Spectrum Management Strategies for Licence-exempt Spectrum: Final Report

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RADIOCOMMUNICATIONS AGENCY

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SPECTRUM MANAGEMENT STRATEGIES FOR LICENCE-EXEMPT SPECTRUM: FINAL REPORT

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EXECUTIVE SUMMARY

This document represents the results of a study carried out by Mason Communications Ltd and DotEcon Ltd on behalf of the Radiocommunications Agency, to identify the impact on present and potential users of radio spectrum of proposed strategies to allow provision of public access systems using 'licence-exempt' spectrum. The three proposed regulatory strategies considered in the study are:

- To maintain the current status quo, requiring public systems in licence-exempt spectrum to be individually licensed
- To apply a light licensing/regulatory scheme
- To allow a completely uncoordinated approach, i.e. 'best effort'.

The study assesses the impact of these strategies from a technical and economic perspective, and considers new service opportunities that might be created from a change of regulation. The technical impact assessment considers the risk of interference and congestion, and the consequential impact on Quality of Service (QoS) to users. The economic impact assessment considers the costs and benefits arising from new services being offered in licence-exempt spectrum. The study also assesses new service opportunities based on primary research conducted by means of a survey of sectors of the telecommunications industry with a potential interest in the proposed regulatory changes, including the existing licence-exempt user base (the Short Range Device community), telecommunications operators, Internet Service Providers (ISPs) and equipment manufacturers. The study makes recommendations concerning the regulatory framework likely to maximise the net benefits from spectrum use and minimise undesired effects such as interference and congestion.

Technical analysis

The technical analysis examines the implications of the expected peak system densities that could occur in licence-exempt spectrum; as an example, the City of London has been used to assess interference assuming peak potential RLAN equipment densities. The technical analysis has concentrated on the licence-exempt bands that have the greatest perceived commercial interest; 1880 – 1900 MHz, 2010 – 2025 MHz, 2400 – 2483.5 MHz and 5150 – 5350/5470 – 5875 MHz. Where there have been previous compatibility studies conducted for these bands, these have been re-examined in the light of technical and market developments to assess the validity of results and conclusions. New analysis using Minimum Coupling Loss and Monte Carlo simulations has been conducted for the 5 GHz band. This has been used to assess the potential for, and the impact of, interference in various scenarios. The analyses indicate that both public and private use of RLANs in the 2.4 and 5 GHz bands is feasible from a technical perspective. The use of mesh FWA systems in the 5 GHz bands appears feasible if geographic limitations, to rural and suburban environments, can be ensured. The lack of progress on standardisation means that no conclusions can be drawn for the 3G TDD licence-exempt band from 2010 – 2025 MHz. The use of the 1.9 GHz DECT spectrum to offer licence-exempt public and private services appears technically feasible, assuming systems conforming to the current DECT specifications are employed. Use of higher gain antennas to deploy WLL services in this band would cause potential problems to current and future users of DECT for telephony. Overall, if systems with homogeneous operating characteristics (i.e. with similar bandwidths, EIRPs, etc) using ‘polite’ technologies (i.e. DFS, TPC) are employed, then generally more benign sharing situations will result.

Economic analysis

The economic impact analysis aims to identify the main drivers of costs and benefits associated with changes in the regulatory regime and the resultant development of new services using licence-exempt spectrum. We argue that incremental benefits from new services that are close substitutes for existing ones are likely to be small, and even though the associated costs may be minimal, such services are unlikely to generate net benefits. By contrast, services that satisfy entirely new and previously unmet demand are likely to generate considerable welfare benefits. The largest benefits can be expected to arise from services that are complementary to existing ones. Given reasonable take-up and pricing assumptions, it is considered that allowing the introduction of RLANs generates a very substantial consumer surplus in the order of £500 million per annum. The overall impact on economic welfare is likely to be of a similar order to this, regardless of whether market conditions are effectively competitive or not. The technical analysis suggests that allowing public access use of the 2.4 and 5GHz bands is likely to generate minimal additional interference costs for existing users. In particular any such costs (including possible costs for existing users of SRDs) are very unlikely to exceed these benefits. Overall, this strongly suggests that allowing public access systems to use licence-exempt spectrum is likely to be beneficial, but that certain conditions ought to be put in place in order to make sure that congestion and interference are minimised. Where there may be difficulties in accommodating all possible uses of unlicensed spectrum, priority should be given to services meeting new demands rather than those substituting for similar existing services supplied by other means. This may imply giving greater priority to RLANs than FWA systems to the extent that the demands they make on unlicensed spectrum conflict.

Opportunities for new services and the drivers for change to the regulatory framework

An industry survey was conducted to gauge the opinion of key players in the telecommunications industry about the impact of the proposed regulatory options. The most important factors identified for regulatory policy were: the potential for congestion to reduce service quality and availability; and the commercial opportunities that might be enabled through a change in regulation that, if exploited, would lead to potentially considerable benefits from innovation and new services. The industry survey found that the licence-exempt nature of frequency bands such as the 2.4 GHz band has fostered innovation within the telecommunications industry, with notable examples being the significant industry efforts in standardising ‘tetherless’ technologies such as Bluetooth and RLANs. The survey also gave indications of: new service opportunities and products that might be enabled by a change in regulation of licence-exempt spectrum; the perceived potential for congestion; management of Quality of Service (QoS); and the impact on the existing UK licence-exempt spectrum user base.

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APPENDICES

1. INTRODUCTION

This report details the work undertaken by Mason Communications (Mason) and DotEcon Ltd (DotEcon) for the Radiocommunications Agency in Autumn 2001, under project PROJ 367, Spectrum Management Strategies for Licence-exempt Spectrum.

The objective of the project was to identify the impact on present and potential users of the radio spectrum of proposed spectrum management strategies enabling the provision of public access services in 'licence-exempt' spectrum. The three proposed strategies are:

- To maintain the status quo
- To apply a light licensing/regulatory scheme
- To allow a completely uncoordinated approach, i.e. 'best effort'.

The project aim was to identify the impact of the proposed strategies from a technical and economic perspective, and to consider new types of services that might be enabled from a change in regulation. From a technical perspective, the study considers the risk of interference and congestion occurring in licence-exempt spectrum arising from a change in regulation, and the consequential impact on Quality of Service (QoS) that users (both private and public) would receive. From an economic perspective, the study assesses costs and benefits arising from the prospect of new services being offered in licence-exempt spectrum as a result of the change in regulation, and the impact of this on total welfare in the UK.

In order to examine the types of new service that might be enabled from a change in regulation and quantify the commercial opportunities that might arise, an industry survey was conducted, drawing on input from key players in the telecommunications sector. Recognising the confidentiality of the information provided, the results of the industry survey are presented in terms of 'broad consensus' and general trends rather than individual responses.

On the basis of the work conducted under the three work streams, conclusions are drawn on the impact of the proposed strategies, and recommendations made on determining an optimum regulatory framework, to maximise benefit to the UK and to continue to encourage innovation in use of licence-exempt spectrum, whilst continuing to facilitate efficient spectrum use.

Mason Communications and DotEcon would like to express their gratitude to all those who provided input to the project as part of the industry survey.

2. BACKGROUND

2.1 Project Overview

In conjunction with the DTI and OFTEL, the RA is reviewing policy in relation to the use of licence-exempt spectrum and, in particular, whether the current prohibition on public system provision in licence-exempt bands should be relaxed. The review was prompted by input to the RA from some industry sectors suggesting that the UK regulatory regime should be changed to enable public systems to be run in spectrum currently designated as 'licence-exempt'. The provision of public systems in licence-exempt radio spectrum is not permitted under present UK regulation.

A change in the present regulations may be attractive for several reasons. Firstly, technology development has meant that devices such as RLANs are designed to be dynamically adaptive to the local operating environment, through means such as dynamic frequency selection and transmit power control, enabling effective co-existence of a large number of devices in the same frequency band. Secondly, the growth in Internet, e-mail and other data applications is driving a demand for technologies capable of providing mobile or nomadic access to corporate intranets and the Internet. Finally, the potential global availability of certain licence-exempt frequency bands, such as 2.4 GHz and 5 GHz, is driving economies of scale for equipment designed to operate in those bands and fostering a global market for equipment. In addition to this, the continuing moves towards liberalisation in the telecommunications market and encouragement of innovation in the use of radio spectrum have raised questions as to whether the present UK licence-exempt regulatory regime may be stifling innovation and new service opportunities in the UK. For example, in a number of other countries, including in Europe, commercial service providers have already begun offering public access RLANs to cater for business users wishing to access company intranets/Internet outside of the office.

The UK regulation governing uses of the radio spectrum exempted from individual licensing is the Wireless Telegraphy Exemption Order (Statutory Instrument) SI 930/2000, which allows the use of specific types of radio device in the UK without an individual operating licence. The current SI exempts equipment from licensing providing it is being used only for private (self-provided) communications. All other uses of the radio spectrum not covered by the Exemption Regulations must be individually licensed under the Wireless Telegraphy Act.

Typically, licence-exempt equipment has been of a low power nature and hence less likely to interfere with other radio users. The use of equipment on a licence-exempt basis is on the understanding that the equipment is not provided with the same protection from interference that would otherwise be available to licensed services.

2.2 Study Method

This report describes the work carried out for the RA by Mason and DotEcon during Autumn 2001 on the potential technical, economic and commercial implications of changing the present licence-exempt regime. The report summarises the work conducted during the project and presents conclusions on the impact of the proposed spectrum management strategies. Recommendations on determining an optimum regulatory framework are then presented, as a basis for the RA in determining future regulatory policy.

The work conducted by Mason and DotEcon as described in this report has been divided into three principal areas:

- Impact of a change in regulation from a technical perspective, focussing on the risk of interference occurring, the potential for congestion and the implications in terms of Quality of Service (QoS) for users
- An assessment of the market for providing public access systems using licence-exempt radio spectrum, achieved through primary research conducted through consultation with key industry players, as well as secondary research on market developments from a number of sources, including previous research studies and other market reports
- Impact of a change in regulation from an economic perspective, in terms of the costs and benefits to the UK of enabling new service opportunities.

The report is structured as follows:

- Section 3 gives a brief overview of licence-exempt spectrum in the UK and its current uses
- Section 4 projects market growth and new services that might be enabled through a change in the licence-exempt regulation, and presents the results of the industry consultation
- Section 5 presents a technical analysis of the risk of interference and the potential for congestion to occur, and how this would impact present and future radio users
- Section 6 analyses the economic impact of a change in regulation in terms of the risks and benefits to the UK from enabling new service opportunities;
- Section 7 analyses the impact of the findings of this report on determining an optimum regulatory framework and draws conclusions based on the results of the work conducted
- Section 8 gives recommendations on which to base future policy determination in this area.

3. USES OF LICENCE-EXEMPT SPECTRUM IN THE UK

3.1 Overview

Various uses of radio spectrum are currently exempt from individual licensing in the UK, providing that equipment operates in accordance with the terms of the Licence-exemption Order SI930/2000 of the Wireless Telegraphy Act. In general, equipment that is exempt from licensing tends to be of a low power nature, where the short operating range of the devices limits the potential for interference between different applications sharing the same spectrum. In regulatory terms, licence-exempt devices operate on a 'non interference, non protection' basis, which means users cannot cause interference to other licensed services, nor can they claim protection from interference.

Examples of equipment covered by the Exemption Regulations range from cordless telephones such as DECT, to consumer 'short range' devices such as radio alarms or key fobs, through to radio local area networks (RLANs). The following sections of this report give a brief summary of the types of device typically exempted from licensing in the UK and across Europe.

