AY4439
Study to quantify the economic impact on the UK spectrum industry and its users of Ofcom not undertaking technical research and standards work in the area of Electromagnetic Compatibility (EMC)

Appendix 1
Future Products and Services

A Study for

Ofcom

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CONTENTS Page

1. INTRODUCTION

This report into the EMC implications arising from future products as services was performed in support of the “Study to quantify the economic impact on the UK spectrum industry and its users of Ofcom not undertaking technical research and standards work in the area of Electromagnetic Compatibility (EMC)”. It forms Appendix 1 of the final report.

The Radiocommunications Agency (the “Agency”), and more recently Ofcom, has defined EMC research as being concerned with the susceptibility of non-radio devices to radio waves, and vice versa. However, for the purposes of our study, the Agency EMC research funding has addressed:

- Interference from non-radio devices on users of the spectrum. The Agency’s primary role is to protect users of spectrum and therefore research into EMC issues involving interference on non-radio devices is not funded (either from radio or other non-radio devices);

- Methods of resolving EMC issues by appropriate measurement techniques or limits applied to interference sources (the Agency feels that users of spectrum should be motivated to fund their own “immunity” research into improving susceptibility measures).

The impact of interference from intentional radio use is considered an interoperability issue and therefore not part of EMC research. Interoperability studies are undertaken before any spectrum allocation is made, to ensure that co-channel and adjacent channel interference is managed. Despite this, Ultra Wide Band (UWB) and Short Range Devices (SRD) are often associated with the EMC environment; therefore an overview of these techniques have also been included.

This report details the primary noise sources and developments in victim systems susceptibility, both currently and anticipated in future years. It is in these areas that EMC research will be necessary to ensure that users of the spectrum are adequately protected. It concludes by identifying the areas where current EMC issues are likely to have a significant economic impact on victim systems.

2. FUTURE USES OF THE RADIO SPECTRUM

2.1 Overview

Many parts of the radio spectrum are coming under pressure from increasing numbers of users and the introduction of new services As a result the UK spectrum is almost fully allocated up to around 60 GHz in the UK. These new spectrum uses may have technical characteristics requiring an allocation within a certain frequency range. Market forces are tending to promote harmonised spectrum allocations across a large economic area, which puts pressure on extant allocations.

As a result there is increasing interest in new technologies that have potential to share the spectrum with existing services; either by operating at low power with low range so as to not interfere with existing usage (such as Short Range Devices); or to spread emissions over a large frequency range with minimal impact on existing users (such as Ultra Wide Band).

When considering the full scope of potential users of the spectrum, there is clearly a huge variation in services. It is useful to understand the major users of the spectrum in terms of economic value to the UK economy. This helps identify the potential victim systems that might be most economically disadvantaged by any increases in Electromagnetic Interference (EMI).

In February 2001, the Agency undertook a study to assess the contribution of the radio industry to the UK economy[1]. The study concluded that the main radio industry sectors had the contributions to the UK economy in the year 2000 as detailed in Table 2.1.

[1] "The Economic Impact of Radio", The Radiocommunications Agency, Feb 2001

Radio Industry Sector	Value (£ billion)	Percentage of total radio contribution
Public Mobile	8.2	40%
Broadcasting	7.4	36%
Satellite links	1.8	9%
Fixed links	1.6	8%
Private Mobile Radio (PMR)	1.1	5%
Other*	0.2	1%
Other includes amateur, citizen's band, aviation, maritime and other equipment and services.		

Table 2.1 Breakdown of value to UK economy in 2000, of radio service sectors

The main EMC issues anticipated within these radio industry sectors are discussed in Sections 3 and 4 for indoor and outdoor environments respectively, highlighting the ways in which further research may be expected to help mitigate these problems.

There have also been new developments in both electronic goods and radio technologies. Some of these have potential to affect both indoor and outdoor environments; they are listed below and considered in detail in Section 2.2.

- Ultra Wide Band (UWB) transmissions;
- Faster clock speeds in digital circuitry;
- Proliferation of switched mode power supplies (SMPS);
- Proliferation of energy efficient lighting;
- More use of electric powered vehicles.

Indoor and outdoor environments and considered in Sections 3 and 4 respectively, for both potential noise sources and susceptible radio systems.

2.2 Developments in radio and electronic technology

2.2.1 Ultra Wide Band (UWB)

Although the deployment of UWB radio systems is considered an interoperability issue rather than EMC, it is nevertheless useful to consider its impact since it may be important when aggregating interference from many sources. UWB radio systems are characterised by having a large fractional bandwidth (i.e. signal bandwidth/centre frequency > ~0.2) or a signal bandwidth exceeding 500MHz. Recent innovations in pulse technology has resulted in an ability to relatively cheaply generate pulse-based UWB signals.

