more recent extensions. All of the buildings are single storey. A plan of the school is shown in Figure 5. The figure shows the measurement locations and the locations of some of the Apple AirPort base stations and microwave dishes. The measurement locations are more fully described in Table 6 along with the day on which the measurements were made.

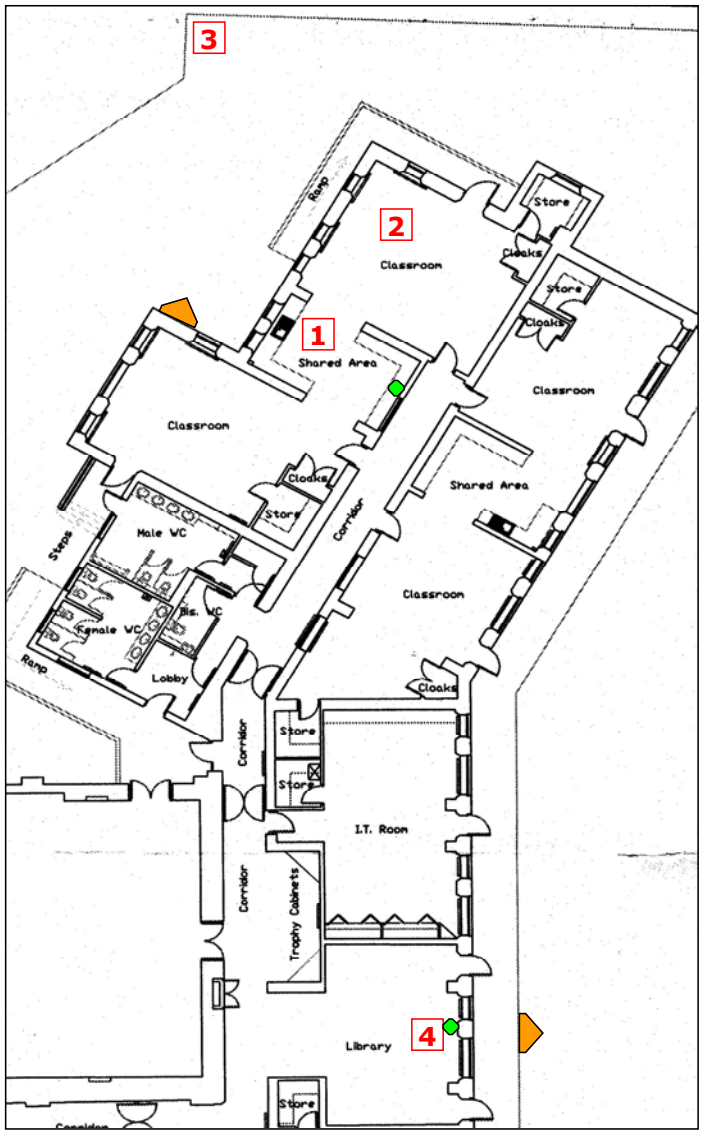



**Figure 5 Measurement locations and wireless LAN hardware at Rushen Primary School**

**1 Measurement location**

**2.4 GHz microwave dish**

**Apple Airport**

**Table 6 Measurement locations at Rushen Primary School**

| Day | Location | Location number | Position |
|---|---|---|---|
| 2 | Year 6 Wet Area | 1.1 | Near RH window facing 2.4 GHz dish outside |
| 2 | | 1.2 | Near RH window facing Apple AirPort on shelf |
| 2 | Year 6W Classroom | 2.1 | Central position facing 2.4 GHz dish outside |
| 2 | | 2.2 | Near teacher's desk facing 2.4 GHz dish outside |
| 2 | Playground | 3.1 | At corner of metalled playground aligned with 2.4 GHz dish |
| 2 | Library | 4.1 | Close to Apple AirPort on wall above bookshelf |
| 2 | | 4.2 | Seated position at Apple Mac workstation |
| 2 | | 4.3 | Central position at workdesk |

## 5.2 Exposures to wireless LAN signals

### 5.2.1 General considerations

The ICNIRP guidelines allow time-averaging of power density over a six minute period before comparing exposures with the reference levels at the frequencies used by wireless LAN devices. Since the signals transmitted by wireless LAN devices are often intermittent, the time-averaged power density will generally be lower than the instantaneous maximum power density. During periods when the clients were not active, the Apple AirPort base stations at the two schools were observed to transmit for periods of 480 μs every 102.5 ms. In these situations the time-averaged power density would have been less than 0.5% of the maximum power density.

Since the narrowband measurement system used for the survey logged the maximum power density, usually over a period of several minutes, and for the other reasons discussed in Section 4.1.3, the results reported below are indicative of the exposure that might be incurred if the sources were to transmit with their highest recorded powers over a prolonged period of time.

In contrast to the narrowband measurements, the broadband instrumentation features an integration time that is long compared with the duration of the shortest pulses. Tests carried out at NRPB showed that the instrument displayed the average power density when measuring pulsed fields with pulse duration and repetition rate similar to those of the signals transmitted by the wireless LAN base stations when their clients were not active.

### 5.2.2 Castle Rushen High School

Narrowband measurements of signals from the Apple AirPort base stations and microwave dish antennas were made at six different locations at Castle Rushen High School. These measurements were carried out during the first and third days of the survey.

#### *5.2.2.1 Laboratory 6*

An Apple AirPort base station was situated on a small table between the blackboard and fume cupboard at the front of Laboratory 6. This situation is shown in Picture 3.

**Picture 3 Apple Airport in Laboratory 6**

The frequency of the signal transmitted by the Apple AirPort was determined using the narrowband equipment. This was approximately 2427 MHz, which is the frequency transmitted on Channel 4.

The narrowband equipment was used to measure power density at one location in Laboratory 6, close to the Apple AirPort. The maximum power density and corresponding signal exposure quotients are shown in Table 7. The exposure quotients are expressed in terms of how many millionths of the ICNIRP guidelines they represent.

**TABLE 7 Maximum power density and signal exposure quotients in Laboratory 6 from the Apple AirPort base station**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.1 | 0.6 m from Apple AirPort | 16000 | 320 | 1600 |

The exposure quotient in Laboratory 6 was 320 millionths of the ICNIRP occupational reference level and 1600 millionths of the ICNIRP public reference level. The ICNIRP guidelines for members of the public are more stringent than those for workers.

#### *5.2.2.2 Laboratory 7*

At the time of the survey, there was no Apple AirPort base station in Laboratory 7. However a laptop computer, fitted with Centrino Mobile Technology, was running on a bench at the front of the laboratory and a 2.4 GHz microwave dish antenna was mounted on an external wall outside the classroom window. These situations are shown in Pictures 4 and 5 respectively.