3.2 Consumer devices/Short Range Devices

The term 'Short Range Device' (SRD) is a broad definition which is used to cover a variety of radio devices providing either unidirectional or bi-directional communication and which, due to their low transmitter power, have a low risk of interference to other devices. Such devices are used in a range of applications, including wireless alarms, short-range data transfer (e.g. automated meter reading), telemetry and telecommand. In many cases, short-range devices operate in frequency bands that are also allocated to other services. The Exemption Regulations applying to such devices typically stipulate that they cannot generally claim protection from interference from other licensed and licence-exempt services sharing the same frequency band.

Frequency bands available for SRDs in the UK are at 173 MHz, 433 MHz, 458 MHz, 868 MHz, 2.4 GHz and 5.8 GHz. As indicated above, these bands are typically available for SRD applications on a shared basis with other allocated services. Most of these bands are designed on a pan-European basis (via Decisions of the CEPT ERC), with the exception of the 173 MHz and 458 MHz bands, which are 'UK only' bands.

The main SRD applications, and the frequency bands in which they operate, are summarised in Table 3.1 [1].

Application	Frequency band(s)	Typical use	Typical Location
General telemetry/telecommand	27 MHz, 40 MHz, 173 MHz, 433 MHz, 868 MHz, 2.4 GHz, 5.8 GHz	Remote equipment control	Warehouses, industrial sites
General purpose alarms/control	49 MHz	Toy model control, baby alarms, car alarms	Home
RLANs	2.4 GHz, 5 GHz	Wireless intranet/internet	Home, office, corporate
Road traffic/transport telematics	5.8 GHz, 63 GHz, 76 GHz	Road-vehicle data links, road toll systems	Roadside
PMR 446	446 MHz	Direct handset to handset communication	Industrial sites

Table 3.1: SRD applications

The use of SRD technologies is largely in the private domain and anticipated to stay so, however there may be interest in using specific types of short-range device (such as PMR446) in a localised public access environment.

3.3 Cordless telephones

Cordless telephones gained popularity in the UK and across Europe in the 1990s and sales have grown steadily since then. Digital cordless phones have now largely superseded the earlier generation analogue cordless phones, with the digital models offering better speech quality, encryption and greater functionality.

The dominant cordless phone specification in Europe is the DECT standard, which operates in spectrum from 1880-1900 MHz. It is estimated that a total of 22.1 million cordless telephones were sold in Western Europe in 1999 of which 12.5 million were DECT. This figure has increased since then, with forecasts of 34.1 million units being sold in 2001, rising to 61.8 million by 2005 [2, 3]. The application of DECT technology in the private domain is predominantly either for domestic use (cordless phone as a replacement for fixed link wired phone), or in the corporate environment, for instance to provide wireless PBXs.

DECT also includes data communication capabilities and DECT technology has been included in the ‘HomeRF’ RLAN specifications. Since DECT is also accepted as an access technology within the ITU IMT-200 family of specifications, there is some suggestion that DECT technology may be standardised for operation in part of the IMT-2000 spectrum (the upper TDD band from 2010 – 2025 MHz).

A number of potential scenarios exist for using DECT technology in the public domain. There has been some interest in using DECT to offer public Wireless Local Loop (WLL) services, for example, and such systems have been deployed in some countries outside Europe (e.g. Africa). This application has not taken off in Europe where fixed wireless access systems have typically been deployed in higher frequency bands using technology optimised to provide longer range, high quality links.

DECT can also be used to provide metropolitan area coverage (e.g. local area mobility within a town or city). So-called 'Cordless Terminal Mobility' (CTM) systems were launched in a number of European countries, most notably Italy where the 'Fido' system used DECT base stations to cover a number of Italian cities. The Fido system eventually failed and there is little evidence that the market for such systems still exists in Europe, given the ubiquitous nature of GSM coverage.

The potential opportunities for using DECT in public access environments prompted the RA to launch its 'Public access cordless' licence in the late 1990s, with the objective of allowing third party providers to offer cordless office systems on a commercial basis. Applicants for the licence are required to pay a fixed fee to the RA, which authorises them to run any number of DECT systems under specified conditions. To date, there is believed to have been little take-up of this licence; this may be due to the conditions of use that the licence stipulates. This is further explored in section 7 of this report.

3.4 RLANs and 'Bluetooth'

3.4.1 RLANs

Radio Local Area Networks (RLANs) are designed to provide wireless connectivity to data applications, for wire-free Internet/intranet access or other data transfer. Examples of usage include in-building corporate RLANs and wireless retail point-of-sale systems, as well as voice services via wireless voice-over-IP technology.

Currently, there are two dominant RLAN types, designed to operate in the 2.4 GHz and 5 GHz frequency bands respectively. The dominant specifications for the 2.4 GHz band are the IEEE 802.11 (frequency hopping) and IEEE 802.11b (direct spread) standards. At 5 GHz, there is the IEEE 802.11a specification, ETSI's HiperLAN and the Japanese HiSWAN.

In terms of data rate, the IEEE 802.11b systems offer rates up to 11 Mbit/s, whereas the 5 GHz products can potentially offer data rates well above this, as summarised in the table below.

	802.11b	802.11a	HiperLAN2	HiSWAN
Frequency band	2.4 GHz	5 GHz	5 GHz	5 GHz
Maximum bit rate	11 Mbit/s	54 Mbit/s	54 Mbit/s	54 Mbit/s
Manufactured by	All major manufacturers	Most major manufacturers	Some manufacturers	Predominantly for the Japanese market
Availability	Now	Autumn 2001	2002	Now

Table 3.2: RLAN parameters

The IEEE 802.11g working group has also been looking at standardising higher data rate RLANs in the 2.4 GHz band, to provide data rates equivalent to those from 5 GHz products.

Although the majority of RLAN equipment currently being sold today is for use within corporate offices, the market for so-called public RLANs is already being tested outside of the UK, with systems operating mainly in Scandinavia and the USA. These public systems allow subscribers to use their laptop or PDA to access the Internet and corporate intranets from access points in public areas. The providers of public RLANs have largely focussed on providing wireless Internet connection in public ‘hot spots’ where users have a need for connectivity, such as airport lounges, hotels, shopping precincts and train stations. There are also some examples of public providers trying to provide contiguous RLAN coverage over wider areas, with limited success. This is thought to be largely due to the cost of covering a wide area with RLAN access points compared with cellular.

In the USA, a number of wireless ISPs have emerged who are offering public access services using IEEE 802.11b equipment operating in the 2.4 GHz band. These providers have tended to target public areas where business travellers may wish to access corporate intranets or the Internet, for instance in hotels or coffee shops.

In some parts of Europe, there are now a number of service providers, both mobile operators and ISPs, offering wireless Internet services based on 802.11b technology in the 2.4 GHz band. There are also a number of other operators in Europe who have publicly confirmed their intentions to trial such services.

There is also growing evidence of market demand for RLANs extending from the corporate into the home environment, which may further stimulate the growth of RLAN products in the 2.4 GHz and 5 GHz bands.

3.4.2 Bluetooth

Bluetooth is the global wireless connectivity standard, which operates in the 2.4 GHz band, aimed at providing wireless device-to-device communication. Developed by the Bluetooth Special Interest Group, a consortium of manufacturers, the objective of Bluetooth is to enable the connection of a wide range of computing and telecommunications devices without the need for cables. The Special Interest Group describes Bluetooth as follows:

'Bluetooth will enable users to connect to a wide range of computing and telecommunications devices easily and simply, without the need to buy, carry or connect cables. It delivers opportunities for rapid ad-hoc connections and the possibility of automatic, unconscious connections between devices. It will virtually eliminate the need to purchase additional or proprietary cabling to connect individual devices. Because Bluetooth can be used for a variety of purposes, it will also potentially replace multiple cable connections via a single radio link. It creates the possibility of using mobile data in a different way for different applications such as 'Surfing in the sofa', 'The instant postcard', 'Three in one phone' and many others'.

Bluetooth chipsets, embedded in handheld devices, have the potential to provide wireless data connectivity between a wide range of applications, from mobile phones and PCs to PDAs and cameras. In comparison to RLANs, Bluetooth offers very short-range connectivity (e.g. 10 metres). Higher power variations on the original Bluetooth concept have the potential to provide longer range coverage. The ability of Bluetooth to easily support voice applications is likely to be a major advantage of the technology.

In view of the similarity of their application areas, Bluetooth has been categorised by some as a competitive technology to RLANs, whereas in practice they offer complementary services. The following table demonstrates this and compares Bluetooth's capabilities with that of IEEE 802.11b RLANs.

	802.11b	HomeRF	Bluetooth
Projected market	Home, school, commercial	Home	Wireless cable, commercial
Technology	2.4 GHz, DSSS	2.4 GHz, FHSS 50 hops/s	2.4 GHz, FHSS 1000 hops/s
Data rate	11 Mbit/s	1 Mbit/s	1 Mbit/s
Range	50 m	50 m	1 – 10 m
Security	Optional	Optional	Encryption, authentication included in standard
Separate voice channel	Optional	Optional	Yes

Table 3.3: Comparing Bluetooth and other 2.4 GHz standards

The applications envisaged from Bluetooth range from those purely in the private domain (e.g. cable replacement, device-to-device data connection) through to public access applications.

A number of trials have already been launched to test Bluetooth in certain public access applications. For example, under a scheme trialed in Sweden, rail customers were able to book and pay for train tickets, confirm reservations and connect to the railway's network for information, via a Bluetooth gateway server.

Other examples often given of the application of Bluetooth in public access systems include the following:

- Walk-in 'kiosks' to provide local information (maps, special offers etc) in public 'hot spot' premises such as shopping centres, airports and exhibition centres. Such Bluetooth-capable kiosks would allow multiple users to access the kiosk simultaneously and would also enable mobility in that the information can be transferred to the user's personal device (e.g. mobile phone or PDA).
- Mobile e-commerce transactions to enable purchase of goods and services, credit authorisation and other transactions to be done wirelessly. Bluetooth would enable transactions to be completed locally and immediately, between the users personal device and some other local device.

3.5 Fixed Wireless Access

Fixed Wireless Access is the name given to radio based systems using either point-to-multipoint or mesh architectures which are designed to provide either narrow or broadband communication services to subscribers, as a replacement to wired connections. In the UK, there are a number of frequency bands that have been designated on a near-exclusive operating basis for either narrow or broadband Fixed Wireless Access (e.g. 3.4 GHz, 10 GHz, 28 GHz). These frequency bands have been licensed, or are being licensed on a competitive basis (e.g. licences for the 28 GHz band were auctioned by the RA last year). In addition to these designated FWA bands, the RA has awarded a number of Fixed Wireless Access licences to providers in the 2.4 GHz band, sharing with other licence-exempt radio users and non-radio applications (ISM). Initially, Atlantic Telecom was the only licensee in the 2.4 GHz band however a subsequent consultation process by the RA led to the award of additional licences. In the other ‘dedicated’ FWA bands there are a number of operators currently holding licences, including Tele2 (at 3.6 GHz), NTL (at 10 GHz), Broadnet, Chorus Communications, Eircom, Energis, Faultbasic and Your Communications, all at 28 GHz.

There are a number of ongoing efforts to design equipment to provide Fixed Wireless Access type services in the 5 GHz band. Examples of this are the ETSI ‘HiperMAN’ and the IEEE ‘WirelessMAN’ specifications. These standards typically specify higher output powers than those of other licence-exempt applications (4 Watts).

4. COMMERCIAL OPPORTUNTIES: INDUSTRY SURVEY

4.1 Overview

The most important factors affecting the design of optimal regulation are:

- The potential for congestion and the resultant reduction in service quality and service availability
- The commercial opportunities that might be enabled through a change in regulation and that, if exploited, would lead to potentially considerable benefits from innovation and new services.

It is well recognised that the licence-exempt nature of frequency bands such as the 2.4 GHz band has fostered innovation within the telecommunications industry, with notable examples being the significant industry efforts in standardising 'tetherless' technologies such as Bluetooth and RLANs.