The wideband nature of UWB signals means that the signal energy cannot be confined to specific frequency bands. Hence, typically, license holders who operate with "conventional" technology in nearby frequency allocations are subject to interference from any UWB devices.

After reports of UWB transmissions interfering with mobile telephone systems and the GPS bands used to control the landing and navigation of aircraft, the Federal Communications Commission held an enquiry into UWB interference effects. This resulted in the publication of the FCC's First Report and Order revising Part 15 of the FCC's rules regarding UWB systems in April 2002.

This FCC's First Report and Order was generally sympathetic to permitting more widespread use of UWB technology. The primary outcomes of the report were:

- The FCC modified their Part 15 rules to relax the regulations governing unlicensed emissions in different bands to permit the marketing and operation of certain types of UWB applications;

- The FCC commissioners stated their belief that the limits identified in the April 2002 R&O are 'ultra-conservative' and that these limits were agreed 'reluctantly'. The commissioners intend to further review the limits in the short term, thereby indicating that the modified FCC rules are likely to be further relaxed.

A recent study on the impact of UWB sources on 3G networks conducted for the Agency by Mason Communications[2], had the following main conclusions:

- The impact is more significant on a mobile handset than a base station;

- The separation distance between UWB devices and a handset is a key driver to the impact of interference (using the UWB emission mask defined by ETSI, there was negligible impact when the separation distance between isolated UWB device and handset exceed a few meters);

- The impact of aggregated interference form a large number of UWB devices on a network is dominated by close proximity events – i.e. the probability of close proximity between victim receivers and UWB devices.

[2] "Impact of UWB on Third-Generation Telecommunications (3G)", Mason Communications Ltd. Study report for Radiocommunications Agency, Feb 2003, available from http://www.ofcom.org.uk

Consistent with an ETSI investigation, the Mason report anticipates that the vast majority of UWB devices will be targeted on domestic applications. ETSI anticipates that indoor communications and measurement devices (particularly wireless LAN) will constitute almost 90% of the UWB market. Mason also reported that a manufacturer estimates that 95% of their market for UWB devices is for domestic applications.

Hence it is likely that there will be a proliferation of UWB applications – mainly targeting domestic applications. The consequences of any increased interference generated by these UWB devices is likely to be most acute on any other devices in local proximity to the UWB devices.

UWB techniques are comparatively new, and while some research has been done on the interference caused by UWB transmissions to other legitimate users of the radio spectrum, very little testing has been done on the susceptibility of other non-communications equipment to the very short pulses used in UWB. No current equipment susceptibility standard specifies immunity to short pulse interference, and this presents a risk to the future uptake of any UWB system, particularly in domestic or medical environments.

2.2.2 Faster clock speeds

Digital clock speeds have been increasing steadily over the last 10 years as shown in Figure 2.1, and this looks likely to continue. Current state-of-the-art personal computers (PCs) operate at speeds exceeding 3 GHz and are therefore likely to have significant emissions up to at least these frequencies.

Opinion is divided within the industry as to how long the trend of Figure 2.1 can be sustained. A more likely estimate of clock range of is 10-20 GHz. This encompasses the frequency range within which mobile phones and wireless LANs operate.

At frequencies above 1GHz (i.e. frequencies with a freespace wavelength of 30cm) even modest domestic appliances can span many wavelengths, whereby interference leaking from many locations on the device can behave like an array, focussing the interference into relatively narrow beams of interference. Clearly with frequencies above 10GHz even small handheld devices have the potential to behave like an array.

The current EMC standards only define limits for frequencies up to 1 GHz, therefore there is effectively no EMC protection to these radio services provided by the current standards. However, the issue has been acknowledged and the Agency has already funded a number of projects addressing this issue.

