Interference Potential from Mass-Deployed Unintentional Radiators

Darren J Carpenter *BSc (Hons.), MSc*
EMC Consultancy, BTexact Technologies,
BT Advanced Communications Technology Centre,
Adastral Park, Martlesham, Ipswich, Suffolk, IP5 3RE
e-mail: darren.carpenter@bt.com
tel. +44(0) 1473 649376

1 Introduction

In recent years, the potential for unintentional radio interference to be caused by the operation of a range of signalling systems that may be mass-deployed within the near term has become of interest to national regulators, spectrum users and the network operators wishing to deploy them. Regulatory effort within the UK and Germany has to date largely concentrated upon the identification of suitable measurement methods and limits to be applied to the unintentional emissions from single systems, such that localised interference to radio reception may be controlled [1,2].

There remains however the more general question concerning the widespread impact on the radio spectrum that mass deployment of such technologies may have. The available literature on this issue [3-6] is noted to consider the impact of mass deployment of these signalling systems in isolation and compares the predictions with figures for radio background established by the ITU. It is noted that these background levels were determined through extensive measurement that took place during the 1960s: a time before the mass-deployment of a number of technologies that are known unintentional radiators.

This paper attempts to apply the framework developed within [5,6] for both those technologies that may be mass-deployed within the near term (specifically VDSL and in-home networking products) and those technologies that have become mass-deployed since the establishment of the ITU RF background values (specifically commercial LAN, luminaires and ITE devices). This allows the interference potential of these future technologies to be compared with that generated by existing systems. Consideration of the existing mass-deployed technologies would potentially serve as a means of validating any predictive framework to an established level of confidence before they are incorporated within the decision-making process.

Commentary is also provided on the framework presented within [6] for the interference potential that mass-deployed technologies presents to aircraft communications and navigation systems.

2 Review of Framework

Within [5,6], the interference potential of an elementary area, dA, is expressed in terms of it's EIRP Density. This value is thus:

$$\text{EIRP Density} = p_{TX}\, g_{TX}\, D$$

where:

p_{TX} is the total power injected into a system (in 10 kHz bandwidth);

g_{TX} is the effective gain of the unintentional emitter;

D is the deployment density

The product $p_{TX}\, g_{TX}$ is referred to as the EIRP.

This section attempts to determine the EIRP Densities for both technologies that may be mass-deployed within the near term (specifically VDSL and in-home networking products) and technologies that are already mass-deployed (specifically commercial LAN, luminaires and ITE devices).

2.1 VDSL

For the purposes of this calculation, the scenario assumed is that in which 25% of the UK Access Network wire-pairs is converted to a VDSL connection. This is noted to be very much an upper-estimate of likely VDSL penetration.

2.1.1 Calculation of $p_{TX}g_{TX}$

This will be calculated from experimental measurements.

The radiated electric field measured within a bandwidth of 10 kHz from a VDSL system at a distance of 1 m is typically ~30 dBμV/m/10 kHz, equating to 32 μV/m/10 kHz. It is important to note that this figure was obtained using a measurement method defined within MPT1570 [1], i.e. using a magnetic field measurement and applying a correction factor that assumes far-field conditions. Given the fact that the measurements were made at a distance of 1 m, the validity of the far-field condition is questionable. However, in the absence of other data, this figure will be assumed. This equates to a radiated power density of 2.72 pW/10 kHz m^2.

Assuming:

(i) an overhead dropwire span of ~30 m (this being very much an upper limit);

(ii) a constant emission at this level over the overhead length (again, an upper limit assumption that does not consider the effect of attenuation of the launched signal along the length of the overhead span)

(iii) a cylindrical radiation pattern from the overhead span;

then the total power radiated by the dropwire may be estimated by multiplying the radiated power density figure by the surface area of the cylinder. This yields a figure of (2π x 1m x 30 m x 2.72 pW/10 kHz m^2) of ~0.5 nW/10 kHz m^2.

1.1.2 Calculation of D

It is noted that the UK Access Network contains ~28 million wire-pairs currently serving both residential or business customers. Given the surface area of the UK [7] (2.45×10^{11} m^2), the average UK wire-pair density is ~10^{-4} m^{-2}.