In order to explore the factors influencing the setting of future regulation on use of the licence-exempt spectrum in the UK, as part of the study we conducted an industry survey, both as input to the technical and economic analysis of the study and as an indicator of new opportunities that might arise from a change in regulation.

The survey was conducted over a 4 week period covering sectors within the telecommunications industry that were identified to have a particular interest in possible change to the UK licence-exempt regime. These sectors were:

- Existing users (principally the SRD industry)
- UK telecommunications operators (fixed and mobile)
- Potential Wireless Internet Service Providers (Wireless ISP's)
- Telecommunications equipment manufacturers
- Service providers with experience in offering public access services in licence-exempt spectrum in overseas markets (e.g. Scandinavia and the USA).

This section of the report describes new service opportunities and products that might be enabled by a change in regulation of licence-exempt spectrum in the UK, based on the industry survey and other secondary research. The survey also identified the perceived impact of the regulatory options on the potential for congestion, management of Quality of Service (QoS) and on the existing UK licence-exempt spectrum user base.

4.2 Commercial opportunities

4.2.1 RLANs and Bluetooth

The 2.4 GHz wireless market has been active for a number of years with 2.4 GHz RLAN products now available from a wide range of manufacturers. Equipment sales have grown at a steady rate, with the US market currently being the main source of worldwide sales.

There has also been significant industry activity over the past few years in the development of RLAN specifications for the 5 GHz band. These efforts have taken place both in Europe and the USA, under the auspices of the HiperLAN project in Europe and IEEE 802.11a in the USA. Recent industry efforts have focussed on harmonising key radio interface parameters between the European and USA solutions in order to foster global economies of scale.

Whilst RLAN usage continues to grow at a steady rate, the demand for wide-area mobile data applications is also expected to grow significantly over coming years with the introduction of GPRS and subsequently Third Generation Mobile, providing users with high speed ‘always on’ data connections. The take-up of mobile data applications is therefore predicted to continue to grow at a significant rate over the next few years.

Predictions for the value of the global RLAN market vary. Within Europe, a RLAN growth rate of 21% per year has been predicted, bringing sales up to $328 million in 2004 [4]. On a worldwide level, it is estimated that worldwide RLAN sales will expand significantly over the next two years, rising to around $2.7 billion in 2003, compared to $1.8 billion now [5]. This growth is predicted to include demand for ‘public access’ coverage in communications hot spots such as airports, stations and exhibitions. These sales are dominated by the US market, which accounted for 65% of 802.11b sales in 2000. It is predicted that the US market will still account for 61% of global RLAN sales revenues in 2006 [6].

The launch of 5 GHz IEEE 802.11a and HiperLAN products is likely to further drive the development of the RLAN market. The first company confirming release of wireless networking equipment based on the IEEE 802.11a specification was USA based Intel Corporation, who announced in September of this year that products would be available by November [7]. The initial price premium for 802.11a products compared to the 802.11b products is predicted to drop as economies of scale are reached.

There was broad consensus from those responding to the industry survey that, whilst 2.4 GHz and 5 GHz RLAN devices will compete in the medium term, 2.4 GHz devices are still expected to retain their market lead until at least 2004/2005. It was also found that, whilst 5 GHz devices will provide greater performance capabilities, there is still expected to be a significant market for 2.4 GHz devices due to their lower cost. It is considered that there will be some migration towards use of the 5 GHz band in the future, as economies of scale are reached. Of the potential service providers who responded to the survey (mobile and/or fixed operators, ISPs), the majority considered that the 2.4 GHz band offered the most immediate commercial opportunity for public access RLANs, as equipment was already available for this band and similar services were already being offered in this band outside of the UK. A number of respondents commented, however, that since products in the 5 GHz band would offer higher data capabilities and potentially higher quality service, this would become more attractive from a commercial perspective once products were more widely available.

An important point noted by a number of respondents to the industry survey was that a number of other countries outside of the UK are already allowing commercial use of the 2.4 GHz band (e.g. Scandinavia and the USA), which is already driving a market for business travellers carrying 2.4 GHz RLAN cards. There is therefore a risk of the UK being at a competitive disadvantage compared to these other countries if this commercial opportunity is further delayed.

4.2.2 Business models for services for the ‘nomadic’ user

Many of the operators already offering public RLAN access in Europe and the USA are providing a similar type of service, targeting travellers or business users wishing to have high-speed Internet access, or access to corporate networks whilst in airports, hotels or other similar places. The services provided are aimed at providing ‘nomadic’ rather than mobile access (i.e. the user is generally stationary whilst accessing the service but may access service in a range of locations where the service is provided). The focus of these services varies between different providers however, as does their implementation. For existing mobile operators for instance, there is the potential to integrate RLAN access zones with wider area cellular coverage, allowing the user to roam between the different access systems, with charging applied via a single bill. Fixed operators may also be able to use integrated billing.

There were mixed views expressed from those responding to the industry survey on whether the most attractive commercial opportunity offered by public access RLANs was in providing public access in selected locations (i.e. hot spots), or in providing coverage over a larger area. A limited number of respondents also highlighted the option of offering Fixed Wireless Access based on 5 GHz mesh technology. Figure 4.1 shows the distribution of responses on this issue. As shown in this figure, the majority of respondents viewed RLANs as being most attractive for providing coverage over small areas at selected locations rather than over a wider area. Of the mobile/fixed operators and ISPs interviewed in the survey, the vast majority (83%) favoured the ‘hot spot’ option.

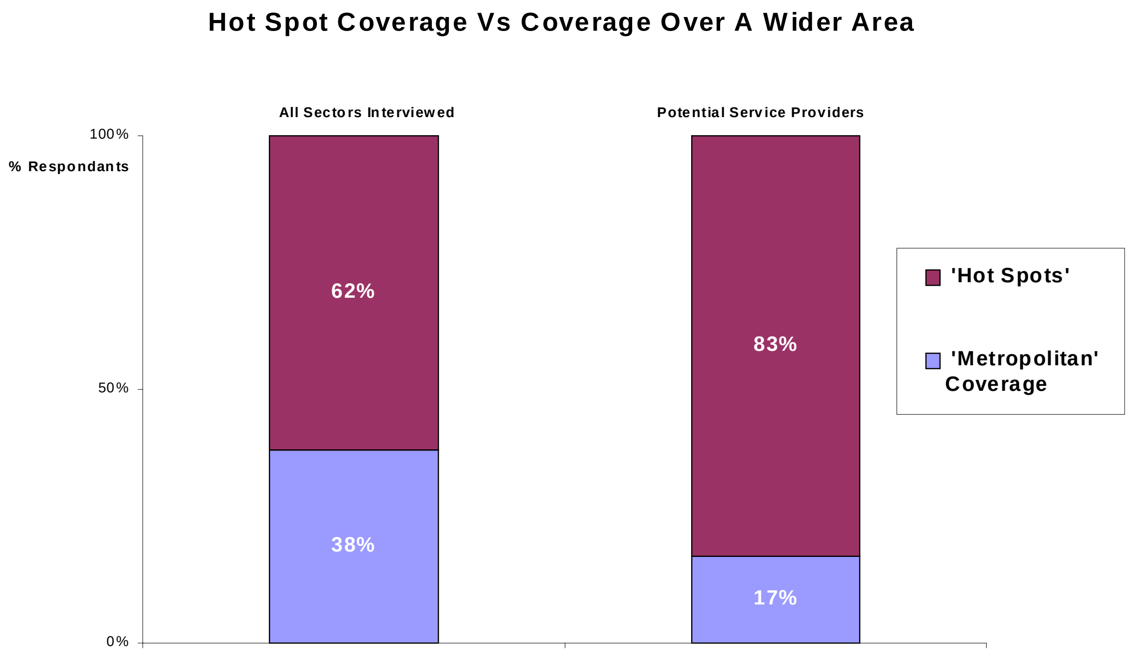

Figure 4.1: Views on RLAN coverage

To illustrate this, some examples of current initiatives in public access RLAN systems are as follows:

- Coffee shops: Wireless ISP's in the USA began the trend for providing broadband wireless Internet access in chains of coffee shops, using RLANs operating in the 2.4 GHz band. Customers can either access the system with their own laptops or rent PDAs directly from the coffee shop
- Airport lounges: A number of service providers in the USA and parts of Europe have launched RLAN systems offering wireless Internet access to users in airport lounges and conference centres, again in the 2.4 GHz band. There is the possibility that, in future, roaming agreements between these operators will mean that travellers are able to access RLANs at their destination airport and billed by their home operator, as is the case currently with GSM
- Shopping centres: There are currently a number of trials ongoing in Japan of Bluetooth based access points in shopping centres, providing users with local information services.

One particular aspect of the RLAN business case explored in the industry survey was the potential 'overlap' with other licensed services. In this context, the main question was the extent to which crossover existed between public access RLANs, Bluetooth and GPRS/3G mobile In theory these services could have some potential to substitute for each other and so compete for traffic and/or subscribers. However, they may also be complementary, with usage of broadband wireless services in one context (e.g. in the office or nomadically) generating additional demand for other services in other contexts (e.g. for wide-area services).

In general, the consensus view was that the different types of access were complementary rather than competing, particularly in view of the different value propositions and performance characteristics. There was recognition that some crossover did exist although the extent of this was difficult to quantify. As pointed out by some respondents, however, the take-up of RLANs and Bluetooth might potentially act as a further driver in the market for mobile data rather than as a direct substitute for existing mobile services. This was confirmed by the general acceptance that RLANs were most attractive in providing coverage in selected 'hot spot' areas rather than providing wider area coverage, since the latter is most effectively provided using cellular technology.

The view that RLANs will be complimentary, rather than competitive, with 3G mobile, has also recently been suggested by the UMTS Forum [40]. In a recent press release, the chairman of the UMTS Forum is quoted as suggesting that use of RLANs will help drive customer demand for 3G when networks launch over the next two years.

Various examples can be given to illustrate the complementary nature of the v alternative access methods, taking account of whether the user is 'nomadic' (i.e. stationary whilst using the service), or mobile (on the move):

- A business person using a laptop to wirelessly access intranets or the Internet is more likely to be stationary whilst accessing the service and hence may use an RLAN whilst sitting in an airport lounge or coffee shop
- A person using a PDA to download directions to a particular location whilst on the move may initially use an RLAN (whilst stationary) then move onto GPRS coverage outside of the RLAN zone
- A person accessing information in a railway station could potentially access this via either GPRS or Bluetooth.

4.2.3 Roaming between different RLAN providers

To date, in countries where a number of public RLAN providers offer services in different areas, roaming between different providers access points has not been offered to the user. It is likely that roaming will be enabled in future, however, since various industry bodies are looking at models to enable this. This would enable end-users to use public RLANs irrespective of provider and also to roam onto systems in other countries whilst travelling (e.g. a traveller arriving in Heathrow Airport might be able to connect to an RLAN in the arrivals lounge). Providers would then be able to bill each other for network use and the user would receive a single bill from their 'home' provider, as currently happens when roaming over GSM.

There was broad consensus from the industry survey that RLAN roaming would be introduced, bringing similar benefits to travellers as already demonstrated by GSM.

This gives another indication of the potential disadvantage to the UK in maintaining the regulatory 'status quo' in bands such as 2.4 GHz, since travellers would be unable to access RLAN coverage whilst visiting the UK.

4.2.4 Security and authentication

Although wireless networking based on the IEEE 802.11b standard has been growing in popularity in recent years, a number of studies have pointed out the vulnerability of the IEEE 802.11b security protocol, Wired Equivalent Privacy (WEP). This has raised concern about the suitability of the technology to provide secure communication. Another often reported problem has been that of authentication, in that 802.11b authenticates the hardware, not the user.

To overcome this, a number of new products are now being piloted that provide additional measures of security and control. A number of manufacturers have announced the launch of proprietary encryption technologies that can be added to RLANs. A number of these are being tested at present, with the intention to launch products by the end of this year.