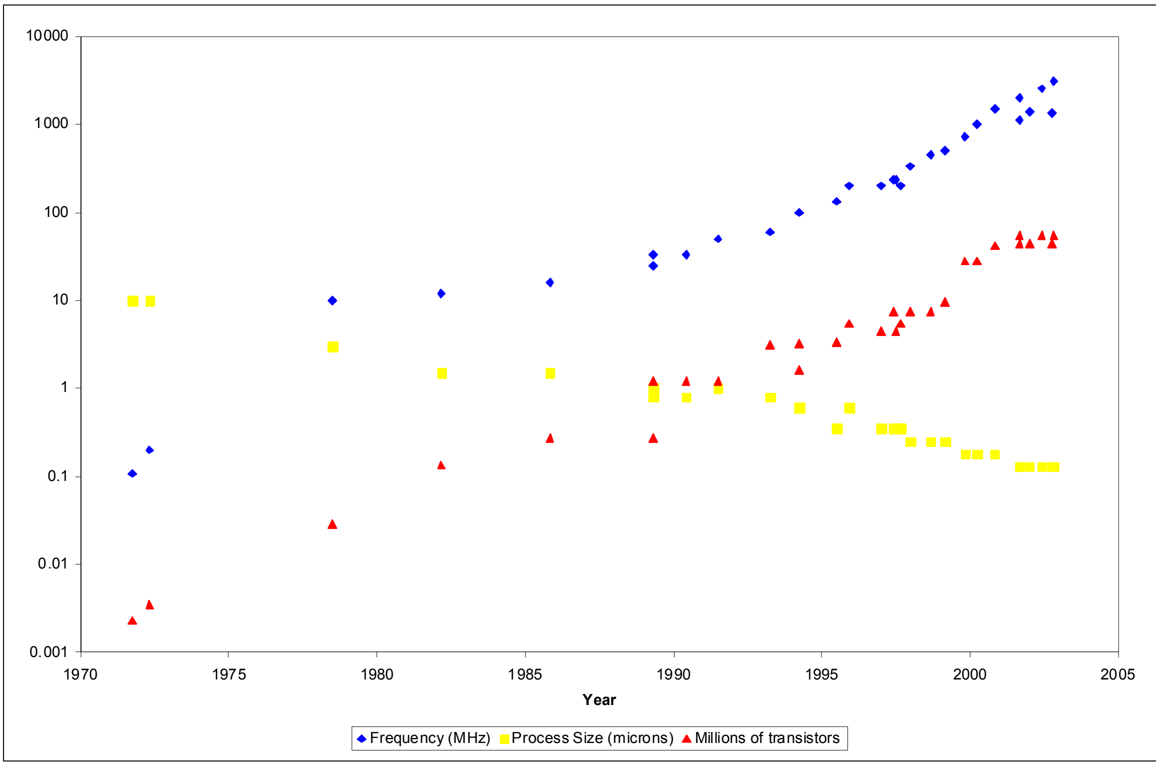

Figure 2.1 Frequency, Process Size and number of transistors in Intel Desktop Processors[3].

Up to the present, use of digital equipment with clock speeds in excess of 1GHz has not been a major problem. Over the next decades, we can expect many more devices in the indoor environment to be fitted with fast clocked electronics. It is this proliferation in conjunction with the increasing clock rates that raises the prospect of interference to radio communications devices and the attendant need for research.

2.2.3 Switched Mode Power Supplies and Switched Electronic Load Controllers

The proliferation of electronic devices powered by switched mode power supplies (SMPSs) looks set to continue. Compared to linear power supplies, SMPSs are smaller, lighter and much more efficient (typically 70-80%, cf. 30% for a typical linear power supply) at converting mains power to low voltages for electronic applications (a modern PC SMPS is able to supply >150W via its 3.3V and 5V rails). This high efficiency is achieved by chopping the input supply at very high frequencies up to

[3] Intel Microprocessor Quick Reference Guide, 2003, available from http://www.intel.com/pressroom/kits/quickreffam.htm

200kHz, then filtering and smoothing to produce the required output. Future operating frequencies of SMPS will increase into the MHz range for higher efficiencies (the faster a device switches, the less wasted heat is involved). The fast chopping of the input supply has the potential to generate significant EMI.

Switched Electronic Load Controllers (SELCs) are employed in lighting dimmer switches and variable speed control devices (e.g. power drills); they work by varying the duty cycle (on:off ratio) of the AC power supplied to the device. SELCs are typically built using thyristors, which reduce the power throughput by switching on the current partway through each mains cycle; because of the very rapid rise time of thyristors (typically 1µs), RF interference can be generated and propagated through the mains wiring unless some form of filtering is fitted.

An additional concern with both technologies is that as their load is reduced, the input power supply is sampled for shorter periods, leading to a corresponding increase in the maximum frequency of the unintended emissions.

Although standards work is in progress to address these issues, it is the proliferation of these devices and the resulting aggregation of interference that must be taken into account to fully understand their future impact.

2.2.4 Lighting technologies

The control of discharge lighting equipment has traditionally been performed using passive components. The use of electronic lighting control devices has the advantages of reducing the operating energy use when applied to fluorescent lighting and enables additional functionality such as the dimming of fluorescent lighting and the use of sensors to dim lights when a room is unoccupied. These devices are essentially developments of the switched mode power supply as described above and so have the potential to produce unwanted interference.