**Picture 4 Laptop with Centrino Mobile Technology**

**Picture 5 2.4 GHz dish outside the classroom window**

The frequency of the signals transmitted by the laptop and microwave dish were determined using the narrowband equipment. For the laptop this was approximately 2442 MHz, which is the frequency transmitted on Channel 7 and for the microwave dish this was approximately 2417 MHz, which is Channel 2.

The narrowband equipment was used to measure power density at one location in Laboratory 7, in the front corner by the windows. Separate measurements were made of the two signals at this position. The maximum power density and corresponding signal exposure quotients are shown in Table 8.

**TABLE 8 Maximum power density and signal exposure quotients in Laboratory 7 from the laptop computer and 2.4 GHz microwave dish**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.6 | Facing laptop computer 1.3 m from window, 2.1 m from front wall | 23 | 0.46 | 2.3 |
| | Facing microwave dish 1.3 m from window, 2.1 m from front wall | 870 | 17 | 87 |
| | Total | 890 | 18 | 89 |

The exposure quotient in Laboratory 7 from the laptop computer was 0.46 millionths of the ICNIRP occupational reference level and 2.3 millionths of the ICNIRP public reference level. The exposure associated with the microwave dish was 17 millionths and 87 millionths of these levels, respectively.

Summing the exposure quotients for the two signals at this position gave a maximum combined exposure quotient in Laboratory 7 of 18 millionths of the ICNIRP occupational reference level and 89 millionths of the ICNIRP public reference level.

*5.2.2.3 Preparation Room between Laboratories 6 and 7*

A 26 GHz microwave dish antenna, manufactured by Andrews, was mounted on an external wall outside the window of the Preparation Room. The situation is shown in Picture 6.

**Picture 6 26 GHz microwave dish outside the Preparation Room**

The broadband probe was used in an attempt to measure power density close to the windows of the Preparation Room. It was also held at arms length outside the window so as to approach the main beam of the microwave dish. The power

density at these locations was found not to exceed the detection threshold of the instrument of 0.1 W $m^{-2}$. The threshold of detection is equivalent to 0.2% of the ICNIRP occupational reference level and 1% of the ICNIRP public reference level.

The frequency of the signal transmitted by the Andrews microwave dish was determined using the narrowband equipment. This was found to be approximately 26.27 GHz.

The narrowband equipment was used to measure power density outside the window of the Preparation Room within the main beam of the microwave dish. The maximum power density and corresponding signal exposure quotients are shown in Table 9. No signal from the microwave dish was detected close to the windows inside the Preparation Room.

**TABLE 9 Maximum power density and signal exposure quotients outside the Preparation Room from the Andrews 26 GHz microwave dish**

| Position | Survey day | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1 m from front face of dish on projected cylindrical surface | Day 1 | 270 | 5.3 | 26 |
| | Day 3 | 320 | 6.4 | 32 |

The maximum exposure quotient outside the Preparation Room was 6.4 millionths of the ICNIRP occupational reference level and 32 millionths of the ICNIRP public reference level.

*5.2.2.4 Storeroom between Classrooms 11 and 12*

The microwave signal generator and feeder cable for the 26 GHz microwave dish are located in the Storeroom between Classrooms 11 and 12. The equipment is shown in Picture 7.

The broadband probe was used to search for leakage of microwave energy close to the equipment and cable in the Storeroom. No leakage was detected and the power density did not exceed the detection threshold of the instrument of 0.1 W $m^{-2}$. The threshold of detection is equivalent to 0.2% of the ICNIRP occupational reference level and 1% of the ICNIRP public reference level.

**Picture 7 Microwave signal generator and feeder cables in the Storeroom**

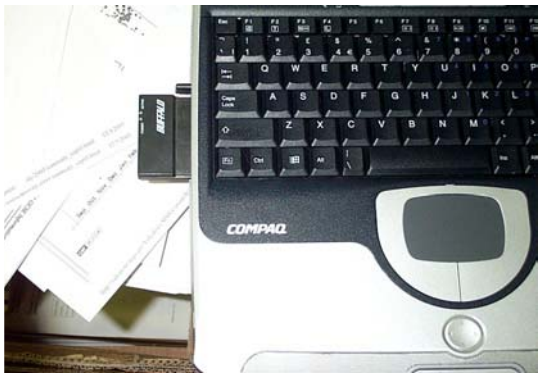
The narrowband equipment was also used to search for microwave leakage from the equipment and cable. No leakage was detected and the power density did not exceed about 100 $\mu$W $m^{-2}$. This is equivalent to 2 millionths of the ICNIRP occupational reference level and 10 millionths of the ICNIRP public reference level.

*5.2.2.5 IT Office (H2a)*

An Apple AirPort base station was situated on top of the patch panel cabinet in the rear portion of the IT Office. In addition, a member of staff in the room was using a laptop computer, fitted with a Buffalo card. These situations are shown in Pictures 8 and 9.

**Picture 8 Apple Airport on the patch panel cabinet**

**Picture 9 Laptop fitted with Buffalo card**



The frequency of the signals transmitted by the Apple AirPort and the laptop in the IT Office were determined using the narrowband equipment. For both devices this was approximately 2427 MHz, which is the frequency transmitted on Channel 4.

The narrowband equipment was used to measure power density at several positions in the IT Office. The maximum power density and corresponding signal exposure quotients recorded at each location are shown in Table 10. The signal recorded at a central position within the within the Office included unresolved contributions from both the base station and laptop.

**TABLE 10 Maximum power density and signal exposure quotients in the IT Office from the Apple AirPort base station and laptop computer**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.8 m | 0.6 m from Apple AirPort on cabinet | 1400 | 28 | 140 |
| 1.2 m | Seated position in front of cabinet | 370 | 7.4 | 37 |
| 0.9 m | Central position 0.6 m from laptop computer | 220 | 4.4 | 22 |

The maximum exposure quotient measured in the IT Office from the Apple AirPort was 28 millionths of the ICNIRP occupational reference level and 140 millionths of the ICNIRP public reference level. The exposure quotient at a central position within the office, due to signals from both the base station and the laptop was 4.4 millionths of the ICNIRP occupational reference level and 22 millionths of the ICNIRP public reference level.

#### *5.2.2.6 Design Technology*

At the time of the survey, there were two Apple AirPort base stations in the Design Technology suite outside the teacher's office. A white unit was on the table just outside the office and a grey unit was on a nearby shelf. These situations are shown in Pictures 10 and 11 respectively.

The frequency of the signals transmitted by the two Apple AirPorts were determined using the narrowband equipment. For the base station on the table this was approximately 2412 MHz, which is the frequency transmitted on Channel 1 and for that on the shelf it was approximately 2447 MHz, which is Channel 8.

The narrowband equipment was used to measure power density at three different positions in Design Technology in the area outside the teacher's office.