Assuming that 25% of wire-pairs are converted to VDSL and 50% of these have an overhead dropwire run (the overhead-underground mix within the UK Access Network being approximate 50-50), the average UK wire-pair density for consideration here is ~10^{-5} m^{-2}.

1.1.3 Calculation of EIRP Density

From the previous sections, we have:

$p_{TX}\,g_{TX}$ = ~0.5 nW/10 kHz

D = ~$10^{-5}m^{-2}$

This yields a value of 5×10^{-15} W/10 kHz m^2, or ~-143 dBW/10 kHz m^2.

1.2 In-Home Networks

The growth in-home networks over the near term can reasonably be expected due to the combination of a number of market trends. First, there is the trend toward the multi-PC household, where older PCs are retained when a newer model is purchased. Generally in such instances the original PC's peripherals (scanners, printers et. al.) are not replaced. Hence there is a need for interconnection of PCs within the home to share common peripherals. Second, the inclusion of LAN networking cards within standard commodity PCs is rapidly becoming a standard feature. Thirdly there is the fact that the tremendous data rates delivered by VDSL will allow the delivery of multiple services that customers will want to use simultaneously at separate locations within the home. For example, it is possible to imagine a scenario in which a single VDSL connection is used to deliver high speed internet access in one or more rooms (study and/or bedroom), voice telephony in another (bedroom) and VoD applications in another (living room). Indeed, in anticipation of this, some home builders within the UK are now incorporating in-home LANs within their more expensive developments.

For the purposes of this calculation, the scenario assumed is that in which every VDSL-enabled home within the UK has an in-home network. The networking technology will be assumed to be 10BaseT delivered over CAT5 cable. While it is acknowledged that other in-home networking systems do exist (examples include HPNA1, HPNA2 and in-home PLT), 10BaseT is assumed because it is a mature technology that is rapidly becoming a standard feature within commodity PCs. By being a standard pre-installed feature, it's inclusion lends the home market towards the uptake of this technology. It is also acknowledged that it is the worse radiator of the candidate in-home networking technologies and hence provides a worse-case figure.

1.2.1 Calculation of $p_{TX}g_{TX}$

The factor $p_{TX}g_{TX}$, this being the actual unintentional power radiated by the in-home network, is to be estimated through measurement.

The radiated emissions from a CAT5 cable carrying a continuous 10BaseT signal was measured at a distance of 1 m. Between 2 and 12 MHz, the typical level measured was 50 dBμV/m/10 kHz. This equates to a radiated power density of 264 pW/10 kHz m^2.

Basing the analysis on a measurement of continuous traffic is acknowledged to be very much a worse-case scenario. However, given the simultaneous, multi-service delivery scenario discussed previously, it is not unrealistic.

If it is assumed that the typical in-home network has a reach of ~10 m and a cylindrical radiation pattern, the total power unintentionally radiated will be (2π x 1 m x 10 m x 264 pWm^{-2}/10 kHz) 16.5 nW/10 kHz.

1.2.2 Calculation of D

It is noted that the UK Access Network contains ~28 million wire-pairs currently serving both residential and business customers. Given the surface area of the UK [7] (2.45 x 10^{11} m^2), the average UK wire-pair density is ~10^{-4} m^{-2}.

Assuming that 25% of wire-pairs are converted to VDSL and 25% of these are to residential customers with in-home networks, the average UK in-home network density for consideration here is ~7 x 10^{-6} m^{-2}.

1.2.3 Calculation of EIRP Density

From the previous sections, we have:

$p_{TX}g_{TX}$= 16.5 nW/10 kHz

D = 7 x $10^{-6}m^{-2}$

This yields a value of ~1 x 10^{-13} W/10 kHz m^2, or ~-130 dBW/10 kHz m^2.

1.3 LAN

In the previous section considering in-home networks, it was noted that LAN cards are rapidly becoming standard features within commodity PCs. This is largely because they are a relatively cheap component for the PC maker to add, this being due to the enormous economies of scale with which they are manufactured. This in turn is a reflection of the number of LANs that are currently deployed within commercial premises. It is therefore useful to use the framework within [5,6] to estimate the EIRP Density that the current deployment level of this technology generates.

Again, 10BaseT will be assumed as the reference technology because it is the most mature and hence is likely to have the highest deployment densities.