The distributed nature of lighting, particularly in typical commercial properties means that there may be particular potential problems associated with this high density of switching power supplies.

Self ballasted compact fluorescent lamps are an increasingly popular ‘drop in’ low energy replacement for traditional filament lamps; high pressure sodium vapour discharge street lights are more energy-efficient than mercury lamps and produce whiter light than low pressure sodium discharge lamps, and will become more common. Each one of these lamps contains an internal electronic power supply.

Low voltage halogen lighting is also popular in domestic and commercial lighting installations or upgrades. The low voltage power supply is likely to be of the switching type for these products.

Other lighting technologies also utilise high frequency techniques in their operation including electrodeless discharge lamps that operate at radio or microwave frequencies. At present these are used mainly in inaccessible areas or in large factories and are not reported to cause problems but their proliferation would raise questions of potential interference.

Of the few cases that York EMC Services has been involved in of a manufacturer investigating and modifying equipment after a customer complaining of radio reception deterioration after installation, two were for lighting related products. The products were for domestic use and street light control and used switching technology. The products met the requirements of the current EMC product standard relevant to lighting (CISPR13/EN55013); however, the interference observed was in a frequency band outside those covered by this standard suggesting that the standard is already inadequate to protect current spectrum usage from current technologies.

Hence the potential issues for lighting in the future are to understand the consequences of widespread deployment of lighting where each light potentially has an internal switched mode power supply; and the consequences of inadequate EMC product standards in this area.

2.2.5 Electric vehicles

Whilst looking at major changes in society over the next thirty years is problematic, and outside the scope of this study, one obvious unavoidable change is the increasing scarcity of oil supplies. This will lead to a much heavier dependence on alternative sources of energy, and in particular, a likely increase in the use of electric or hybrid powered vehicles. These can generate significant sources of noise over the whole radio spectrum, and are likely to be used in large numbers in close proximity to residential areas.

The issue with the EMC testing of these vehicles is that they only generate their maximum signals when accelerating or braking. Although some new EMC standards have been proposed to accommodate these devices[4], they specify the use of a peak detector, since there isn't enough time while the vehicle moves past to use a quasi-peak detector. This potentially allows a very large amount of narrowband noise to be transmitted by these vehicles, which can cause disruption to radio services up to a few kilometres away from the vehicle. New methods of testing, and appropriate limits are required for these vehicles.

[4] "Potential Electromagnetic Interference to Radio Services from Railways", T Konefal, DAJ Pearce, AC Marvin, L McCormack, CA Marshman, EMC Europe 2002: International Symposium on Electromagnetic Compatibility, Sorrento, Sep 2002.

3. EMC ISSUES IN INDOOR ENVIRONMENTS

3.1 Emerging and potential noise sources

3.1.1 Radar emissions to within airport buildings

Radar systems, due to their necessarily large transmit powers, have been known to cause problems with any sensitive radio receiver in the vicinity, including car security devices[5]. With the increasing use of devices operating around the 2.4 GHz ISM band, this problem is likely to get worse rather than better, as many radar systems, for example airport radar, operate in the S-band (2 - 4 GHz). This could cause issues for the use of systems based on ISM bands in certain locations, notably airport terminals; where it could be particularly disruptive if these services formed part of the airport's revenue stream.

The use of frequency-selective surfaces shows promise in reducing this problem - the use of building materials that can pass frequencies up to 2 GHz (allowing mobile phones to work), whilst effectively blocking the harmful interference at the higher frequencies used by wireless Local Area Networks (LAN) and Personal Area Networks (PAN). Plans to harmonise the allocation of further 3G spectrum between 2.500 and 2.690 GHz from 2007 can only serve to complicate this problem.

At present, frequency selective surfaces do not have the selectivity required to achieve a significant level of isolation at 2.4 GHz while being transparent at third-generation mobile phone frequencies (1885 - 2025 MHz and 2110 - 2200 MHz). Further work in this area could significantly reduce the problems of excessive interference within the ISM bands.

3.1.2 Short-range devices and home area networks

The increasing use of short-range devices (SRDs), including hi-fi wiring replacement, central heating thermostats, doorbells, electronic security devices, smoke detectors, is likely to replace all wiring in the home except power due to the benefits of reduced installation costs.

Conventional SRDs that are not based on UWB are subject to co-existence studies before their use is permitted in the UK. Part of any such study should incorporate a forecast of the likely density of such devices to understand the aggregated interference effects.

[5] "433.920 MHz Radio Keys", D. Lauder, Newsletter of the Northampton Amateur Radio Group, 1998.