These positions were in the centre of the area; close to the base station on the table; and close to the base station on the shelf. Separate measurements were made of the signals from both base stations at all three positions. The maximum power density and corresponding signal exposure quotients for both signals are shown in Table 11, along with the total power density and exposure quotients at each position.

**Picture 10 Apple Airport on the table outside the teacher's office**

**Picture 11 Apple Airport on a nearby shelf**

**TABLE 11 Maximum power density and signal exposure quotients in Design Technology from two Apple AirPort base stations**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.35 | Outside teacher's office, central position between two Apple AirPorts facing grey unit on shelf | 780 | 16 | 78 |
| 1.35 | Outside teacher's office, central position between two Apple AirPorts facing white unit on table | 93 | 1.9 | 9.3 |
| | Total | 870 | 18 | 87 |
| 0.95 | Outside teacher's office, 0.6 m from white Apple AirPort on table facing grey unit on shelf | 130 | 2.6 | 13 |
| 0.95 | Outside teacher's office, 0.6 m from white Apple AirPort on table | 5200 | 100 | 520 |
| | Total | 5300 | 100 | 530 |

**TABLE 11** ***Continued***

| | | | | |
|---|---|---|---|---|
| 1.35 | Outside teacher's office, 0.6 m from grey Apple AirPort on shelf | 1800 | 37 | 180 |
| 1.35 | Outside teacher's office, 0.6 m from grey Apple AirPort facing white unit on table | 27 | 0.53 | 2.7 |
| | Total | 1800 | 38 | 180 |

The maximum exposure quotient in Design Technology was from the white Apple AirPort on the table. Close to the device this was 100 millionths of the ICNIRP occupational reference level and 520 millionths of the ICNIRP public reference level.

Summing the exposure quotients for the two signals in a central position gave a maximum combined exposure quotient in Design Technology of 18 millionths of the ICNIRP occupational reference level and 87 millionths of the ICNIRP public reference level.

### 5.2.3 Rushen Primary School

Narrowband measurements of microwave signals from the Apple AirPort base stations and microwave dish antenna were made at four different locations at Rushen Primary School. These measurements were carried out during the second day of the survey.

#### *5.2.3.1 Year 6 Wet Area*

An Apple AirPort base station was situated on a shelf on the wall backing onto the corridor. A 2.4 GHz microwave dish antenna, linking with Castle Rushen High School, was mounted outside the building on an adjacent wall. This microwave dish was clearly visible through the windows of the room. These situations are shown in Pictures 12 and 13, respectively.

**Picture 12 Apple Airport on the shelf**

**Picture 13 2.4 GHz dish outside**

The broadband probe was used in an attempt to measure power density close to the Apple Airport on the shelf. It was held at 10 cm from the outer casing of the unit. The power density was found not to exceed the detection threshold of the instrument of 0.1 W $m^{-2}$. The threshold of detection is equivalent to 0.2% of the ICNIRP occupational reference level and 1% of the ICNIRP public reference level.

The frequency of the signals transmitted by the base station and the external microwave dish were determined using the narrowband equipment. For the base station this was approximately 2427 MHz, which is the frequency transmitted on Channel 4 and for the microwave dish this was approximately 2417 MHz, which is Channel 2.

The narrowband equipment was used to measure power density at one location in the Year 6 Wet Area. This was in the corner of the room adjacent to the right hand window. This location had a clear line of sight to the external microwave dish. Separate measurements were made of the two signals at this location. The maximum power density and corresponding signal exposure quotients are shown in Table 12. The exposure quotients are expressed in terms of how many millionths of the ICNRP guidelines they represent.

**TABLE 12 Maximum power density and signal exposure quotients in the Year 6 Wet Area from the Apple AirPort base station and 2.4 GHz microwave dish**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.6 | Facing Apple AirPort<br>1.3 m from wall,<br>0.6 m from double door | 260 | 5.2 | 26 |
| | Facing microwave dish<br>1.3 m from wall,<br>2.1 m from double door | 260 | 5.2 | 26 |
| | Total | 520 | 10 | 52 |

The exposure quotient in the Year 6 Wet Area from the Apple AirPort was equivalent to that from the microwave dish. These exposures were both 5.2 millionths of the ICNIRP occupational reference level and 26 millionths of the ICNIRP public reference level.

Summing the exposure quotients for the two signals gave a maximum combined exposure quotient in the Year 6 Wet Area of 10 millionths of the ICNIRP occupational reference level and 52 millionths of the ICNIRP public reference level. The ICNIRP guidelines for members of the public are more stringent than those for workers.

#### *5.2.3.2 Year 6W Classroom*

At the time of the survey, there was no Apple AirPort base station in Year 6W Classroom. However, this classroom is adjacent to the Year 6 Wet Area and also had a clear line of sight of the 2.4 GHz microwave dish through the windows. This situation is shown in Picture 14.

**Picture 14 2.4 GHz dish outside the Year 6W Classroom**

The frequency of the signal from the microwave dish had already been determined (see 5.2.3.1) as approximately 2417 MHz, which is Channel 2.

The narrowband equipment was used to measure power density at two positions in Year 6W Classroom. These were in the centre of the eastern quarter of the classroom and close to the teacher's desk. Measurements were made of the signal from the microwave dish at these locations. No signal from the Apple AirPort base station in the adjacent Wet Area was detected. The maximum power density and corresponding signal exposure quotients are shown in Table 13.

**TABLE 13 Maximum power density and signal exposure quotients in the Year 6W Classroom from 2.4 GHz microwave dish**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.5 | Facing microwave dish 2 m from SE wall, 3 m from NE wall | 9 | 0.18 | 0.9 |
| 1.5 | Facing microwave dish, close to teacher's desk, 0.8 m from window wall, 2.2 m from dividing wall | 14 | 0.27 | 1.4 |

The maximum exposure quotient in the Year 6W Classroom close to the teacher's desk was 0.27 millionths of the ICNIRP occupational reference level and 1.4 millionths of the ICNIRP public reference level.

*5.2.3.3 Playground*

A 2.4 GHz microwave dish, was mounted outside the building on an external wall just below the level of the eves. The situation is shown in Picture 15.

**Picture 15 2.4 GHz dish as seen from the Playground**

The frequency of the signal from the microwave dish had already been determined (see 5.2.3.1) as approximately 2417 MHz, which is Channel 2.

The narrowband equipment was used to measure power density at the corner of the metalled playground on the line of the main beam of the microwave dish. The maximum power density and corresponding signal exposure quotients are shown in Table 14.

**TABLE 14 Maximum power density and signal exposure quotients in the Playground from the 2.4 GHz microwave dish**

| Height of measurement position above floor (m) | Position in Playground | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.5 | Corner of metalled area, 16 m from protruding wall of store along line of external access ramp. | 680 | 14 | 68 |

The maximum exposure quotient in the Playground was 14 millionths of the ICNIRP occupational reference level and 68 millionths of the ICNIRP public reference level.