1.3.1 Calculation of $p_{TX}g_{TX}$

The calculation for in-home networks assumed a typical in-home run of CAT5 cable of ~10 m. For the commercial scenario, a typical length of ~100 m is more reasonable, since commercial premises are typically very much larger than domestic premises. Also, the commercial scenario needs to include some consideration for building attenuation (due to the higher amount of steel present in commercial buildings). A value of 10 dB is assumed. Following the same methods used for the in-home case yields an unintentional radiated power of 16.5nW/10 kHz per LAN.

It is noted that the measured emissions used as the basis of this estimate were performed with the 10BaseT system transmitting continuously. For a commercial LAN, the use of these measurements is quite realistic, since as the number of connected users increases, the level of LAN traffic will grow towards a continuous traffic level. Hence this is the worse-case level that may be expected during the height of the working day.

1.3.2 Calculation of D

This is noted to be difficult to calculate. If it is assumed that there are 10 million (i.e. 10^7) LANs deployed within commercial premises within the UK, given the surface area of the UK (2.45×10^{11} m^2), the average UK LAN deployment density is ~4×10^{-5} m^{-2}

1.3.3 Calculation of EIRP Density

From the previous sections, we have:

$p_{TX}g_{TX}$ = 16.5 nW/10 kHz

D = $4 \times 10^{-5} m^{-2}$

This yields a value of ~0.7 pW/10 kHz m^2, or ~-122 dBW/10 kHz m^2.

1.3.4 Sensitivities

If the number of LANs within the UK was overestimated by a factor of ten, the EIRP Density from the existing deployment of LANs would fall to ~-132 dBW/10 kHz m^2.

1.4 Luminaires

1.4.1 Calculation of $p_{TX}g_{TX}$

Measurements of a number of commercially available luminaire products at a distance of 1 m and within a bandwidth of 10 kHz have indicated that the emission level is generally around 50 dBμV/m/10 kHz (316 μV/m/10 kHz) between 4 and 6 MHz. This equates to a radiated power density of 264 pW/m^2/10 kHz.

Assuming that the luminaire radiates cylindrically (a reasonable assumption given the physical dimensions) and a typical luminaire length of 1 m, the surface area of the cylindrical surface is (2π x 1 m x 1 m) ~6.28 m^2. The total power radiated by the luminaire is therefore (264 pW/m^2/10 kHz x 6.28 m^2) 1.66 nW/10 kHz.

1.4.2 Calculation of D

The density of simultaneously active luminaires is noted to be difficult to calculate. One problem that needs to be addressed is the likely time-dependence of this value, since it can reasonably be expected that the number will have a seasonal variation (being highest during the winter months, lowest during the summer months) and an additional diurnal variation (for domestic deployments being highest in the evening, lowest during the day; for commercial deployments being highest during the working day, lowest during the evenings and weekends).

It is reasonable to assume that, on average, there will be one luminaire product installed per household within the UK, where luminaires tend to be deployed singly for single-room lighting (typically within kitchens and garages).

A far greater number can be expected to be deployed within commercial and industrial premises, where deployment takes place in regularly spaced clusters to provide a uniform level of lighting. This number can reasonably be expected to have increased within the UK during recent years as business practice has moved towards the establishment of large open-plan office layouts. This number is noted to be unknown and hence is estimated.

The scenario considered here will be that of an early evening during the Autumn and Winter months, during which both commercial and residential lighting are simultaneously active. If it is estimated that the number of simultaneously active luminaires within the UK is of the order of 100 million (i.e. 10^8) (i.e. 25 million residential, 75 million commercial) then (given the surface area of the UK as 2.45×10^{11} m^2) the residential deployment density is ~10^{-4} m^{-2} and the commercial deployment density is ~3×10^{-4} m^{-2}.

1.4.3 Calculation of EIRP Density

From the previous sections, for the residential deployment we have:

$p_{TX}\ g_{TX}$= 1.66 nW/10 kHz

D = 10^{-4} m^{-2}

This yields a residential EIRP Density value of 1.66×10^{-13} W/10 kHz m^2.

For the commercial deployment we assume a 10 dB building attenuation and hence have:

$p_{TX}\ g_{TX}$= 0.166 nW/10 kHz

D = 3×10^{-4} m^{-2}

This yields a commercial EIRP Density value of ~5×10^{-14} W/10 kHz m^2.

Summing the two EIRP Densities yields a value of ~21×10^{-14} W/10 kHz m^2, or ~-127 dBW/10 kHz m^2.