To address the authentication issue, one of the main solutions being considered is the development of SIM-based authentication for accessing RLAN networks. This is already available; the Nokia C110/C111 RLAN card for example features a SIM that provides authentication in the similar way to a GSM SIM card. Sonera is currently trailing the Nokia solution in Finland in its 'wireless Gate' public access RLAN service [8].

4.2.5 Public cordless systems

The use of DECT technology to provide metropolitan wireless networks was tested in a number of European countries in the late 1990s, most notably in Italy with the 'Fido' system. Such initiatives did not survive far beyond initial launch however, mainly due to the difficulty in competing with the ubiquitous, low cost coverage already provided by GSM.

At the time systems such as 'Fido' were being launched, DECT proponents highlighted that one of the benefits of these would be the ability for users to roam across different environments, e.g. from a home system to an office system to metropolitan coverage, using the same handset. The same concept was subsequently introduced through the launch of dual mode DECT/GSM phones.

Renewed interest in offering the user the ability to roam across different operating environments came with the development of standards for Third Generation Mobile, where it was envisaged that a portion of the spectrum designated for 3G would be used in a deregulated manner. This spectrum, from 2010 – 2020 MHz was subsequently reserved across Europe by ERC Decision (99)25 for operation of self-provided 3G systems, most probably utilising the UTRA TDD mode of operation. Subsequent developments have questioned this decision however since some European administrations have subsequently awarded TDD carriers in the 2010 – 2025 MHz band to licensed 3G operators.

The types of applications being envisaged with 3G include providing customers with seamless access to their services from home, office or on the move. Office systems could either be privately run or could be run by third parties. Similarly, 3G coverage over a wide area might be provided by a mobile operator using its dedicated 3G spectrum, with, if regulation were to permit, additional ‘hot spot’ services being provided in public areas such as train stations using the 3G licence-exempt spectrum.

To date, standardisation activity on the TDD operating mode has progressed at a slower rate than the 3G FDD modes and the broad consensus from the industry survey was that it was too early to determine the appropriate regulatory regime for this spectrum, as equipment specifications have not been finalised and there is no indication of when products might reach the market. It was also pointed out by some respondents that both DECT and TDD are predominantly European technologies and therefore, compared with other devices such as 2.4 GHz and 5 GHz RLANs, did not benefit from the same global economies of scale. This was confirmed by indications from the industry survey that the main commercial opportunities in use of licence-exempt spectrum were expected to be in the RLAN area.

It was also noted, however, that the use of licensed TDD spectrum once 3G networks are rolled out would likely drive applications in the licence-exempt portion, and vice-versa. This relationship would appear to be an important consideration in setting the regulatory framework.

4.3 Managing Quality of Service expectations

One of the key issues in determining the impact of changing the regulation on use of licence-exempt spectrum was the perception that public services could not be satisfactorily provided in shared spectrum due to the potentially variable nature of Quality of Service (QoS) due to use of spectrum being on a non-protected basis. Whilst for most respondents QoS is of considerable concern, the majority of respondents did not expect to encounter significant QoS issues. There are a number of reasons given for this:

- Importantly, there is a clear difference between QoS for those types of services envisaged being offered over unlicensed spectrum (predominantly Internet applications which are inherently ‘best effort’) compared with conventional telecommunications networks (fixed or mobile). The impact of congestion in the types of scenario considered in this study would most likely be a temporary reduction in data rate or range limitation. In an Internet environment this is unlikely to be distinguishable from bottlenecks occurring in other parts of the Internet or at servers. Therefore, some spectrum congestion would not necessarily mean that the service would fail to meet customer expectations as Internet users are already experienced in variable data throughput and the intrinsically best efforts nature of such services.

- In managing QoS in public access RLANs, there are a number of low-cost measures that operators could take to improve quality. These include installation of additional access points, or moving an access point (e.g. if two operators are covering the same area) or in the choice of antenna.
- It was also pointed out that RLAN technology is inherently designed to co-exist with neighbouring devices through built-in features such as transmit power control and dynamic frequency selection. Transmit power control will decrease the overall level of interference and, therefore, improve the quality received by users. Dynamic frequency selection will enable the RLAN device to select the best channel for operation within the available band. This will also tend to facilitate an even distribution of devices across the band, again improving the quality received by users. A number of potential service providers commented that they would be unlikely to offer a service if it was failing to meet customer needs and, therefore, it would be in their commercial interest to manage the system to overcome any customer complaints over service quality.
- Looking at the 2.4 GHz band in particular, the main co-existence problem that was highlighted was that of Bluetooth and RLANs operating in close vicinity. However, it was noted that most Bluetooth manufacturers also produce 2.4 GHz RLANs. This implies that equipment manufacturers should have strong incentives to resolve potential interference issues in order to stimulate the demand they face for their products.
- It was also recognised that the introduction of 5 GHz RLANs would offer a potentially ‘higher quality’ alternative to the 2.4 GHz band in view of the greater data throughput from 5 GHz devices and the wider bandwidth available. It would also be more likely that higher data rate links could be maintained in the 5 GHz band without degradation whereas at 2.4 GHz, typical ‘user’ data rates can be considerably less than the maximum due to link degradation.

Respondents were also asked about the extent to which they saw the regulator having a role in advising users on QoS in licence-exempt spectrum. In all cases, respondents believed this to be largely a commercial matter. However, a number of examples were given of where the RAs role might lie:

- In providing an Information Sheet on types of service offered in licence-exempt spectrum
- In ensuring that the technical regulations governing use of the bands (i.e. the Interface Requirements) were appropriately set
- In providing guidelines to equipment manufacturers to ensure that products meet the relevant requirements
- Taking action against breaches in adhering to the technical regulations (e.g. transmitting above the maximum power limit).

4.4 Potential for congestion

Another key consideration in changing in regulation is the extent to which removing the current prohibition on offering public services in licence-exempt spectrum might lead to an increased potential for congestion.

In this case, it is illustrative to consider countries outside of the UK where public access systems are already being provided, primarily in the 2.4 GHz band. Although there are a number of competing wireless ISP's and other operators now offering 2.4 GHz services in some countries (with some reportedly covering the same hot spot areas with RLAN access points), there has, to date, been no reported instances of widespread interference or congestion occurring.

In general, the potential for congestion in licence-exempt spectrum appeared to be less of a concern than earlier reports might have suggested. This was confirmed by a number of service providers approached during the industry survey. In terms of system planning, different service providers displayed different approaches to providing service, but certain general themes emerged:

- In the case where RLAN access points are being provided in a particular location (e.g. airport lounges), the operator needs to approach the site owner in the first instance for permission to offer the service. This gives the opportunity either for an exclusive arrangement to be made with the site owner or, if there are a number of operators covering the same area, for operators to co-operate in the location of access points
- In the same way as with other telecommunications networks using radio, the operator can monitor the service and in so doing, identify any trouble spots which can then be rectified (e.g. by installing additional access points or moving the access point, as described earlier).

Since congestion will depend on the density of devices in a given area, an important consideration in this regard is the location of devices and the potential for a 'cluster' of devices to operate in a particular area. It is noted that, to a large extent, RLANs will be predominantly, though not entirely, used in indoor or closed environments. This improves the link budget since building penetration loss is added, providing additional isolation between systems.

As noted in Section 3 of this report, one of the SRD uses of the 2.4 GHz band is for telemetry/telecommand. Such applications would typically be in 'warehouse' type locations. This would generally be distinct from typical private and public RLAN locations, which might be more focussed on either corporate premises for private systems or travel hubs and other largely indoor hot spots for public systems. This will improve co-existence between the different types of application. The potential for congestion is likely to be exacerbated in the 2.4 GHz band by more widespread deployment of outdoor systems, particularly those radiating at higher powers.

4.5 Impact on existing users

4.5.1 Short range devices

As indicated earlier in this report, SRDs operate in the UK in frequency bands at 173 MHz, 433 MHz, 458 MHz, 868 MHz, 2.4 GHz and 5.8 GHz, providing a range of applications from telemetry to Radio Frequency Identification Devices (RFID) tags to social alarms.

Given the diverse range of uses to which SRD's are put, and the regulatory regime in which they operate, it is very difficult either to quantify the numbers of devices in current use, or the forecasted growth in use of these devices in future.

As indicated earlier in this report, there appears to be a broad consensus that the licence-exempt frequency bands that offer the most attractive commercial opportunities for the provision of public access services are the 2.4 GHz and 5 GHz bands, using either RLAN or Bluetooth technologies. There is little evidence to support the view that other SRD applications will be used for the provision of new 'commercial' services or create significant new service opportunities, although there is some suggestion that certain applications could be exploited on a commercial basis, for example networked telemetry to provide third party security or asset tracking systems.

All the frequency bands used by SRDs in the UK are shared with other allocated services and SRD devices operate on a 'non interference, non projection' basis. This creates direct incentives within industry to improve the design of devices to give increased immunity from interference. There are also a number of precedents for sharing spectrum between SRDs and public systems, with two notable examples being Atlantic Telecom operating in the 2.4 GHz band and Quiktrack in the 866 – 868 MHz band.

It could therefore be considered that the impact on the SRD community of changing the regulation on use of licence-exempt spectrum in the UK may be limited to impact on devices operating in the 2.4 GHz and 5 GHz bands. The reason for this is that applications using other SRD frequency bands are unlikely to be put to widespread third party use as a result of a change in regulation, and therefore it could be assumed that a change in regulation will not impact significantly on the numbers of devices using these bands, and consequently the interference/congestion potential. In view of the commercial opportunities in providing public access RLANs in hot spots, however, a change in regulation in these bands is likely to create new service opportunities in these bands. This may further drive demand in RLAN use, which could have the potential to create congestion and/or interference to the detriment of SRD applications also using this spectrum.

If it is assumed that public and private RLANs operate under the same technical restrictions (e.g. the same EIRP limit), then increased interference is unlikely to occur as a direct result of enabling public access provision. The potential for interference may increase if public access systems with higher powers, covering wider outdoor areas, were to be permitted. This can be avoided, however, through setting appropriate technical conditions for use of the 2.4 GHz and 5 GHz bands, as described later in this report.

As is also discussed later in this report, the potential for congestion in either the 2.4 GHz band or the 5 GHz band will in any case be caused by the density of devices operating in a given area, which could potentially exist irrespective of a change in regulation (for example, the density of private RLAN use may grow significantly in the future).

4.5.2 Private RLAN users

As indicated earlier in this report, a market for 2.4 GHz RLANs already exists, with an increasing number of corporate offices using RLAN cards to cater for today's 'nomadic' working environments (e.g. hot-desking).

In terms of the impact on this existing user base from a change in regulation, the main impact would be if the regulatory change were to lead to a significant increase in congestion in the 2.4 GHz band, or increased instances of interference (e.g. if public systems were to be offered over wider outdoor coverage areas with high EIRP).

As indicated in the previous section however, such impact can be minimised through the determination and regulation of appropriate technical conditions for operation of public (and private) systems. The issue of RLAN-RLAN sharing is explored in further detail in the technical analysis section of this report, where it is indicated that, particularly in the 5 GHz band, densities of use would need to be very high before the potential for interference became unacceptable.

4.5.3 Fixed wireless access

At the present time, the only fixed wireless operator providing service in licence-exempt spectrum in the UK is Atlantic Telecom, who were licensed by the RA in the mid 1990s to operate in the 2.4 GHz band (operating under an individual Telecommunications Act and Wireless Telegraph Act licence). Other operators hold licences in dedicated FWA frequency bands, such as 3.6 GHz, 10 GHz and 28 GHz. These operators typically either hold national operating licences for a dedicated block of channels, or, in the 28 GHz case, regional licences.

In future, there may be further interest from service providers wishing to use 5 GHz wireless mesh technologies to provide fixed wireless access in the 5.8 GHz band (possibly sharing with RLANs in part of the band). The co-existence between these mesh technologies and RLANs is explored in the technical analysis section of this report.