*5.2.3.4 Library*

An Apple AirPort base station was situated on the wall above a bookshelf in the Library. A 2.4 GHz microwave dish antenna, linking with Phurt le Moirrey Primary School, was mounted outside the Library on an external gable. These situations are shown in Pictures 16 and 17 respectively.

**Picture 16 Apple AirPort on the wall of the Library**

**Picture 17 2.4 GHz dish outside the Library**

The frequency of the signal transmitted by the base station in the Library was determined using the narrowband equipment. This was approximately 2412 MHz, which is the frequency transmitted on Channel 1.

The narrowband equipment was used to measure power density at several positions in the Library. No signal from the external microwave dish was detected. The maximum power density and corresponding signal exposure quotients recorded at each position are shown in Tables 15.

**TABLE 15 Maximum power density and signal exposure quotients in the Library from the Apple AirPort base station**

| Height of measurement position above floor (m) | Position in room | Power density ($\mu W\ m^{-2}$) | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|---|
| | | | Occupational | Public |
| 1.55 m | 0.6 m from Apple AirPort on wall | 20000 | 400 | 2000 |
| 0.95 m | Seated position at Apple Mac workstation, 1.1 m from central window ledge | 330 | 6.6 | 33 |
| 0.95 m | Central position at workdesk, 3.2 m from LH wall, 1.5 m from end of long bench | 180 | 3.6 | 18 |

The maximum exposure quotient measured in the Library was 400 millionths of the ICNIRP occupational reference level and 2000 millionths of the ICNIRP public reference level.

## 5.3 Environmental assessments

Full environmental surveys of all radio signals that could be detected with frequencies between 30 MHz and 3 GHz were carried out at two locations at Castle Rushen High School and two locations at Rushen Primary School. The threshold of detection ranged from about 0.001 to 0.1 $\mu W\ m^{-2}$ over this frequency range with the spectrum analyser settings employed at these locations.

### 5.3.1 Castle Rushen High School

Environmental surveys were carried out in Laboratory 6 (Location 1.1) and the Design Technology suite (Location 6.1). These locations are shown in Figures 3 and 4 and also in Pictures 17 and 18. A total of 23 signals were detected at both locations.

**Picture 17 Laboratory 6**

**Picture 18 Design Technology**

Spectra showing the power density and frequency of the strongest signals are shown in Figures 6 and 7. The radio signals detected in Laboratory 6 originated from the Apple AirPort base station and from other more distant transmitters, including those mentioned in Section 2.2. The signals detected in Design Technology were similar to those in Laboratory 6, although because there were two rather than one Apple AirPort base stations, two wireless LAN signals were observed.

In order to provide a context for the radio signal power densities, it is useful to consider the ICNIRP reference level for exposure of the general public, although this would appear off the top of the scale of the graphs shown below. The reference level is most restrictive over the frequency range 10–400 MHz, where it is 2 000 000 $\mu W\ m^{-2}$. It then rises over the range 400-2000 MHz and is 10 000 000 $\mu W\ m^{-2}$ at frequencies above 2 GHz (see Figure 2).