Although emissions from SRDs (as intended emissions) do not constitute EMC sources, their aggregated power must be considered along with unintended transmissions in the indoor environment to fully quantify any degradation.

3.1.3 Domestic appliances

It is unlikely that the fundamentals of heat generation, whether using electricity, gas or oil, will change significantly over the next 30 years. Electronic controls and thermostats are common to all types of central heating; hot water and blown-air systems use motors to drive pumps and fans; and gas and oil fuelled systems require igniters. In the future, intelligent wireless control and inter-device communication are likely developments, building on current short range techniques and technologies.

The sources of EMI that can be expected from various types of cooking appliance are listed in Table 3.1.

Type	Current interference issues	Future interference issues
Electric hob (hot element & halogen)	Electronic control, thermostats	Addition of wireless control functions possible
Electric hob (induction)	Electronic control, induction frequency	
Electric oven	Electronic control, thermostats, motors	
Microwave oven	Power supply, cooking frequency, electronic control, motors	
Gas cooker	Electronic control, igniters, motors	

Table 3.1 Sources of EMI from cooking appliances

The sources of EMI that can be expected from various types of cooling appliance are listed in Table 3.2. Intelligent control and inter-device communication are likely as future developments as an expansion of current short range techniques and technologies.

Type	Current interference issues	Future interference issues
Refrigerators	Electronic control, thermostats, motors	Addition of wireless control functions possible
Freezers		
Air Conditioning	Power supply, electronic control, motors	Addition of wireless control functions possible. Increase in density of installations may be expected

Table 3.2 Sources of EMI from cooling appliances

The sources of EMI that can be expected from various types of laundry appliance are listed in Table 3.3. Intelligent control and inter-device communication are likely as future developments as an expansion of current short range techniques and technologies.

Type	Current interference issues	Future interference issues
Washing machines	Electronic control, thermostats, motors	Addition of wireless control functions possible
Dishwashers		Addition of wireless control functions possible. Increase in density of installations may be expected
Tumble dryers		Addition of wireless control functions possible. Increase in density of installations may be expected

Table 3.3 Sources of EMI from laundry appliances

3.1.4 Lighting

The sources of EMI that can be expected from lighting devices are listed in Table 3.4.

Type	Current interference issues	Future interference issues
Dimmer switches	SELCs	Addition of wireless control functions possible
Energy-efficient bulbs	SMPSs	Addition of wireless control functions possible. Increase in density of installations may be expected.

Table 3.4 Sources of EMI from lighting

Entertainment and Home Computing

As entertainment systems develop they are increasingly converging with information technology equipment (computing equipment) and are consequently better referred to as 'multi-media' systems. This is an issue taken on board by CISPR with the demise of CISPR sub-committees E and G, and the combination of ITE and broadcast reception interference activities under the new CISPR I (multimedia) sub-committee.

It is therefore sensible to consider developments in home entertainment technology with those in Information Technology Equipment (ITE) and home computing technology.

The convergence of entertainment systems and ITE will continue, making use of faster processors in greater numbers, coupled with a Switched Mode Power Supply (SMPS) in each discrete item. Not only will more ITE/entertainment devices exist in a home, but there will be separate adapters to recharge mobile phones, digital cameras, personal audio devices, PDAs etc.

Inter-device communications (and device-appliance communications) will be digital and wireless in nature. A broadband internet connection (eg xDSL, cable modem, Power Line Transmission (PLT)) may be wired to one node of the home network; whether this is connected to a set-top box in the living-room, a more conventional PC in a bedroom/home office or a 'home automation' server (which also controls appliances in the rest of the house) in the loft will affect the emissions from the varying vertical length of wire. Emissions from the external cabling are discussed with in Section 4.1.4.

In summary there are four noise sources related to entertainment and home computing to consider: proliferation of processors and SMPS, interdevice communications, and emissions from the broadband connection within the home.

Home energy

The domestic conversion of alternative energy sources can be segmented into those separate from the mains power supply (e.g. direct solar water heating, isolated electricity generation by wind or solar power) and those that the consumer wishes to connect to the mains power supply. Connected systems will have the potential to cause more types of interference regardless of the alternative energy source used. The sources of EMI expected from home energy sources are listed in Table 3.5.

Type	Current interference issues	Future interference issues
Direct solar water heating	Pump motors	Addition of wireless reporting functions possible
Wind powered generator	Dynamo, inverter/alternator	
Solar panel	Inverter/alternator	
System connected to mains power supply	Phase, harmonic distortion	

Table 3.5 Sources of EMI from home energy sources

DIY power tools

The use of SELCs to drive variable-speed motors in power drills, multitools, saws and electric screwdrivers is likely to increase.