In terms of the impact to existing FWA licensees from a change in regulation governing use of licence exempt spectrum, the main issue would appear to be on a commercial level, in terms of the potential crossover between services provided by FWA operators at 3.6 GHz, 10 GHz and 28 GHz, and services that might be provided using 5 GHz mesh technology. The extent of the crossover will depend on individual FWA business plans and so is difficult to quantify in general terms.

5. TECHNICAL ANALYSIS

5.1 Introduction

The purpose of the technical analysis in this study is to examine the impact of a change in regulation on the risk of interference occurring, the potential for congestion to occur and the consequence impact on users in terms of Quality of Service (QoS).

An extensive number of bands can currently be used for licence-exempt applications; see Appendix C. Of these bands, the analysis concentrates on those that are considered the most commercial significance, which are the following bands:

- 1880 – 1900 MHz
- 2010 – 2025 MHz
- 2400 – 2483.5 MHz
- 5150 – 5350/5470 – 5875 MHz.

Considerable technical analysis has already been undertaken in some of these bands, most notably at 2.4 GHz. This analysis includes previous studies undertaken for the Radiocommunications Agency, as well as studies in ETSI, CEPT and ITU. Given the extent of these earlier studies, and the widespread industry input to the European/international work, it is not possible, or desirable, to reproduce this work. Where previous studies have been conducted, their assumptions have been re-examined in this study to determine:

- The effect of any modifications or updates to specifications, equipment or other technical assumptions
- Market developments since the previous studies were conducted that might impact on growth assumptions
- The requirement for any additional considerations.

The majority of new technical analysis presented in this report concentrates on the 5 GHz bands. The Radiocommunications Agency has indicated that it sees the most potential, in the short term, for changing the regulatory status of these bands.

Brief consideration is also given to remaining licence-exempt bands beyond those listed above.

In the technical analysis presented here, both Minimum Coupling Loss (MCL) and Monte Carlo (MC) techniques have been used.

5.1.1 Minimum Coupling Loss analysis

Minimum Coupling Loss (MCL) analysis, in its most basic form, examines the potential for interference from a single transmitter into a victim receiver, usually under worse case conditions. Practical situations are usually much more complex than can be modelled by MCL analysis; for example, multiple distributed transmitters operating with power control. However, MCL analysis is useful as it can often be used to dimension limits on the extent of interference.

MCL analysis has been used here to examine various interference scenarios considered.

5.1.2 Monte Carlo analysis

Monte Carlo (MC) analysis allows a more pragmatic analysis of interference situations than MCL. MC analysis is the statistical analysis of interference situations potentially involving multiple interferers.

The Monte Carlo modelling tool SEAMCAT, developed within CEPT, has been used to analyse various interference scenarios. SEAMCAT is a very flexible tool for undertaking Monte Carlo analysis of various compatibility scenarios. As described by the ERO:

'SEAMCAT offers some particularly important features:

- *Quantification of interference levels; the level of interference between different radio systems is expressed in terms of a probability that the reception capability of the receiver under consideration is impaired by the presence of an interferer.*
- *Consideration of spatial and temporal distributions of the received signals; this is helpful in developing appropriate frequency planning arrangements or necessary limits for transmitter/receiver parameters.*
- *SEAMCAT can address any interference scenario regardless of the type of victim and interfering radio systems'.*

One of the key elements of the MC analysis undertaken here is the propagation model. The model used in the MC analysis in this study was a spherical diffraction model, which was developed for rural environments. It has been used across all environments considered in this study, and hence will provide worse case results. Additional losses in suburban and urban environments will occur in practice. SEAMCAT models these by the addition of further losses on top of the basic loss calculated by spherical diffraction. Again, this should result in worse case scenarios being demonstrated.

SEAMCAT is still being developed and so suffers from some limitations. However, due to the nature of MC analysis, many of these limitations will also be present in other MC analysis tools. This implies that MC simulation results must not be taken at face value; it is essential to carefully consider any results that are produced before conclusions are drawn. Relevant considerations are discussed in more detail with each particular scenario examined in this study.

In summary, the most significant limitations affecting the SEAMCAT simulations are:

- In suburban and urban environments, SEAMCAT models building loss by examining the distance between transmitter and receiver, deciding if they are in the same room and/or building, and then applying appropriate additional propagation loss due to floors and walls. However, for walls, this extra loss is limited to loss travelling through either one or two walls. More significant additional path losses can be expected to occur in practice in an urban environment (particularly dense urban), principally for the interfering signal.
- SEAMCAT provides a very limited mechanism for simulating the use of Dynamic Frequency Selection (DFS). To overcome this it has been assumed that DFS, where used, operates perfectly to evenly distribute interference across all available channels. This allows the simulations to be simplified; only a single channel needs to be considered with the results being aggregated to the full number of channels available.
- SEAMCAT defines an interfering transmitter radius, referred to as the 'simulation radius', which attempts to take into account all relevant interferers. However, the use of the spherical diffraction propagation model implies that this interfering transmitter radius can become very large, particularly over non-rural propagation paths. The interfering transmitter simulation radius has therefore been limited. This implies that, for example, at RLAN densities consistent with a dense urban environment, interference is only received into an RLAN from sources located within, typically, no more than 250m.

For a full description of the SEAMCAT tool, and its capabilities, see [9][1].

5.2 1880 – 1900 MHz

5.2.1 Overview

The band 1880 – 1900 MHz is currently identified internationally for use by IMT-2000. As shown in Table 5.1 below, the primary use of this band currently within the CEPT is for DECT (now one of the IMT-2000 family members), with some limited Fixed Service use for troposcatter links.

[1] The majority of the SEAMCAT simulations undertaken in the analysis below have used a constant active number of interfering transmitters with varying simulation radii to provide varying interfering transmitter densities. Where this leads to unreasonably small simulation radii, compared to the victim receiver coverage radii, the simulation radii has been fixed (to the same as the coverage radii) and the number of active interfering transmitters increased to provide increasing interfering transmitter densities. This latter case occurs only in section 5.5.5 where it is discussed in considerably more detail.

Frequency Band and Allocation to UK Services	Comments
1880-1885MHz FIXED MOBILE S5.149, S5.385, S5.386, S5.387, S5.341, S5.388	DECT on 1880-1900 MHz; CEPT Recommendation T/R 22-02 and ERC Decision ERC/DEC/(94)03 refer. IMT-2000 band 1885-2025 MHz identified at WARC-92. 1900-2025 MHz to form part of the core UMTS/IMT-2000 band. ERC Decision ERC/DEC/(97)07 refers. FIXED use on 1873.5-1897.5 MHz for off shore links. CEPT Recommendation T/R 22-02 refers.
1885-1900 MHz FIXED MOBILE S5.388	

Table 5.1: Extract from the UK Allocation Table [9] for the band 1880 – 1900 MHz

Current DECT use is limited to private residential and business systems, with the relevant Interface Regulation, IR 2011 [11], limiting peak EIRP to a maximum of 250 mW. The DECT standards also include a profile for Radio Local Loop (RLL) operation.

5.2.2 Analysis of previous studies

In 1999, The Smith Group carried out a comprehensive study, on behalf of the Radiocommunications Agency on the implications of licensing public services in the 1880 – 1900 MHz band [12]. This study examined current and potential use of the band for Residential and Business telephony, as well as the potential use of the band by Cordless Telephony Mobility (CTM) and Wireless in the Local Loop (WLL). Potential interference scenarios between these different services were examined.

In reviewing the Smiths study, the key issues that might impact on the validity of the results are:

(1) The validity of the technical parameters assumed

(2) The market developments since the study's production.

At the time that the Smith study was conducted, DECT was already a well-established technical specification and the parameters required for interference analysis have not changed significantly during the intervening time. It can therefore be considered that the technical analysis will remain valid.

In terms of market development, as discussed earlier in this report, DECT has seen significant uptake in recent years for cordless telephony and cordless office use. The Smith study anticipated this uptake by modelling high-density use and assumed a considerable increase in traffic density, which appears to remain valid in today's environment.

One of the service areas that the Smith study considered was that of 'Cordless Terminal Mobility', where DECT base stations are used to cover a metropolitan sized area, giving cellular-like coverage. It is noted, however, that CTM has not subsequently proven to be successful in Europe and, given the ubiquitous coverage of GSM and the anticipated coverage of 3G, a market for CTM is not expected to develop in future.

Another area covered by the Smith study was the use of DECT in Radio Local Loop/Fixed Wireless Access (FWA) systems. However, the use of DECT in this environment has not been widespread and a number European regulators have subsequently awarded licenses for FWA in spectrum designated on a near-exclusive basis for such services. In the UK for instance, the 3.5 GHz, 10 GHz and 28 GHz have been designated for narrow and broadband FWA.

Recent auctions for FWA licences, in bands outside the DECT band, have met with varied success across Europe. It is still not clear whether sustainable business models in the FWA market will develop in the UK.

With regard to the use of DECT for basic cordless telephony, the Smith study concludes that under extreme future projections a loss of range in busy multi-storey office blocks could be experienced. In the RLL/FWA case, two scenarios are analysed in the study; a short range 'fill-in' service (using 0 dBi base station and consumer station antennas) and a wider area long-range service (using directional antennas; 4 dBi at the base station and 12 dBi at the consumer station). In terms of the modelling undertaken, the study concludes that:

- The short range service '*would not be able to be used in metropolitan areas, but would be able to be used in less built-up areas subject to assessment of the local environment*'
- The long-range service '*should be isolated from any form of intensive private DECT usage, and should large volumes of traffic be routinely conveyed by the system, restrictions would need to be imposed to prevent potentially devastating interference to residential users*'.

Overall conclusions of the study include that:

- '*the use of DECT to offer public services is feasible, but under certain conditions problems may be encountered*'
- '*further work could be usefully carried out to verify the findings of this [study]'*.

5.2.3 1.9 GHz Conclusions

Based on a re-evaluation of earlier DECT studies, it appears that the use of the DECT band to offer licence-exempt public and private services is technically feasible, if it is assumed that all systems conform to the standard DECT operating parameters (e.g. 250 mW EIRP). It appears that use of higher gain antennas to deploy RLL services would cause potential problems to present and future users of DECT private systems. It is possible that restrictions on the use of such services could alleviate potential interference problems however further work would be needed to examine detailed requirements for restrictions. Without this further work, it is concluded that, from a technical point of view, it remains feasible that public and private licence-exempt DECT systems could operate in these bands under the restrictions of the current Interface Regulations.

5.3 2010 – 2025 MHz

5.3.1 Overview

The band 2010 – 2025 MHz is part of the frequency spectrum identified internationally for IMT-2000. ERC Decision (99) 25 [13] provides that, subject to market demand, the band 2010 – 2020 MHz should be made available for the operation of 3G ‘self provided applications in a self coordinated mode’. The RA, in its 3G Information Memorandum [14], indicated that the band 2010 – 2025 MHz was to be made available for such operations and the UK is a signatory to the ERC Decision.

Frequency Band and Allocation to UK Services	Comments
2010-2025 MHz FIXED MOBILE S5.388	In the band 2110-2120 MHz IMT-2000 band 2110-2200 MHz identified at WARC-92. To form part of the core UMTS/IMT-2000 band. ERC Decision ERC/DEC/(97)07 refers

Table 5.2: Extract from the UK Allocation Table [10] for the band 2010 – 2025 MHz

The global standardisation forum 3GPP has devoted significant effort to the development of the UMTS specifications for operation by MNOs. To date, significantly less effort has been devoted to the development of specifications for self-provided applications.

In addition, the ETSI DECT committee, EP-DECT, is understood to have commenced a Work Item to develop the DECT specifications to incorporate operation in this band. However, this Work Item still appears to be at a very early stage.

There is currently no UK Interface Regulation applicable to the 2010 – 2025 MHz band since this appears to be out with the 3G Interface Regulation.