1.4.4 Sensitivity to Commercial Deployment

If the number of simultaneously active commercially deployed luminaires within the UK was *underestimated* by an order of magnitude and is in fact 750 million (i.e. 7.5×10^8), the commercial EIRP Density will increase by 10 dB to a level of ~5×10^{-13} W/m^{-2}/10 kHz. Hence the total EIRP Density would be ~6.6×10^{-13} W/10 kHz m^2, or ~-122 dBW/10 kHz m^2.

1.5 ITE Mains-Borne Emissions

CISPR 22:1997 places a series of conducted emissions limits on the mains ports of ITE equipment between 150 kHz and 30 MHz. A conducted limit is used in recognition of the fact that the systematic measurement uncertainties that apply are far smaller than those that apply to radiated measurements over this frequency range. Between 5 and 30 MHz (i.e. within the HF band), the tightest, Class B (i.e. residential) conducted emissions Quasi-Peak limit is 60 dBμV measured in a 10 kHz bandwidth. The Class A (i.e. commercial/light industrial) limit is more relaxed, but ITE manufacturers tend to certify to the Class B requirements to allow freedom of product deployment between the residential and commercial/light industrial environments.

The EU has adopted CISPR 22:1997 as one of the Harmonised Standards used by manufacturers to demonstrate product compliance with the EU EMC Directive. Hence every piece of ITE sold within the UK since the introduction of the EMC Directive on 1/1/96 has met this limit. For the purpose of this study, the term ITE applies to PCs, printers, sound systems and external (i.e. separately powered) CD-burners, modems etc.

1.5.1 Calculation of p_{TX}

Between 5 and 30 MHz (i.e. within the HF band), the Class B (i.e. residential) conducted emissions limit in the Quasi-Peak is 60 dBμV measured in a 10 kHz bandwidth (equivalent to a 1 mV/10 kHz).

CISPR assumes a common-mode impedance value of mains cables to be 50 Ω. Hence the power injected by a device meeting the CISPR 22:1997 Class B limit is ~21 nW/10 kHz.

1.5.2 Calculation of g_{TX}

Since the signals of interest are transmitted over mains cabling, the value of g_{TX} assumed within [5,6] for PLT are assumed here for consistency. Hence $g_{TX} = 0.01$.

1.5.3 Calculation of D

The density of simultaneously active ITE devices is difficult to calculate. As with the luminaires, the assessment must include both residential (i.e. low density) deployment and commercial (i.e. high density) deployments to come by an average value.

For the purposes of this study, it is assumed that the largest number ITE devices that may be simultaneously activated within the UK will be 50 million. This scenario is felt by the author to be a reasonable assessment of the number of ITE devices active during the typical working day. Given the surface area of the UK (2.45×10^{11} m^2), the average deployment density is ~2×10^{-4} m^{-2}.

1.5.4 Calculation of EIRP Density

From the previous sections, we have:

p_{TX} = 21 nW/10 kHz

g_{TX} = 0.01

$D = \quad 2 \times 10^{-4} m^{-2}$

This yields a value of 4.2×10^{-14} W/10 kHz m^2, or ~-134 dBW/10 kHz m^2.

2 Scenario Summary

The scenarios considered within Section 2 are now summarised for completeness.

Scenario Number	Technology	Summary
1	VDSL	25% of wire-pairs within the UK Access network converted to VDSL, half having an overhead connection typically 30 m in length
2	In-Home Networks	Every VDSL-enables home within UK having an simultaneously active in-home LAN consisting of 10BaseT technology transmitting continuously over a 10 m run of CAT5 cable
3	Commercial LAN	10 million simultaneously active LANs consisting of 10BaseT technology transmitting continuously over a 100 m run of CAT5 cable located in business premises (assumed 10 dB building attenuation)
4	Commercial LAN	1 million simultaneously active LANs consisting of 10BaseT technology transmitting continuously over a 100 m run of CAT5 cable located in business premises (assumed 10 dB building attenuation)
5	Luminaires	25 million simultaneously active domestically installed luminaires and 75 million simultaneously active commercially installed luminaires (assumed 10 dB building attenuation) within the UK
6	Luminaires	25 million simultaneously active domestically installed luminaires and 750 million simultaneously active commercially installed luminaires (assumed 10 dB building attenuation) within the UK
7	ITE	50 million simultaneously active items of mains-powered ITE equipment each generating mains-borne conducted emissions at the CISPR-22 level

Table 1: Scenario Summary

3 Interference to Aircraft: Overview of Approach

The framework presented within [6] attempts to predict the cumulative interference that mass-deployment of a given technology has upon aircraft navigation and communications. An integral formulation is employed that sums the effect of deployment within a number of concentric circles around the surface of a sphere. This integration considers only that part of the sphere's surface that can 'see' the aircraft. This area depends upon the height of the aircraft and is referred to hereafter as the 'visible earth'.