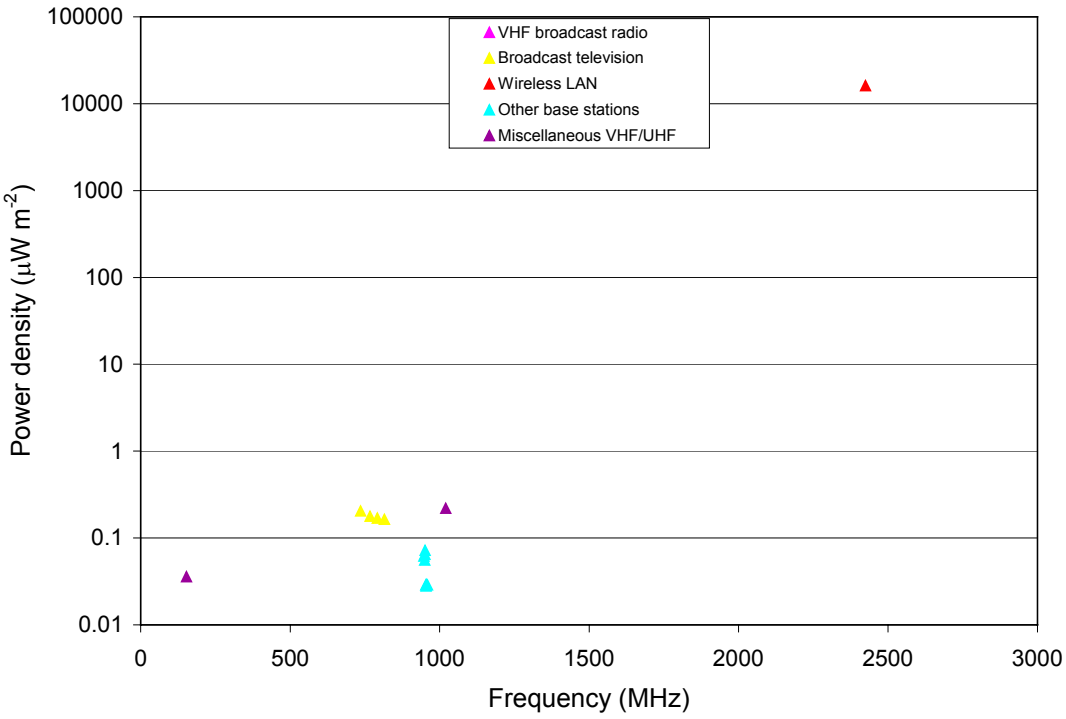



**Figure 6 Power density spectrum measured at Location 1.1 in Laboratory 6**

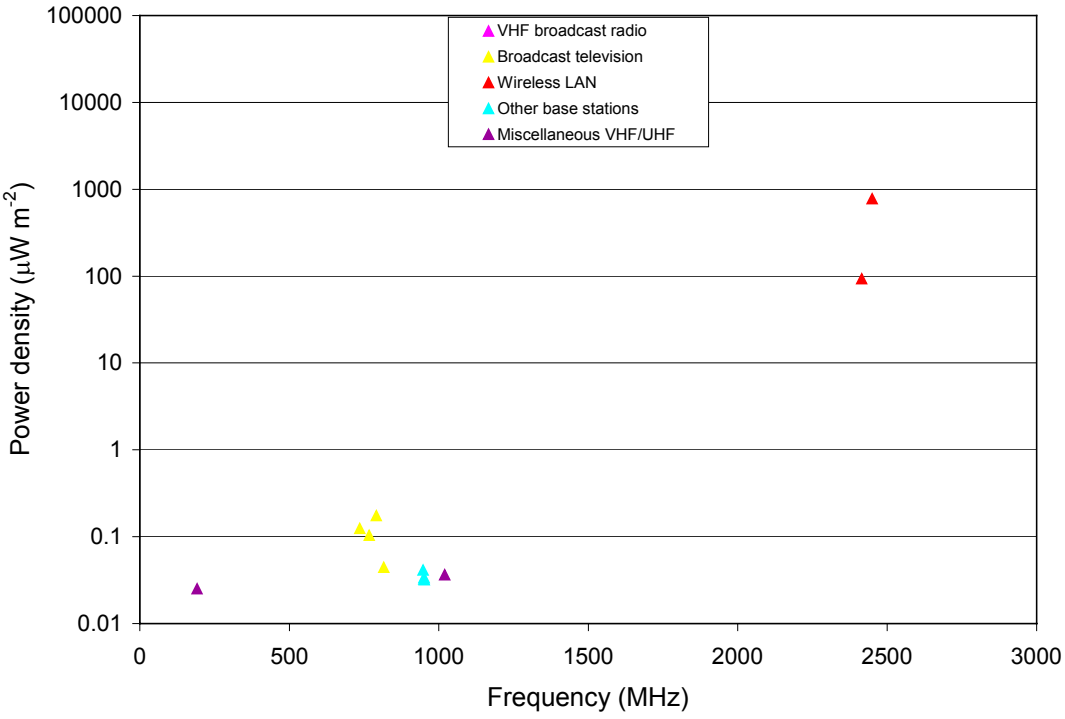



**Figure 7 Power density spectrum measured at Location 6.1 in Design Technology**

### 5.3.2 Rushen Primary School

Environmental surveys were carried out in the Year 6W Classroom (Location 2.1) and the Playground (Location 3.1). These locations are shown in Figure 5 and also in Pictures 19 and 20. A total of 41 signals were detected in the classroom and 45 in the Playground.

**Picture 19 Year 6W Classroom**

**Picture 20 Playground**

Spectra showing the power density and frequency of the strongest signals are shown in Figures 8 and 9. The radio signals detected in the classroom originated from the external microwave dish antenna and from other more distant transmitters, including those mentioned in Section 2.2. The signals detected in the Playground were similar to those in the classroom, although as this was an outdoor location they were generally stronger. At both locations broadcast television signals were measured from the nearby Port St Mary transmitter and a pair of signals was detected from the primary surveillance radar at Ronaldsway Airport.