5.3.2 2 GHz Conclusions

Given the current state of standardisation, it has not been possible to provide a technical analysis on the potential for future congestion in this band.

5.4 2400 – 2483.5 MHz

5.4.1 Overview

This band is one of the most heavily used of the licence-exempt bands. As shown in Table 5.3, several services currently make use of this band in the UK, including:

- Bluetooth
- Industrial, Scientific and Medical (ISM), including equipment such as sulphur plasma lighting and microwave ovens
- Outside Broadcast Television (OBTV)
- Radio Fixed Access (RFA)
- RLANs
- Various types of Short Range Device (SRD), including radio frequency identification tags.

Frequency Band and Allocation to UK Services	Comments
2310-2450 MHz FIXED MOBILE Amateur Amateur-Satellite Radiolocation S5.150, S5.282	Military band - mainly fixed and transportable links Home Office/Office of The Scottish Executive for the Emergency Services in the band 2320-2380 MHz Amateur secondary at 2310-2450 MHz using powers of up to 26 dBW for many modes including packet, TV, Morse, etc. Amateur-Satellite on 2400-2450 MHz; S5.282 refers Civil LPDs such as tagging (2445-2455 MHz - MPT1349), Spread Spectrum devices, including Radio LANs (2400-2483.5 MHz - CEPT Recommendation CEPT/ERC/REC 70-03, specification ETS 300 328) ISM at 2400-2500 MHz PMSE (20 MHz channels) across the band 2390-2690 MHz CEPT Recommendations T/R 01-04, T/R 10-01 refer.
2450-2483.5 MHz FIXED MOBILE Radiolocation S5.150	Civil band LPDs such as tagging (2445-2455 MHz - MPT1349), Spread Spectrum devices, including Radio LANs (2400-2483.5 MHz - CEPT Recommendation CEPT/ERC/REC 70-03, specification ETS 300 328) ISM at 2400-2500 MHz PMSE (20 MHz channels) across the band 2390-2690 MHz CEPT Recommendations T/R 01-04, refer.

Table 5.3: Extract from the UK Allocation Table [10] for the band 2400 – 2483.5 MHz

The DECT standards have recently been updated to facilitate use of DECT in this band; this is commonly referred to as DECT-ISM. The main modification over the 1.9 GHz DECT standard is the addition of frequency hopping to meet the FCC Part 15 rules. However, DECT-ISM will have certain limitations compared with standard DECT, inter alia:

- As noted in TS 101 948 [16], other modifications in the standard (higher frequency and lower EIRP) could reduce the link budget by up to 10 dB, so reducing coverage;

- The significant installed base at 1.9 GHz implies that 1.9 GHz equipment will benefit from greater economies of scale than 2.4 GHz
- The 2.4 GHz band has a potentially significant interference environment due to the current and future use of other technologies.

The application of DECT in these bands is therefore only anticipated in those countries that do not have a 1.9 GHz band allocation available for DECT. Considering both the current and potential future interference environment in the UK for DECT at 1.9 GHz, it is difficult to see a compelling case for using DECT-ISM. No further consideration to DECT-ISM is therefore given in this report.

5.4.2 Analysis of previous studies

a) Aegis Systems Limited; Compatibility between Radiocommunication and ISM Systems in the 2.4 GHz Frequency Band, Final Report; June 1999

Aegis Systems Limited undertook a comprehensive study, on behalf of the Radiocommunications Agency in 1999, on the co-existence of various systems operating in the 2.4 GHz band [17]. This study examined the current and future interference potential between the different services using the 2.4 GHz band in the UK. The principal objective of the study was to determine whether there was sufficient spectrum capacity in the longer term to support the range of applications using the band.

In reviewing the results of this study, the key issues that may impact on the conclusions drawn are:

(1) The validity of the technical parameters assumed

(2) Subsequent market developments since the study's production.

The majority of the services considered by the Aegis study were relatively well established at the time of the study's development and the parameters required for interference analysis have not changed significantly during the intervening time. It is therefore considered that these remain valid.

In terms of market development, the most significant issue is the current difficulties faced by the only operational FWA operator at 2.4 GHz in the UK, which raises questions as to whether FWA systems will continue to operate in the 2.4 GHz band in the longer term.

In considering the impact of a change in regulation on use of the 2.4 GHz band, the issue that requires the most consideration is the density of usage assumed for Bluetooth and RLANs and whether a change in regulation will impact on earlier assumptions on take-up of these devices. However, the densities assumed for Bluetooth in the Aegis study are based on mobile penetration and it is therefore considered that this remains valid. The highest density assumed for RLANs is 800 systems per sq. km. Including both potential public and private use, this is considered to represent an upper limit (i.e. a worst case) for the majority of the UK. The only area where such a density may be exceeded is in limited very dense urban environments, such as City of London.

In our analysis of the 5 GHz band, section 5.5.2 of this report indicates that densities up to approximately double this could be expected.

i) Interference from RLANs into RFA

Re-examining the results presented in the Aegis study shows that, with increased indoor RLAN densities, there is an increased potential for interference in urban areas, with the interference expected to become severe in dense urban areas. The operation of RFA in these dense urban areas, with their high densities of indoor RLANs, would appear not to be feasible.

For outdoor RLANs, the study results show that the interference level is exceeded at relatively low densities (0.4 systems per sq. km). There is therefore significant potential for severe interference where outdoor RLANs are employed and RFA operation would not appear feasible in these areas.

ii) Interference from RLANs into RLANs

For indoor RLANs, at the peak density modelled in the study of 800 systems per sq. km, interference levels are exceeded for just over 10% of time. Increased RLAN densities in limited dense urban areas would lead to a rise in this percentage. However, the net result is expected to be that in these limited areas, coverage limitations will occur and the actual practical densities achieved will be self-limiting.

The same conclusions can be applied for outdoor RLANs, but occurring in much lower density environments.

iii) Interference from RLANs into Bluetooth/HomeRF

Minimum Coupling Loss analysis is presented for these two scenarios in the study. This analysis will not change significantly with increased densities.

b) Ericsson: Bluetooth Voice and Data Performance in 802.11 DS WLAN Environment; May 1999

This study [18] examines the potential interference, and its impact, on Bluetooth of IEEE802.11b RLANs. The interference into a Bluetooth link is studied in a typical office environment with a small number of RLAN access points and a large number of RLAN terminals.

This study was undertaken relatively recently and therefore the technical parameters assumed for IEEE 802.11 DSSS and Bluetooth are representative of today's equipment. Relatively dense scenarios are postulated for equipment deployment.

The study concludes that:

- '*Under normal traffic conditions in the WLAN, the Bluetooth voice user is not affected as long as his operating distance remains below 2m. If the operating distance increases to 10m, the probability that there is a noticeable interference on the link increases to 8%.*'
- '*The Bluetooth data link allows and experiences more degradation. A throughput reduction of more than 10 % occurs with 24 % probability at an operating distance of 10m.*'
- '*However, because of the limited frequency overlap of the WLAN and Bluetooth systems, the throughput reduction in the Bluetooth system can never exceed 22%.*'

c) Intersil Corporation; Reliability of IEEE 802.11 Hi Rate DSSS WLANs in a High Density Bluetooth Environment; June 1999

This study [19] examines the coexistence between IEEE 802.11 Direct Sequence Spread Spectrum (DSSS) and Bluetooth radios, with both located within a mixed environment. The study analyses the reliability of IEEE 802.11 DSSS radios within this environment.

This study was undertaken relatively recently and therefore the technical parameters assumed for IEEE 802.11 DSSS and Bluetooth are representative of today's equipment. Again, relatively dense scenarios are postulated for equipment deployment.

Whilst the study states that '*further work which includes lab testing with DSSS and BT radios operating in close proximity is required*', one of its key conclusions is that '*based on the utilisation models studied, IEEE 802.11 WLANs show good reliability even in a fairly dense environment of [Bluetooth] piconets'*.

5.4.3 2.4 GHz Conclusions

As earlier studies have demonstrated, at high RLAN densities, interference into RFA from RLANs can be expected. At very high densities, for example over limited areas such as the City of London, this interference is expected to become severe and could prevent practical operation of RFA networks. Interference from outdoor RLANs, even if they represent only a fraction of total RLANs deployed, will tend to dominate over indoor use.

At high RLAN densities, mutual interference will limit RLAN coverage areas and the actual practical densities achieved will be self-limiting.

At high densities, both Bluetooth equipment and RLANs are expected to be able to operate in the presence of each other with reasonable limitations.

Generically, it can be concluded that the use of systems with homogeneous operating characteristics, i.e. similar power limits, bandwidths and interference avoidance techniques, will tend to lead to a more benign interference environment. This is clearly demonstrated when considering the potential difficulties presented to RFA systems.

From a technical perspective, and with the exception of RFA, the operation of private and public systems in the 2.4 GHz band appears viable assuming they both conform to the technical conditions set in the current Exemption Regulations. RLANs will tend to dominate any interference that does arise, and will, in high density areas, tend to be self-limiting. However, provided this limitation is acknowledged, operation of RLAN networks should remain technically possible. High densities of RLANs will however cause a severe potential for interference into RFA networks.

5.5 5150 – 5350/5470 – 5875 MHz

5.5.1 Overview

In the UK, the bands 5150 – 5350/5470 – 5875 MHz are allocated to a number of services, as shown in Table 5.4. RLANs can currently be used in these bands in the UK provided they satisfy the provisions of EN 300 652, EN 300 836 and ERC Decision (96)03. Only private operation of RLANs is currently permitted on a licence-exempt basis.

Frequency Band and Allocation to UK Services	Comments
5150 - 5250 MHz AERONAUTICAL (1) RADIONAVIGATION Mobile (2) FIXED SATELLITE SERVICE (3) S5.367, S5.444, S5.445, S5.447	(1) ARNS band (2) Devices operating to the CEPT HIPERLAN specification EN 300 652 and ETS 300 836 ERC Decision: ERC/DEC/(96)03: ERC Decision on the harmonised frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs) CEPT/ERC/REC 70-03 relating to the use of Short Range Devices (SRD) (3) MSS feeder Links (E-->s)
5250 - 5255 MHz RADIOLOCATION (1) Space Research	(1) Government Devices conforming to the CEPT HIPERLAN specification may operate in the band 5250-5300 MHz ERC Decision: ERC/DEC/(96)03: ERC Decision on the harmonised frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs) CEPT Recommendation: CEPT/ERC/REC 70-03 relating to the sue of S5.333 Short Range Devices (SRD).
5255 - 5350 MHz RADIOLOCATION (1)	(1) Government Devices conforming to the CEPT HIPERLAN specification may operate in the band 5250-5300 MHz ERC Decision: ERC/DEC/(96)03: ERC Decision on the harmonised frequency bands to be designated for the introduction of High Performance Radio Local Area Networks (HIPERLANs) CEPT Recommendation: CEPT/ERC/REC 70-03 relating to the use of S5.333 Short Range Devises (SRD).
5470 – 5650 MHz MARITIME RADIONAVIGATION (1) RADIOLOCATION (2) Land Mobile (3) S5.451, S5.452	(1) Shipborne and associated land based radars (2) Government (3) 5470-5815 MHz – PMSE.
5650 – 5725 MHz RADIOLOCATION (1) Amateur (2) Amateur-satellite (E-->s) (3) Land Mobile (4)	(1) Government (2) 5650-5680 MHz (3) 5650-5670 MHz (4) 5470-5815 MHz – PMSE.
5725 - 5850 MHz RADIOLOCATION (1) Amateur (2) Amateur-satellite (s-->E) (3) Land Mobile (4) FIXED SATELLITE SERVICE	(1) Government (2) 5755-5765 MHz and 5820-5850 MHz (3) 5830-5850 MHz (4) 5470-5815 MHz - PMSE Between 5725-5850 MHz the land mobile service is subject to power limitations (see S5.451) ISM apparatus operates at 5725 -5875 MHz CEPT Recommendation: T/R 22-04 Harmonisation of frequency bands for road transport information systems (RTI) ERC Decision ERC/DEC/(92)02: Frequency bands to be designated for the co-ordinated introduction of Road Transport Telematic Systems ETSI standard under development.
5850 - 7075 MHz FIXED (1) FIXED-SATELLITE (E-->s) (2) S5.458	(1) Non government, operated by PTO, within the band 5925-7110 MHz (2) Intended for mainly non government systems 6725-7025 MHz allotment plan band ISM apparatus operates at 5725 -5875 MHz.