Security systems

Whether wired or wireless, the EMC issues associated with intruder alarms are similar to ITE/entertainment devices, since they are electronic devices powered by a SMPS. The signal wiring may act as an antenna to help radiate any EMI, but this is true of any other wiring in a house. Security systems based on wireless technology use designated frequency bands, making them more likely to be a net victim of EMI. Future advances may see the addition of wireless control/reporting functions and/or a move to UWB for communications. Home CCTV systems may be treated in much the same way, though the bandwidth requirements for wireless video are rather larger.

3.2 Potential victim systems

3.2.1 Wireless LANs

At present, by far the most widespread Wireless LANs are based on the 802.11b standard, and can achieve up to 11 Mbit/s using the ISM band at 2.4 GHz. Over the next few years, there is likely to be a trend to move towards the 802.11a standard, which operates in the 5GHz ISM band and can support bit rates up to 54 Mbit/s. The

802.11g standard is based on the 802.11b standard but uses a higher order modulation scheme to allow support of faster bit rates than 802.11b.

European sales of Wireless LAN equipment are anticipated to be approximately Euro 330M in 2004[6]. By 2006, the number of 802.11 Wireless LAN users in Western Europe is expected to reach 20 million.

Like Personal Area Networks (PAN), Wireless LANs have targeted the ISM bands for two reasons: they are free, and available across large market areas without the need for dedicated spectrum allocation. This has reduced time to market for an industry that is anxious to gain market share. This increasing popularity of the ISM bands has potential to raise congestion and make it more susceptible to interference from other sources.

As the data rates required by typical users continue to expand it is likely that new spectrum and communication techniques will be used to target this large market. UWB techniques are the favourite candidates to provide these future higher data rates.

3.2.2 Personal area networks

Recently, low cost, short range radio applications have begun to emerge based on the Bluetooth and ZigBee radio standards. The use of these technologies is expected to increase, replacing just about all traditionally wired-based systems except power. These new wireless communications standards are expected to replace wire links between hi-fi components, headphones, keyboard and mouse wiring, doorbells, central heating thermostats, monitor and television video leads, etc. Both Bluetooth and ZigBee target the 2.4 GHz ISM band, suggesting that this band is likely to be very congested in the future.

[6] IDC, Western Europe RLAN Market Forecasts and Analysis, 2000 – 2005.

4. EMC ISSUES IN OUTDOOR ENVIRONMENTS

4.1 Emerging and potential noise sources

4.1.1 Ad-hoc networks

Ad Hoc networks use an interconnected web of short range communication links to (dynamically) establish an communications network that can transmit information to a suitable Point of Presence. In this way, a large geographical coverage can be achieved without the need of an infrastructure of base stations.

Initial uses of such a system are likely to be short text messages operated on a store-and-forward basis; however the technology has the possibility to spread to include other services where coverage is available. Due to the shortage of low-frequency spectrum available, and the necessity of low-frequency spectrum for non-line-of-sight and into-building transmission, low frequency (< 1 GHz) UWB systems are the favourite candidates for any such system.

Although no such system currently exists, the potential for such a system is enormous, and looking over thirty years these devices could be nearly universal, and be generating a significant increase in the background noise level up to 1 GHz, covering all the terrestrial broadcasting bands.

Clearly the introduction of UWB for wide area systems must be undertaken in a manner that is cognisant of the technical and economic impact on all existing spectrum users.

4.1.2 Transport

The sources of EMI expected from various types of transport are listed in Table 4.1.

In the railway environment, interference can occur from rolling stock as a result of the sliding contact, traction drives and other train borne equipment such as air-conditioning units. Standards are currently in place to limit the emissions but these are based on achievable limits from transient sources such as the sliding contact. However, the standards do not specifically cover continuous emissions (which may be generated by the traction package for example) and, in theory, continuous emissions could be at the transient levels and still conform to existing EMC standards.

Type	Current interference issues	Future interference issues
Car (carbon-based fuel)	Ignition systems, electronic car management systems, data buses and new lighting (discharge based) technology	Addition of wireless reporting functions possible
Car (electric)	Motors, regenerative brakes, electronic car management systems	
Buses	Electronic control/communications systems	
Trains	Electricity supply/conversion systems, DC commutator motors, regenerative brakes, electronic control/communications systems	
Autonomous systems		More intensive wireless reporting/control functions

Table 4.1 Sources of EMI from types of transport

4.1.3 Lighting

Energy-efficient street lighting (e.g. high pressure sodium discharge lamps) will become more commonplace. Technical lighting issues are substantially the same for both domestic and outdoor/industrial lighting. The major differences lie in the installations, both in location and density with the majority of any problems to be expected to be seen in the domestic (or indoor) environment first. The major future direction of outdoor lighting may be driven politically as well as technologically - issues such as light pollution may become higher priorities influencing the technologies employed.