The framework assumes a uniform deployment density of simultaneously active, unintentional emitters over the 'visible earth'. The implications of this assumption are now discussed.

The first implication is the limitation of the framework to those situations in which the aircraft's position and height are such that the associated 'visible earth' region corresponds with an area of populated land over which this uniform density may be assumed. There are therefore significant portions of the Earth's surface over which this framework cannot be applied. Some 70% of the Earth's surface is covered by ocean, where the deployment density of any unintentionally emitting technology will be effectively zero. Considering the remaining 30% of the Earth's surface covered by land, it is noted that there exists significant portions where population densities are so low as to drive the density of any unintentionally emitting technology to zero. These include the desert regions that together account for approximately 33% of the Earth's land surface area, the Amazon basin etc. When considering the remaining, populated land surface, it is noted that significant areas are unlikely to see mass-deployment of any high technology unintentional emitting technology. For example, it is highly unlikely that continental Africa will see significant deployments of any high technology within the foreseeable future. Similarly, the ability of the fledgling economies within Eastern Europe and the former Soviet republics to mass deploy such technologies is also in question. Essentially, the issue of radio interference to aircraft communication and navigation from xDSL technologies must limit the sources to those regions that are likely to see mass-deployment within the near term. These regions consist of North America, Northern Europe, the Tiger economies along the Pacific Rim and the populated coastal region of Australia.

Thus, to apply this formulation to assess the interference threat to passenger aircraft over the North Atlantic routes between Europe and North America would be, in the view of the author, fundamentally flawed. This is because for a large part of the flight-path, the ‘visible earth’ region encompasses an area that is primarily ocean, where the deployment density is effectively zero, or land where the population densities are so low that the deployment density is also effectively zero.

It is interesting to note that, given the ‘typical’ cruise altitude of an aircraft over the North Atlantic (this being ~24,000 ft or ~8,000 m), the radius of the ‘visible earth’ is noted, from [6], to be in excess of 300 km. Assuming a radius of 300 km and a surface area of πr^2 (admittedly an approximation), the ‘visible earth’ covers an area of $\sim 3 \times 10^{11}$ m^2, i.e. an area in excess of the surface area of the UK (2.45×10^{11} m^2).

The second implication is the inability of the framework from successfully considering those situations in which the ‘visible earth’ contains a discontinuity in deployment density. Considering xDSL, it is noted that the deployment of interest is on overhead wire-pairs within the Access Network. Within Northern Europe, the proportion of overhead/underground wire-pairs within national Access Networks varies greatly between nations, a natural consequence of each national network’s separate historical development. For example, Germany has an Access Network that is primarily underground and is hence expected to be a greatly reduced emissions source. Hence the validity of applying the formulation to a scenario in which the ‘visible earth’ region encompasses an area that contains two (or more) national networks, each with very different overhead deployment regimes and hence different deployment densities is in question. Given the size of the ‘visible earth’ noted previously, this situation may occur over large proportions of an aircraft’s flight path when travelling over Northern Europe.

When the aircraft’s position and height are such that the ‘visible earth’ region corresponds to a single nation, the density will still in practice vary between areas of open countryside (low deployment densities) and conurbation (high deployment densities).

Hence it is the view of the author that application of this framework can only really be applied to heights and positions at which the ‘visible earth’ corresponds with a conurbation. Even then differences in deployment density will occur, for instance between the conurbation’s central business district (where a relatively high density of xDSL deployment can be expected, emulating the existing deployment densities of LANs) and its residential areas (where relatively lower deployment densities can be expected). However, the use of an average density over a smaller area is likely to be more valid. This therefore restricts application of the framework to very low heights. To illustrate this, consider an aircraft positioned over the centre of London. If we assume that London is a conurbation covering a circle of 50 km radius, the aircraft would have to be very low. The figure displayed on page 10 of [6] shows the radius of the ‘visible earth’ region plotted against aircraft height. To limit the ‘visible earth’ region to a radius of 50 km, the aircraft is clearly required to fly low. The author is unaware of typical flight altitudes currently allowed over London and details of when exactly during the flight path that the aircraft will reach these heights.