Table 5.4: Extract from the UK Allocation Table [10] for the bands 5150 – 5350/5470 – 5875 MHz

5.5.2 RLAN and FWA system densities

From a technical perspective, the likely user densities that may result from a change in regulation is the main drivers for the analysis since the potential for congestion is directly related to the density of devices operating in a given area.

For the purposes of this analysis, the following assumptions on user density are used.

a) Peak RLAN system density; Central Business District environment

The City of London may be expected to experience peak RLAN operating densities and hence has been used as the basis of the analysis presented here. The City of London (as defined by the Corporation of London's boundaries) has been overlaid with postcodes to perform the analysis, as illustrated in Figure 5.5. On the basis of this, the following postcodes have been assumed to encompass the Corporation of London's boundaries; EC1A, EC2N, EC2R, EC2V, EC2Y, EC3A, EC3M, EC3N, EC3R, EC3V, EC4M, EC4N, EC4R, EC4V.

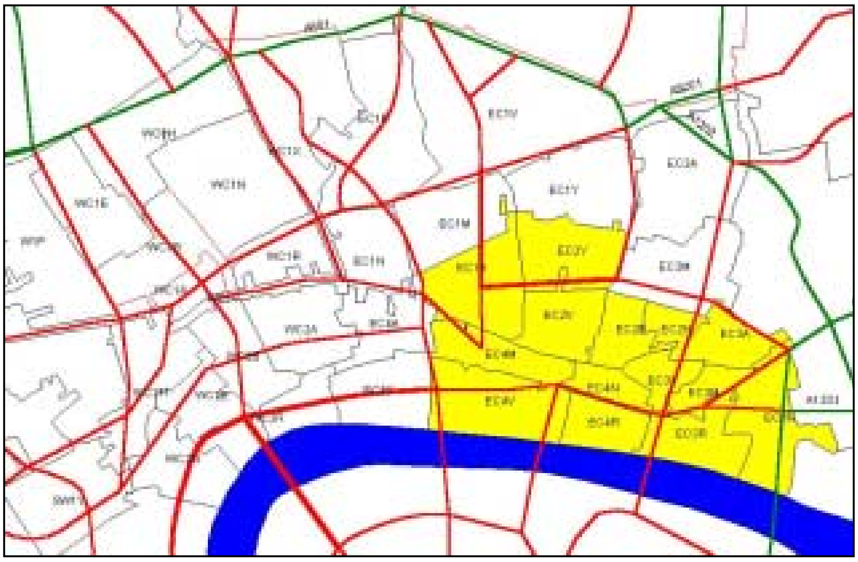

Figure 5.5: Postcodes used to define City of London

Using the software tool 'MapInfo', the classifications of businesses, and their respective numbers operating in the Corporation of London, have been produced.

Classification	Number of businesses
Unclassified	396
1-4 employees	1,371
5-9 employees	889
10-19 employees	805
20-49 employees	586
50-99 employees	237
100-199 employees	156
200-499 employees	97
500-999 employees	46
1000+ employees	40
TOTAL	4,623

This suggests an average working population in the Corporation of London of 208,000, calculated by assuming an average number of employees per classification and distributing the 'unclassified' businesses across the remaining sectors. The area encompassed by these postcodes is 2.52 square kilometres (sq. km), equivalent to 1.0 square mile (sq. mile), which implies a working population density of 83,000 employees per sq. km.

The potential peak RLAN density will be considerably less than this in practice as not every employee will use RLAN equipment. To estimate the potential peak density the following assumptions have been made:

- Only businesses of 20 employees and above (representing approximately 90% of the employees) will consider using RLANs
- Of these businesses, the availability of alternative technologies, both wired and wireless, limit the businesses that actually use 5 GHz RLANs to 10%
- A significant requirement of employees' use of RLANs is mobility, and so it further assumed that only 10% of the employees of businesses using RLANs actually have a requirement for RLAN use.

With these assumptions, the peak RLAN system density, for the purposes of this study, is assumed to be 1,855 RLAN systems per sq. km.

b) Minimum RLAN system density; Rural environment

A minimum RLAN system density of 0.1 RLANs per sq. km has been assumed.

c) Peak FWA system density

Most implementations discussed by industry suggest a nominal FWA BS density of around 1 per sq. km. In order to model the peak FWA system density, a peak of 3 BSs per sq. km has been assumed. This represents a reasonable upper limit on dense FWA implementations in heavily population areas.

d) Minimum FWA system density

The minimum FWA system density considered here is 0.2 BSs per sq. km. This represents the lower practical limit using the system parameters described in Appendix C, limited by propagation effects.

5.5.3 Sharing with other services; Analysis of previous studies

A considerable amount of study has been undertaken, both within CEPT and ITU, on the potential for interference from RLANs to other systems and services. ERC Reports 67 [22] and 72 [20] present analysis of the potential for RLANs to share with other systems and services in frequency bands around 5 GHz. The assumptions, results and conclusions of each of these Reports are re-examined below in the light of subsequent developments.

Neither of these Reports considers the use of the 5725 – 5875 MHz bands specifically for higher power, outdoor use by FWA-type systems. No consideration is presented in this Report as to the potential for FWA-type systems sharing with other services, since it is the prime commercial interest in RLANs that is concentrated on. However, since the RF parameters being considered for RLANs and FWA systems are very similar, the results and conclusions, with appropriate tempering for higher EIRPs and outdoor use, are relevant.

a) ERC Report 67; Study of the Frequency sharing between HIPERLANs and MSS feeder links in the 5 GHz band, February 1999

Report 67 calculates the maximum tolerable number of HiperLAN1 terminals in the feeder link footprint of MSS satellites operating in the band 5150 – 5250 MHz. The technical characteristics of HiperLAN2 terminals were not available at the time of production of the Report. At that stage however, the compatibility issues for HiperLAN2 terminals were expected to be largely similar to those for HiperLAN1.

In reviewing Report 67, the key issues are therefore the validity of the technical parameters assumed, any potentially higher HiperLAN densities resulting from potential de-regulation and use of RLAN technologies other than HiperLAN.

Comparing the key HiperLAN parameters assumed in the Report with the up to date RLAN parameters contained in Appendix C shows that there have been no significant changes since the time of the Report's development.

The coverage of an MSS satellite's feeder link footprint will generally extend beyond the UK and the satellite will observe interference from equipment spread across a wide area and from more than one country. It is therefore assumed that the aggregate number of RLANs in satellite's footprint considered in the Report remains appropriate, even with potentially some very limited areas of increased RLAN density.

RLAN standards around the world are converging, and it is therefore anticipated that the parameters affecting interference potential will be similar.

The results and conclusions of Report 67 therefore appear to remain valid. The sharing between MSS Feeder links and HIPERLAN in the frequency band 5150-5250 MHz therefore remains feasible with restrictions on EIRP and outdoor use placed on HiperLAN operations.

b) ERC Report 72; Compatibility Studies related to the Possible Extension Band for HIPERLAN at 5 GHz, May 1999

Report 72 examines the compatibility between HiperLANs and other services operating in the frequency range 5250 – 5875 MHz in order to identify possible extension bands for HiperLANs. Some parameters for both HiperLAN1 and HiperLAN2 could not unequivocally be determined at that the time of the Report, and so several values of such parameters were used.

In reviewing Report 72, the key issues are therefore the validity of the technical parameters assumed, the potential for higher HiperLAN densities to occur as a result of a change in regulation on public access RLANs, and use of RLAN technologies other than HiperLAN in the same frequency band.

Comparing the key HiperLAN parameters assumed in the Report with the confirmed parameters contained in Appendix C shows that there have been no significant changes since the production of the Report.

Increased RLAN density has the most significance in terms of interference to the Space Services (Earth Exploration Satellite Services and Fixed Satellite Services). The Report was developed using forecast RLAN market penetrations across Europe. Penetration forecasts have not changed significantly since the production of the

Report and it is therefore assumed the aggregate number of RLANs in a satellite's beam remains appropriate.

RLAN standards around the world are converging, and it is therefore anticipated that the parameters affecting interference potential will be very similar.

The overall conclusions of ERC Report 72, as detailed in Table 5.6, therefore appear to remain valid.

<table>
<tr><th>Frequency band</th><th>CEPT allocation</th><th>Requirements for HiperLAN use</th></tr>
<tr><td>5250 – 5255 MHz</td><td>Radiolocation
EESS (active)
Space Research</td><td rowspan="2">Sharing is feasible with restrictions – see Note 1</td></tr>
<tr><td>5255 – 5350 MHz</td><td>Radiolocation
EESS (active)
Space Research (active)</td></tr>
<tr><td>5470 – 5650 MHz

5600 – 5650 MHz</td><td>Maritime Radionavigation

S5.452 Meteorological Radars</td><td rowspan="2">1 W EIRP
Indoor and Outdoor use
Dynamic Frequency Selection</td></tr>
<tr><td>5650 – 5725 MHz</td><td>Radiolocation</td></tr>
<tr><td>5725 – 5850 MHz

5795 – 5805 MHz</td><td>FSS (E-to-S) Radiolocation

RTTT</td><td rowspan="2">Sharing is feasible with restrictions – see Note 1</td></tr>
<tr><td>5850 – 5875 MHz</td><td>Fixed
FSS (E-to-S)
Mobile</td></tr>
</table>

Note 1: For the satellite services (EESS in the band 5250-5350 MHz and FSS in the band 5725-5875 MHz) sharing between HiperLAN and satellite services is feasible under the following conditions:

- HiperLANs are limited to indoor use
- The power is limited to an EIRP of 200 mW
- Transmitter Power Control is employed
- Dynamic Frequency Selection is used.

Table 5.6: Conclusions of ERC Report 72 on the use by HiperLANs of the bands 5150 – 5350/5470 – 5875 MHz

The restrictions described in Note 1 above, would tend to indicate that the widespread use of the bands 5725 – 5875 MHz for higher EIRP, outdoor FWA systems would not be feasible without additional mitigation. Such mitigation could include the use of directional antennas. Further detailed analysis on sharing with other services is required before any such use should be considered. Although the sharing situation with other services in the bands 5470 – 5725 MHz seems more feasible, similar analysis would need to be undertaken, as for 5725 – 5875 MHz, in order to confirm the feasibility of operation of FWA systems.

5.5.4 Intra RLAN compatibility

a) Interference scenarios and assumptions

This section examines the interference potential between different RLAN systems. Only co-channel interference is considered, as it is expected to dominate over interference from unwanted emissions.

There are four potential interference paths between Mobile Terminals (MT) and Access Points (AP). These are illustrated in the matrix below.

Wanted Link		**Interfering Link**	
Wanted Transmitter	**Victim Receiver**	**Interfering Transmitter**	**Wanted Receiver**
MT	AP	MT	AP
MT	AP	AP	MT
AP	MT	MT	AP
AP	MT	AP	MT

Table 5.7: Intra RLAN interference paths

Initial studies indicate that, for the wanted link, paths with an AP as victim receiver are the critical paths since (1) the AP is the network 'hub' and (2) interference to a wanted MT receiver can be overcome more easily by re-transmission and, if necessary, re-location. Of the remaining two paths, it is less likely that an AP will interfere directly with an AP, since they are likely to be located distantly.