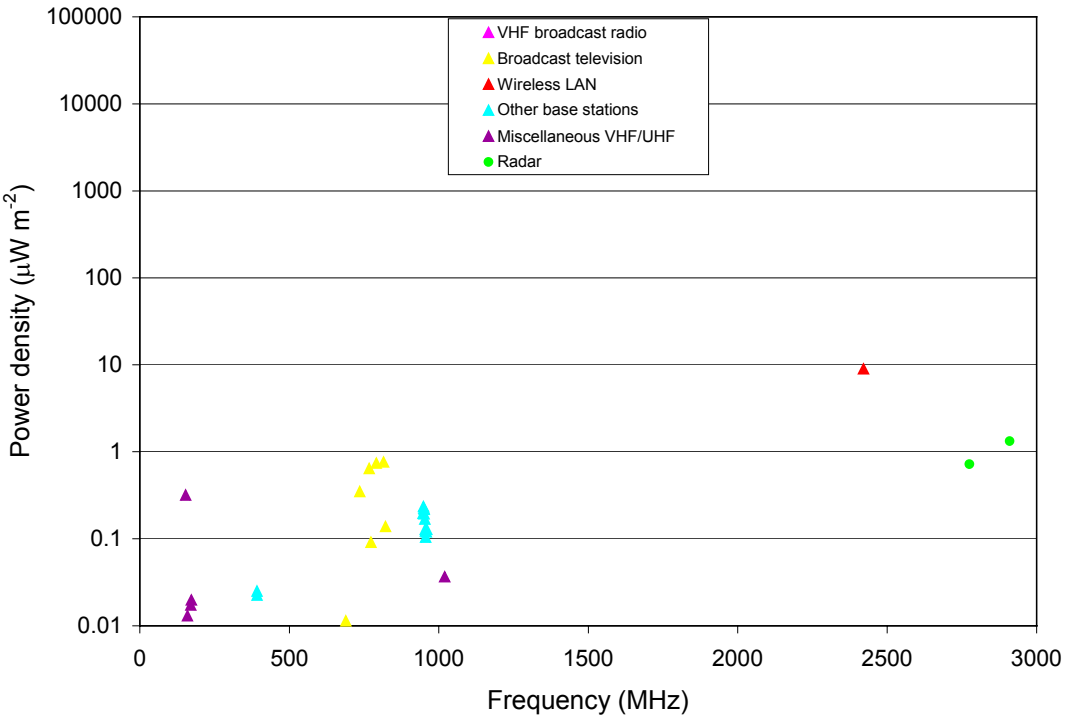



**Figure 8 Power density spectrum measured at Location 2.1 in Classroom 6W**

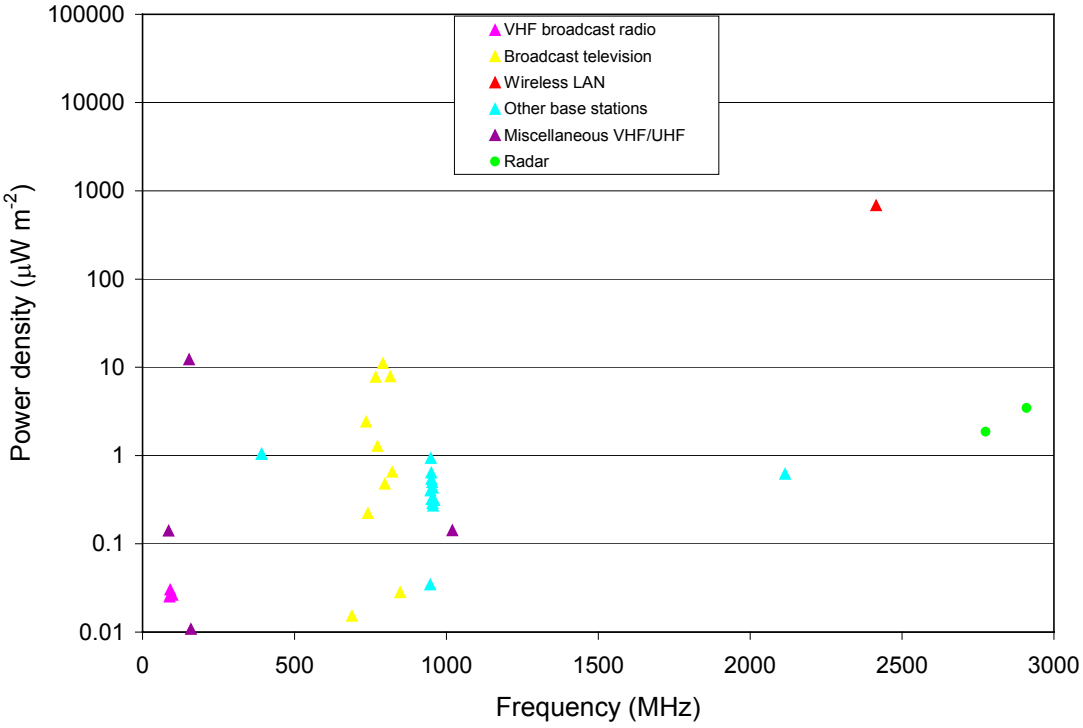



**Figure 9 Power density spectrum measured at Location 3.1 in the Playground**

### 5.3.3 Total exposures

All of the detected signals would contribute to the exposure of a person at a survey location so they were all accounted for in calculating the total exposures. A degree of caution is necessary when comparing measured power densities of radio signals from different sources. Signals from some sources, such as broadcast radio and television, are transmitted continuously whereas signals associated with mobile telephony, mobile radio, wireless LANs and radar may be present intermittently with varying radiated powers. Since the measurement system used for the survey logged the maximum power density of each signal over a period of time, the results may be considered indicative of the exposure that might be incurred if all of the sources detected were to transmit simultaneously with their highest recorded powers. The pulsed signals from the rotating radar antenna at Ronaldsway Airport are an extreme example of an intermittent source and consequently have not been included in the exposure analysis. The total exposures at Castle Rushen High School and Rushen Primary School are shown in Tables 16 and 17 respectively.

**TABLE 16 Total exposures at Castle Rushen High School at Locations 1.1 and 6.1**

| | Total exposure in millionths of the ICNIRP reference levels | |
|---|---|---|
| Location | Occupational | Public |
| 1.1 Laboratory 6 | 320 | 1600 |
| 6.1 Design Technology | 17 | 87 |

At Castle Rushen High School, the signals from other radio wave sources with frequencies between 30 MHz and 3 GHz, contributed very little to the total exposures at these two locations. As a consequence the total exposures were numerically equivalent to those due solely to the wireless LAN base stations. This is due to the relatively strong signals from these base stations (the detecting antenna was close to the Apple AirPorts) and also the relative weakness and low number of environmental radio wave signals detected at these locations.

**TABLE 17 Total exposures at Rushen Primary School at Locations 2.1 and 3.1**

| | Total exposure in millionths of the ICNIRP reference levels | |
|---|---|---|
| Location | Occupational | Public |
| 2.1 Classroom 6W | 0.44 | 2.2 |
| 3.1 Playground | 17 | 85 |

At Rushen Primary School, the signals from other radio wave sources with frequencies between 30 MHz and 3 GHz, contributed proportionally more to the total exposures at these two locations. These tended to be slightly more powerful (for example, the broadcast television signals from the Port St Mary transmitter) and more numerous than those at Castle Rushen High School. As a consequence the total exposures were roughly twice those due solely to the microwave dish antenna.

### 5.3.4 Exposure proportions

Since all of the radio signals detected at a survey location would contribute to the total exposure of a person, it is possible to assign a proportion of the total exposure to each individual signal. Pie charts are given in Figures 10 to 13, which display the exposure data separated into contributions from different categories of source. These categories were defined according to the frequency of each measured signal and the information in Section 2.2. The percentage contributions given are in the context of the ICNIRP public guidelines. It should be noted that the sum of percentages may not exactly equal 100% due to rounding errors.

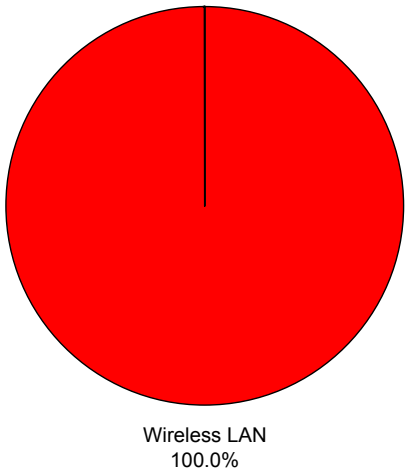



**Figure 10 Exposure contributions at Castle Rushen High School in Laboratory 6. Total exposure = 1600 millionths (0.16%) of the ICNIRP public reference level**

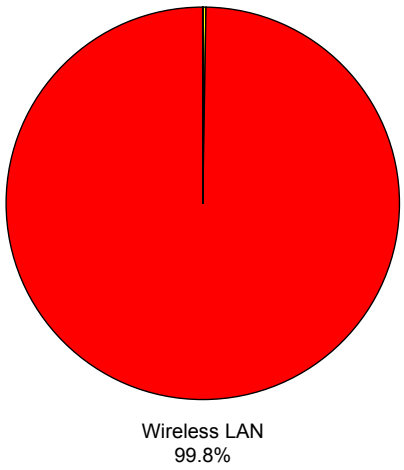



**Figure 11 Exposure contributions at Castle Rushen High School in Design Technology. Total exposure = 87 millionths (0.0087%) of the ICNIRP public reference level**

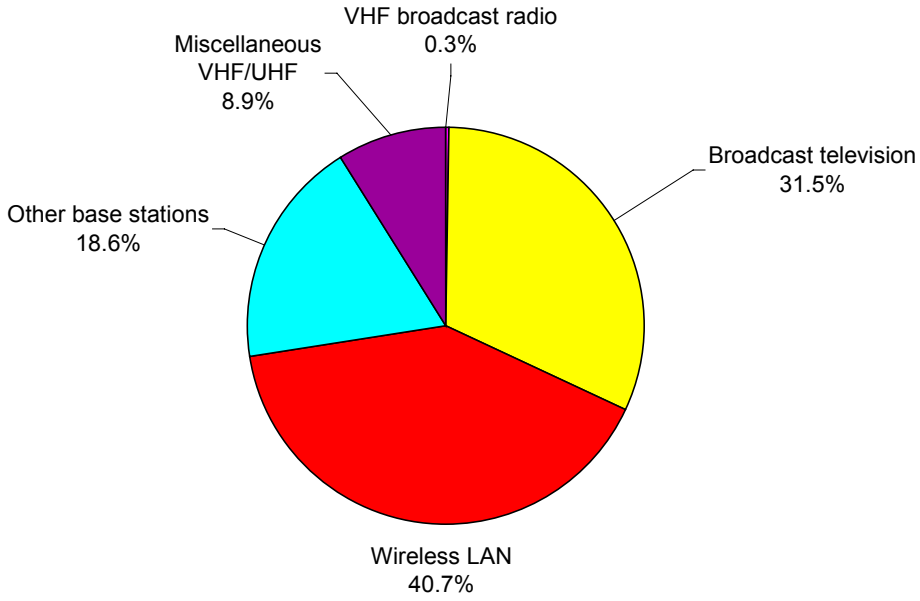



**Figure 12 Exposure contributions at Rushen Primary School in Classroom 6W. Total exposure = 2.2 millionths (0.00022%) of the ICNIRP public reference level**