4.1.4 Broadband access technologies

Some broadband internet connection technologies (particularly xDSL and PLT) use extant cabling, ie telephone and power lines, to provide broadband connectivity. Unintentional RF emissions from such cabling, not designed to carry radio frequency signals, may adversely affect the radio noise floor[7,8,9].

4.1.5 Medical and sciences

The use of high level radiofrequency signals is commonplace in some areas of medical sciences (MRI scans, diathermy etc). Concerns over sensitive medical monitoring equipment means, however, that a high degree of self-regulation can be expected in the area of medical technology.

4.1.6 Industrial

Many industrial causes of EMI are similar in principle to those found domestically, just on a larger scale - SMPSs supplying racks of fast digital electronics, SELCs driving variable speed motors and more robust communication channels. Additionally there are electric spark generating processes (eg arc welding), but these are already covered by relevant standards.

4.1.7 Power distribution

Apart from possible future large-scale deployments of PLT (see section 4.1.4), there have been anecdotal reports of jitter in the 50Hz mains supply causing visible interference on the screens of 100 Hz refresh rate CRT televisions.

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[7] Final Report on a Study to Investigate PLT Radiation, RV Womersley, RD Simmons and CV Tournadre, Nov 1998, available from http://www.radio.gov.uk/topics/research/topics/emc/plt/plt_intr.htm

[8] Cumulative Effect of Radiated Emissions from Metallic Data Distribution Systems on Radio Based Services, DW Welsh, ID Flintoft and AD Papatsoris, Jun 2000, available from http://www.radio.gov.uk/topics/research/topics/emc/ay3525/intro.htm

[9] Continuation of investigations into the possible effect of DSL related systems on Radio Services, ERA Technology Ltd, May 2001, available from http://www.radio.gov.uk/topics/research/topics/emc/ay3949/ay3949.htm

4.1.8 Law enforcement systems

Radar-based speed measuring devices operate in designated bands (around 24 GHz in the UK); it is likely that developments of radar-based devices will continue to use allocated bands (though devices based on non-emitting technologies are likely to become more prevalent). Tasers and other weapons based on electrical discharges are likely to be strictly controlled; the fast transients generated are similar to those emanating from other sources of electrical discharge.

4.2 Potential victim systems

4.2.1 Public mobile telephony

A new generation of mobile phones occurs about once every decade, with the third generation starting to emerge in this country now. Looking thirty years ahead implies looking at the birth of the sixth generation: something not even considered in the most forward-thinking research proposals.

It is likely that public mobile infrastructure as we know it today is unlikely to still be around. The use of large base stations covering several city blocks in urban areas is not the most efficient use of the radio spectrum, and as more information is transmitted over the airways (including a constant monitoring of our location and health indicators) the demand for spectrum will increase. Instead, we will see increasing use of small ‘picocells’ with a range of a few tens of metres, making access to the phone system, the internet and broadcast radio and television available anywhere in urban areas and selected rural areas such as car parks, picnic sites and playgrounds.

The issue for public mobile systems is the impact of interference that may by aggregated from the multiplicity of interference generating devices in the wide area.

4.2.2 Digital broadcast TV and radio

It is assumed that the retreat of analogue broadcasting expected over the next decade will continue: digital broadcasting can offer services more robust to fading and co-channel interference, resulting in greater frequency re-use and higher spectrum efficiency. Analogue radio broadcasting will continue over the coming decade due to the limited advantages for listeners in many environments to switch over, the cost of DAB receivers and the number of analogue receivers per household to replace. Most current digital broadcasting use orthogonal frequency domain multiplexing (OFDM) techniques, and employ forward error-correction coding with the energy associated with each bit of information spread in both the time and frequency dimensions.

This has the effect of averaging out any broadband burst of interference, or narrow-band frequency-interferer amongst many received bits. Hence, modern digital communications links, are less susceptible to interference owing to the use of coding and interleaving schemes.

Under these conditions, the average power in the interference signal provides a more accurate measure of the disruption to the service than the current 120 kHz bandwidth quasi-peak detector specified in the existing EMC standards[10].