For such low altitudes, the use of a spherical Earth model is something of an over-complication. It would have been easier to develop a ‘flat-earth’ model for this instance.

4 Conclusions

While BTexact Technologies does not endorse the use of the framework presented within [5,6], it has been used within this paper to compare the interference potential arising from a number of highly simplistic scenarios for the mass-deployment of various unintentionally emitting technologies. Considering the parameters used with respect to VDSL, the resulting prediction is noted to be an over estimate of the interference potential. The following table summarises the scenarios considered and compares the results.

Currently Mass-Deployed Technology	**Proposed Mass-Deployed Technology**	**EIRP Density (dBW/10 kHz m^2)**
	PLT (scenario within [5,6])	-107
Commercial LANs[3]		-122
Luminaires[6]		-122
Luminaires[5]		-127
	In-Home networks[2]	-130
Commercial LANs[4]		-132
ITE[7]		-134
	VDSL[1]	-143

Table 2: Comparison of Interference Potentials

It is noted that almost all of the assumptions made within each scenario are open to question. For example, when considering luminaires, a 1 m effective length has been assumed. This assumes that the bulb itself is the source of emissions and does not consider the radiation caused by the attached mains cabling. Similarly, the deployment numbers assumed are open to question: the assumption of one luminaire product per household may need to be addressed in the light of the recent trend towards the domestic installation of low-voltage lighting. Hence the interference potential from the luminaire scenario could easily be increased. The in-home networking scenario is also noted to be simplistic, failing to consider the true complexity of multiple networking technologies. It also fails to consider the existing mass-deployment of USB technology.

Of the currently mass-deployed technologies, it is noted that the commercial LAN deployment scenarios considered generate the highest range of interference potential (-122 to –132 dB/10 kHz m^2) and encompasses the range of interference potential arising from the luminaire scenarios considered (-122 to -127 dB/10 kHz m^2). The ITE deployment scenario is noted to generate the lowest level of interference potential (-134 dB/10 kHz m^2).

Of the future technologies, the PLT deployment scenario considered in [5,6] is noted to generate the highest interference potential (-107 dB/10 kHz m^2). This is followed by the worse-case in-home network scenario considered (-130 dB/10 kHz m^2) and the worse-case VDSL deployment scenario considered (-143 dB/10 kHz m^2).

The interference potential due to the existing mass-deployment of LANs, luminaires and ITE devices is therefore noted to be at least 10 dB in excess of that computed here for VDSL.

5 Glossary

Acronym	**Meaning**
ADSL	Asymmetric DSL
BT	British Telecommunications plc
CAT	Category
CISPR	Special International Committee for Radio Protection
DSL	Digital Subscriber Line
EIRP	Equivalent Isotropically Radiated Power
HF	High Frequency
HPNA	Home Phone Networking Alliance
ITE	Information Technology Equipment
ITU	International Telecommunications Union
kHz	Kilohertz
LAN	Local Area Network
m	Metre
MHz	Megahertz
PC	Personal Computer
PLT	Power Line Transmission
PSD	Power Spectral Density
UK	United Kingdom
USB	Universal Serial Bus
VDSL	Very High Speed DSL
VoD	Video on Demand
W	Watts

6 References

[1] MPT1570 Radiation Limit and Measurement Specification, *Electromagnetic radiation in the range 9 kHz to 1.6 MHz from material substances forming part of a telecommunication system*, August 2001

[2] NB30

[3] *Cumulative Effect of Radiated Emissions from Metallic Data Distribution Systems on Radio Based Services*, Radiocommunications Agency Document No. R/00/026

[4] ERA Work

[5] *Protection of 'Sensitive' Receiving Sites*, Jonathan Stott, BBC R&D

[6] *Cumulative Effects of Distributed Interferers*, Jonathan Stott, BBC R&D, TWG (05) 03

[7] General Household Survey 1998, National Statistics Office