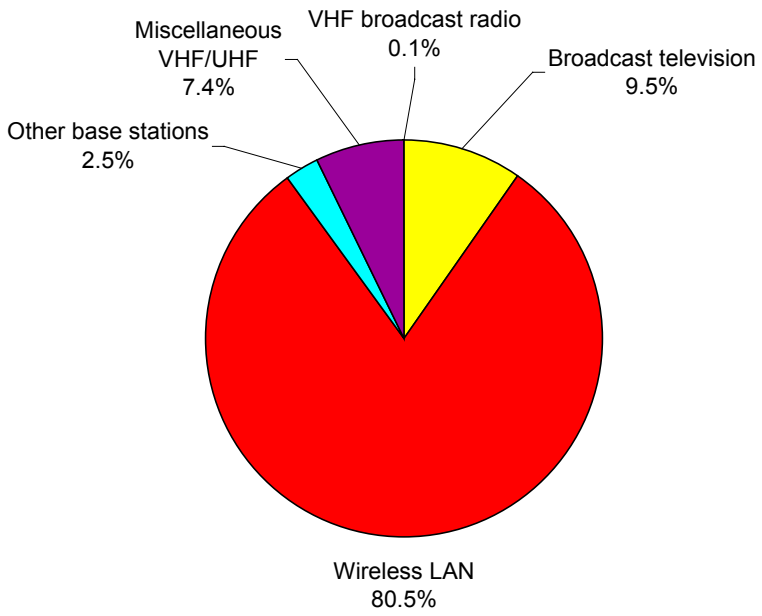



**Figure 13 Exposure contributions at Rushen Primary School in the Playground. Total exposure = 85 millionths (0.0085%) of the ICNIRP public reference level**

The pie charts indicate that the dominant contribution to exposure at the two locations at Castle Rushen High School came from the wireless LAN base stations.

At Rushen Primary School the microwave dish antenna made the largest contribution to exposure at both locations. However there were also contributions from environmental radio wave sources including VHF broadcast radio, miscellaneous VHF/UHF, other base stations and broadcast television. Other base stations, which comprised of signals from TETRA, GSM900 and 3G mobile phone base stations, contributed 18.6% and 2.5% towards the total exposure in the Classroom 6W and Playground locations, respectively. Broadcast television, which was dominated by signals from the Port St Mary transmitter, contributed 31.5% and 9.5% towards the total exposures, respectively.

## 5.4 Summary of exposures to wireless LAN and microwave dish signals

The maximum exposure quotients due to wireless LAN and microwave dish signals determined at each measurement location using the narrowband instrumentation are summarised in Tables 18 and 19. All of the measured exposures were well below the ICNIRP guideline levels and are therefore considered not to be hazardous.

**TABLE 18 Maximum exposure quotients due to wireless LAN and microwave dish signals at Castle Rushen High School**

| Location | Location number | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|
| | | Occupational | Public |
| Laboratory 6 | 1.1 | 320 | 1600 |
| Laboratory 7 | 2.1 | 18 | 89 |
| Preparation Room between Labs 6 and 7 | 3.2 | 6.4 | 32 |
| Storeroom between Classrooms 11 and 12 | 4.1 | <2 | <10 |
| Room H2a (rear portion) | 5.1 | 28 | 140 |
| Design Technology | 6.2 | 100 | 530 |

**TABLE 19 Maximum exposure quotients due to wireless LAN signals at Rushen Primary School**

| Location | Location number | Exposure quotient in millionths of the ICNIRP reference levels | |
|---|---|---|---|
| | | Occupational | Public |
| Year 6 Wet Area | 1.1 | 10 | 52 |
| Year 6W Classroom | 2.2 | 0.27 | 1.4 |
| Playground | 3.1 | 14 | 68 |
| Library | 4.1 | 400 | 2000 |

# 6 CONCLUSIONS

A survey of radiofrequency radiation has been undertaken at Castle Rushen High School and Rushen Primary School in order to investigate exposure to radio waves and perform a hazard assessment through comparison with the guidelines on limiting people's exposure published by ICNIRP. Wireless LANs have been installed in the schools and Apple AirPort base stations have been located throughout the buildings. The schools are connected together and to the service provider by point-to-point microwave dish antennas mounted outside the buildings.

Measurements of power density were made at various locations throughout the two schools. The results were used to evaluate exposure quotients that quantify exposure in the context of the ICNIRP reference levels. The most stringent of these levels is the reference level advised by ICNIRP for exposure of the general public. Exposure quotients less than one indicate compliance with the guidelines. A conservative approach was adopted whereby the maximum power density

measured over a period of time was recorded, even though the time-averaged power density may have been well below this value.

Power densities 10 cm from the base station in the Year 6 Wet Area at Rushen Primary School did not exceed the threshold of detection of the broadband instrumentation used during the survey. The detection threshold was 0.1 W $m^{-2}$, equivalent to 1% of the ICNIRP public reference level. Similar results using this instrumentation were obtained for the 26 GHz microwave dish and associated microwave signal generator at Castle Rushen High School.

Measurements using narrowband equipment were made at six different locations at Castle Rushen High School. The greatest power density due to an Apple AirPort device was measured in Laboratory 6 where the maximum exposure was evaluated at 1600 millionths (0.16%) of the ICNIRP public reference level. Exposures from laptop computers configured for wireless LAN were measured in Laboratory 7 and Room H2a. At 60 cm from one such laptop the exposure was found not to exceed 22 millionths (0.0022%) of the ICNIRP public reference level. A signal from the 26 GHz microwave dish antenna mounted outside the Preparation Room could not be detected within the room, however outside the window the maximum exposure was evaluated at 32 millionths (0.0032%) of the ICNIRP public reference level. Exposures due to wireless LAN signals at all other measurement locations did not exceed 530 millionths (0.053%) of the reference level.

Measurements using narrowband equipment were made at four different locations at Rushen Primary School, including one outdoors in the Playground. The greatest power density due to an Apple AirPort device was measured in the Library where the maximum exposure was evaluated at 2000 millionths (0.2%) of the ICNIRP public reference level. A signal from the 2.4 GHz microwave dish antenna mounted outside the Year 6 Wet Area was measured at three locations, including the Playground where the maximum exposure was evaluated at 68 millionths (0.0068%) of the ICNIRP public reference level. Exposures due to wireless LAN signals at all the other measurement locations did not exceed 52 millionths (0.0052%) of the public reference level.