The quasi-peak detector was first specified to reflect the subjective levels of interference to an amplitude-modulated radio spectrum. It was built into test equipment, and has been used ever since, despite amplitude modulation being of little interest at frequencies above 1 MHz. As a result, digital radio may not be adequately protected by current EMC regulations, which could result in either too much interference to these services; or a non-optimum allocation of spectrum, limiting the availability of these services. Therefore current EMC standards are based on techniques that are not well suited to digital communications signals. However, research is currently underway with the aim of updating the quasi-peak detector with a new detector more suitable for digital transmission in both CISPR[11] and the ITU-R[12].

For narrowband continuous transmission interference sources, this will not make a significant difference: however over the next three decades there is likely to be a move towards using UWB communication techniques, which provide impulsive interference to other users of the communications spectrum, and which would be over-estimated by the use of a peak or quasi-peak detector. This, in turn, would lead to unnecessarily severe restrictions on the use of UWB systems, limiting the growth of this sector of the market.

4.2.3 Broadband Fixed Wireless Access (BFWA)

The RA has awarded a number of Broadband Fixed Wireless Access (BFWA) licences and the process is continuing with the auction of 3.5 GHz licences and the planned auction of the remaining 28 GHz licences. The appeal of this technology has traditionally been for the provision of large scale telecommunications services and high speed internet access for Small and Medium sized Enterprises (SME). So far there has

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[10] "Using the Root-Mean-Square Detector for Weighting of Disturbances According to Its Effect on Digital Communication Services", PF Stenumgaard, IEEE Transactions on Electromagnetic Compatibility, Vol. 42, No. 4, Nov 2000, pp. 368-375.

[11] "Determination of Measurement and Calculation of limits for the protection of radio services from man-made radio noise", CISPR study question 94.

[12] "Characterisation and measurement of various interference sources to digital communication services (according to their interference effect)", ITU-Doc. 1/1-E, Question ITU-R 202/1, Nov 1995.

been only limited rollout of systems, with Your Communications having rolled out the most extensive network based in the North West and Yorkshire.

Future systems are likely to be more localised in nature and this is reflected in the Agency's consultation process for the 28 GHz band where the issue of licences based on smaller areas (postcode or individual base stations) is being considered.

Like cellular systems they tend to use elevated base station sites and therefore we can expect the impact of aggregated interference and UWB to be similar. However, at the customer premises, antenna installation is usually outside the building in a location inaccessible to the general public and employees. Therefore we would not expect BFWA systems to be subject to the same close proximity effects to EMI sources, as cellular handsets.

5. CONCLUSIONS

This report has highlighted a number of technologies and systems where there are likely to be EMC problems in the future. Although many of the interference effects predicted within this report are concerned with intentional RF emissions (such as Ultra Wide Band and Short Range Device transmissions), work in these areas is not classified as EMC research and is not considered further.

Agency funded EMC research projects undertaken within the last three years have begun to address many of the issues outlined in this report.

In the indoor environments these include:

- Faster clock processors – processor clock speeds have already achieved 3GHz and have potential to rise to 20GHz in the future. The current EMC standards only apply to 1GHz and EMC research is being currently undertaken to extend this to 18GHz in order to protect services using frequencies above 1GHz, such as mobile telephony. In the longer term, proliferation of fast processors may demand reappraisal of the standards to accommodate limits more appropriate for aggregated interference;

- SMPS and SELCs - there are current EMC issues with both SMPS and SELCs which are associated with their emissions under loading conditions less than those under which testing was performed. In the longer term, aggregated interference due to proliferation of these devices may also become an issue.

- Lighting - there are EMC concerns associated with the power supplies driving new lighting technologies, which are the subject of current EMC research. The future proliferation of these devices both indoors and outdoors may also lead to reappraisal of the standards to accommodate aggregated interference;

In the outdoor environments:

- xDSL and Power Line Technologies - penetration of ADSL in the UK is increasing, and is currently the subject of measurement work to assess the aggregated interference affects of this technology. In future, there will be deployment of enhanced DSL systems operating at higher transmission speeds.

- Railway technology - the current issue with railway technology is that the standards are based on protecting services against transient emissions. New equipment introduced onto trains could potentially emit continuously at this level, causing interference to sound broadcasting services within a few kilometres of the line.

- Electric vehicles - there are few electric vehicles deployed at the moment, however usage is expected to increase in future, and result in large numbers in close proximity to residential areas. There are practical EMC measurement issues to ensure high emissions when accelerating or braking are taken into account when testing.

Although many of the current issues associated with these technologies are already being addressed in current EMC research projects funded by the Agency, this report shows that there is likely to be a continuing emergence of new technology with potential to cause EMC problems into the future. Analysis of these recent projects can provide a foundation for understanding the economic impact of future research.