Full environmental surveys of all radio signals that could be detected with frequencies between 30 MHz and 3 GHz were carried out at two locations at Castle Rushen High School and two locations at Rushen Primary School. The total exposures ranged from 2.2 to 1600 millionths of the ICNIRP public reference level. These exposures were dominated in most cases by signals from wireless LAN base stations and microwave dishes.

All of the exposures measured at Castle Rushen High School and Rushen Primary School were well below the ICNIRP guideline levels and are therefore not considered to be hazardous. No further action is considered necessary, although it is suggested that the results of this work should be disseminated to the schools.

# 7 REFERENCES

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# APPENDIX A

## Statement by the National Radiological Protection Board: Advice on Limiting Exposure to Electromagnetic Fields (0–300 GHz)

The Board of NRPB has recommended the adoption in the UK of the guidelines of the International Commission on Non-Ionizing Radiation Protection (ICNIRP) for limiting exposures to electromagnetic fields (EMFs) between 0 and 300 GHz. This follows a thorough review of current scientific knowledge on the effects of EMFs and an extensive consultation exercise. The Board recognises the need to adopt a cautious approach in the interpretation of scientific knowledge and the benefits of common international guidelines.

**BOARD STATEMENT**

1. Following a review of the relevant scientific data (NRPB, 2004a) and an extensive consultation exercise, NRPB has issued new advice on exposure guidelines for electromagnetic fields (EMFs) (NRPB, 2004b). In establishing quantitative restrictions on exposure to EMFs a range of values are possible, particularly when taking into account uncertainties in the responses of different groups of individuals in the general population. The review of current scientific knowledge by NRPB staff, the adoption of a cautious approach to the interpretation of these data, and a recognition of the benefits of international harmonisation, combine in the Board's recommendation to adopt the ICNIRP exposure guidelines for occupational and public exposure to EMFs between 0 and 300 GHz (ICNIRP, 1998).

2. The detailed scientific analysis by NRPB staff supports the recommendation by ICNIRP that exposure guidelines for members of the public should be more restrictive than for workers. This allows for a greater sensitivity to adverse health effects in the general population than for the working population. Increases in sensitivity may occur in infants and children, individuals being treated with medication, and those in the later years of life. The ICNIRP recommendation of a reduction factor of five in the basic restrictions for members of the public compared with workers is appropriate.

3. In the light of ongoing research, major health risk assessments being carried out by the World Health Organization (WHO), and the possibility of further advice from ICNIRP, the Board considers that guidelines on limiting exposure to EMFs should be kept under review. NRPB staff will continue to monitor the results of research related to the effects of EMFs on health and to make further recommendations when appropriate.

4. The Board recognises that there are concerns that prolonged low level exposure to EMFs across the range 0–300 GHz may be implicated in the development of long-term health effects, in particular cancer. Relevant epidemiological and biological studies have been reviewed in reports by the independent Advisory Group on Non-ionising Radiation (AGNIR, 2001a,b, 2003). These conclude that there is no firm evidence of such adverse health effects at the levels of EMFs to which people are normally exposed.

5. An association between prolonged exposure to intense power frequency magnetic fields and a small raised risk of childhood leukaemia has, however, been found, the scientific reasons for which are presently uncertain. In the light of these findings and the requirement for additional research, the need for further precautionary measures should be considered by government.

**BACKGROUND**

6. The National Radiological Protection Board (NRPB) has the responsibility for providing advice on limiting exposure of people to electromagnetic fields (EMFs). These include static, power frequency (50 Hz in the UK), and other extremely low frequency (ELF) electric and magnetic fields, and radiofrequency (RF) fields and radiation. The new advice from NRPB (2004b), supported by a review of the scientific evidence (NRPB, 2004a), updates previous advice on limiting exposure to EMFs (NRPB, 1993, 1999).

7. These revised recommendations have been developed as part of the ongoing review by NRPB of the scientific evidence underlying the exposure guidelines for EMFs. The present review was requested by the Department of Health and has particularly examined the issues of uncertainty in the science and aspects of precaution. The advice on exposure guidelines is based on an assessment of the possible effects of EMFs on human health. It is derived from epidemiological studies of exposed human populations, experimental investigations, results from volunteer studies, and dosimetric information.

8. In developing these recommendations, NRPB has drawn upon advice from individual UK and international scientific experts and from published comprehensive reviews by expert groups. It has additionally sought advice from an ad hoc expert group on weak electric field effects in the body. NRPB organised an open meeting to listen to public concerns about power lines in December 2002 and it was also aware of issues raised at open meetings organised by the Independent Expert Group on Mobile Phones (IEGMP, 2000). A consultation document on the new guidelines was issued in May 2003. Comments received from that consultation have been addressed in completing a review of the science and in formulating the advice.

9. Generally, occupational exposure concerns healthy adults working under controlled conditions. These conditions include the opportunity to apply engineering and administrative measures and, where necessary and practical, to provide personal protection. For members of the public, similar controls do not generally exist, and individuals of varying ages can have wider variability in health status and responses to exposures to EMFs. For these reasons exposure restrictions for the public are lower than those recommended for the working population.

10. Restrictions on exposure to EMFs are designed to prevent adverse health effects and are based on their interactions with body tissues. They are termed basic restrictions as they are developed from experimental data relating to thresholds for direct and indirect health effects, which give rise to the fundamental limits on exposure. Generally, the basic restrictions are not readily measurable.

11. Direct effects are those resulting from the interaction of EMFs with the human body. For exposure to static magnetic fields, the restrictions are intended to avoid the induction of vertigo and nausea. For electric and magnetic fields, up to a frequency of about 100 kHz, which include microwaves, the restrictions are intended to prevent adverse effects due to excessive whole- and partial-body heating.

12. Indirect effects are those resulting from an interaction between EMFs, an external object such as a vehicle or other mechanical structure, and the human body. For these effects, advice on limiting exposure is provided to avoid the shocks and burns that might result. Such effects may be avoided by limiting the external electric field or by other engineering or administrative controls.

13. Reference levels are also given; these are conservatively derived levels relating to the electric field, magnetic field, or current for comparison with measurements that can readily be made. Comparison of measurements with the reference levels can be used to assess whether compliance with the basic restrictions has been achieved. If the field to which a person is exposed exceeds the relevant reference level it does not necessarily follow that the basic restriction is exceeded. It is, however, then necessary to investigate compliance with the basic restriction using more detailed methods of exposure assessment. The reference levels may be used to indicate whether there is a need to take appropriate action to prevent shock and burn.

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