The interference path examined in the analysis was therefore where both the wanted and interfering transmitters are MTs. However, it should be noted that since the link budgets are relatively reciprocal, so too are the interference paths; the results produced can therefore be interpreted across all four interference paths. This interference path has been studied using both Minimum Coupling Loss (MCL) and Monte Carlo (MC) analysis.

Minimum Coupling Loss analysis

To demonstrate the potential worse case interference between a single interfering transmitter and single wanted receiver, Minimum Coupling Loss analysis has been used. Several scenarios have been examined, looking at a data rate of 6 Mbit/s with various additional path loss factors beyond basic free space path loss. Each scenario assumes a maximum EIRP of 30 dBm, with omnidirectional transmit and receive antennas and a C/I of 20 dB.

Table 5.8 describes the full set of intra RLAN interference scenarios examined.

Scenario	Propagation	Additional Path Loss
(A1)	Free Space	0 dB
(A2)	Free Space	10 dB
(A3)	Free Space	20 dB
(A4)	Free Space	30 dB

Table 5.8: Intra RLAN MCL interference analysis scenarios

Monte Carlo analysis

To examine this interference path in more detail, Monte Carlo analysis has been used. Again, several scenarios have been examined:

- A 'base case', assuming RLAN parameters equivalent to those assumed in earlier CEPT studies
- Reduced EIRP operation
- Operation of outdoor RLANs
- Use of higher gain antennas.

Each MC scenario was examined at data rates of 6 Mbit/s and 54 Mbit/s, with a C/I of 20 dB. The base case scenarios assume a maximum EIRP of 30 dBm with omnidirectional antennas. The reduced EIRP scenarios assume a peak EIRP of 23 dBm with omnidirectional antennas. The higher gain antenna scenarios assume employment of MT antennas with a 5 dBi gain across a beam width of 10 degrees and 0 dBi gain elsewhere. The majority of manufacturers are currently concentrating on producing omnidirectional antennas, as systems employing antennas with gain do not fall inside the usual definition of RLANs. The antenna pattern assumed is therefore nominal and used to demonstrate the effect of using directional antenna.

Table 5.9 describes the full set of intra RLAN interference scenarios examined by Monte Carlo analysis.

Scenario	Data Rate	Wanted Link	Interfering Link	Maximum EIRP	Peak antenna gain
(B1)	54 Mbit/s	Indoor	Indoor	30 dBm	0 dBi
(B2)	6 Mbit/s	Indoor	Indoor	30 dBm	0 dBi
(B3)	54 Mbit/s	Indoor	Outdoor	30 dBm	0 dBi
(B4)	6 Mbit/s	Indoor	Outdoor	30 dBm	0 dBi
(B5)	54 Mbit/s	Indoor	Indoor	23 dBm	0 dBi
(B6)	6 Mbit/s	Indoor	Indoor	23 dBm	0 dBi
(B7)	54 Mbit/s	Indoor	Indoor	30 dBm	5 dBi
(B8)	6 Mbit/s	Indoor	Indoor	30 dBm	5 dBi

Table 5.9: Intra RLAN MC interference analysis scenarios

b) Results and analysis

Minimum Coupling Loss analysis

Figure 5.10 shows the MCL analysis results for the various scenarios considered.

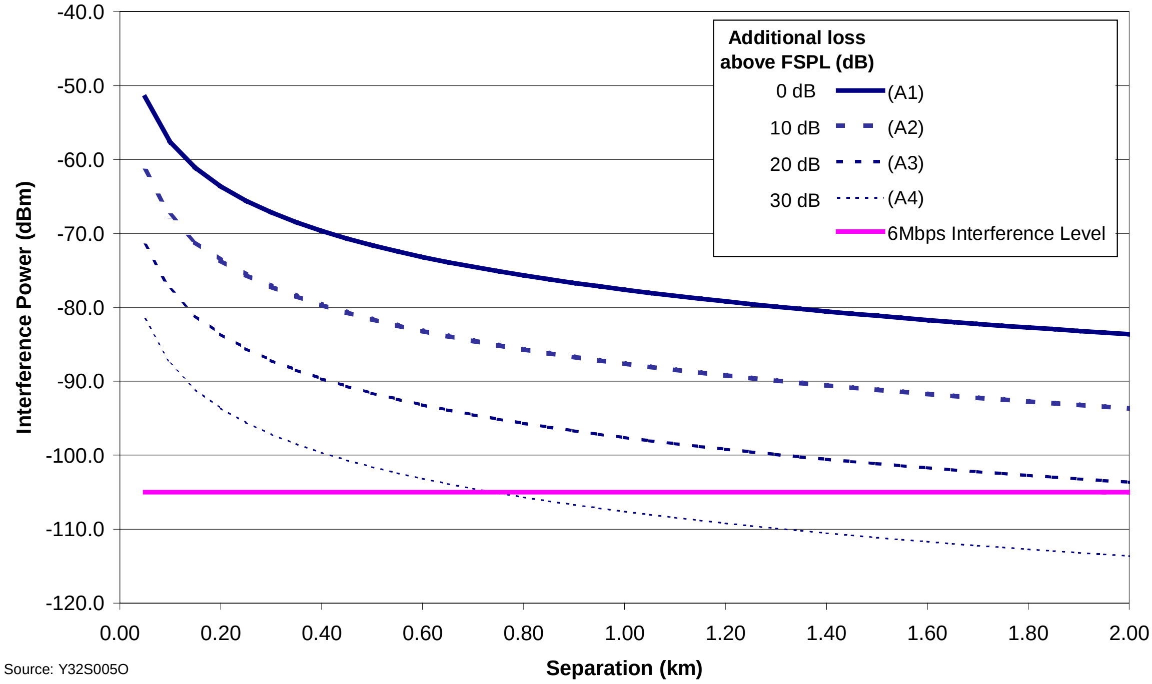

Figure 5.10: Intra RLAN MCL interference analysis results

For line-of-sight paths it is clear that considerable co-channel interference will occur unless there is a sufficiently large separation distance. Under such conditions it would not be possible to reuse that particular frequency for a considerable distance. However examination of the curves with additional path losses indicate that reasonable re-use distances can be achieved if losses above free space propagation occur. Additional losses for the interference link budget aggregating to at least 35 dB are expected:

- The Peak to Average Power Ratio (PAPR) of OFDM is typically larger than 6 dBs
- Transmit Power Control is expected to reduce average EIRP by at least 3 dB
- In practice, actual activity ratios will be much reduced over those assumed provide additional mitigation of up to 13 dB
- Location of equipment indoor (as most RLAN equipment is expected to be) will increase propagation losses by at least 10 dB (i.e. traversing one external wall), and possibly up to 20 dB (i.e. traversing two external walls)
- Manufacturers are claiming significantly lower required C/I ratios than the 20 dB assumed in this analysis; for example, a C/I ratio of 6 dB for a 6 Mbit/s service has been claimed.

In practice therefore, it can be considered that sufficient isolation should exist between an interfering transmitter and a wanted receiver, operating co-channel.

Monte Carlo analysis

Figure 5.11 shows the results from the SEAMCAT Monte Carlo analysis of the various intra RLAN interference scenarios.

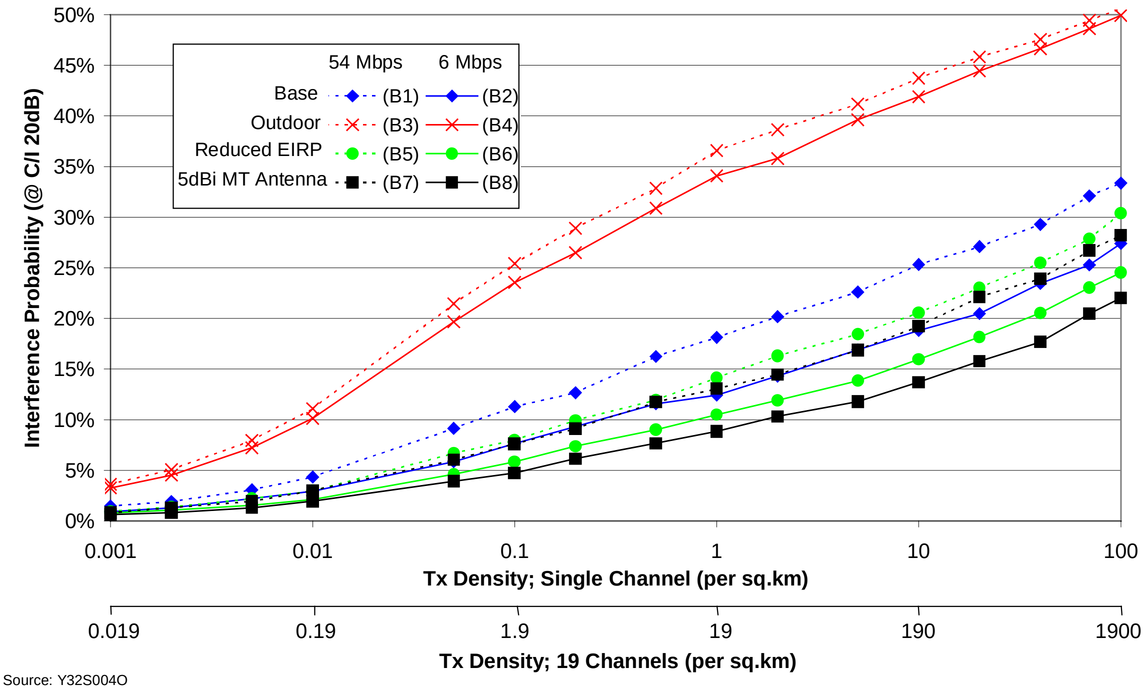

Figure 5.11: Intra RLAN SEAMCAT Monte Carlo interference analysis results

As noted above, the effect of the various limitations inherent in SEAMCAT, as well as other mitigating factors, must be considered in interpreting these results.

At higher densities, i.e. in urban and dense urban environments, SEAMCAT will add at most an additional 20 dB to the propagation loss for the interfering link, which would represent a signal travelling through two external walls. However, additional propagation losses in these environments are expected for the interfering simulation radii considered. To illustrate the potential effect of additional attenuation in urban and dense urban environments, simulations have been performed for paths with an average additional 15 dB loss. An average increase of 15 dB in the propagation loss on the interfering link reduces the probability of interference, for a 6 Mbit/s signal at 100 transmitters per sq. km, to 19%.

The simulations performed permit the interfering transmitter to be co-located with the wanted receiver. Whilst this may occasionally occur, it is more likely that the wanted transmitter in this situation would hand-over to a closer AP, with a resulting reduction in interference on the wanted path. Modelling this scenario is complex and beyond the scope of SEAMCAT. However it is possible to obtain an order of magnitude result by limiting the positioning of the interfering transmitter. Limiting the positioning in a relevant manner reduces the probability of interference, for a 6 Mbit/s signal at 100 transmitters per sq. km, to 16%.

Finally, it is expected that receivers will perform better than those currently modelled. More realistic C/I ratios is one area where significant effects could be foreseen; some manufacturers have claimed C/I ratios of 6 dB for a 6 Mbit/s signal. Such a C/I ratio would reduce the probability of interference to 17% for a 6 Mbit/s signal at 100 transmitters per sq. km.

Assuming all three of these mitigating factors together reduces the interference probability shown in Figure 5.11 for a 6 Mbit/s signal at 100 transmitters per sq. km to below 4%.

An acceptable interference probability of 10% is typically assumed in MC analysis of comparable situations. With the mitigation factors described, it can be seen that all the interference scenarios modelled, with the exception of the outdoor scenario, meet this criteria.

For the outdoor scenario, employing only the co-location and reduced C/I ratio mitigation factors, at 6 Mbit/s, results in a 10% interference probability occurring at a density of around 0.2 RLANs per sq. km. Including the 15 dB additional path loss (which is appropriate for urban and dense urban environments) as well, results in a 10% interference probability occurring at a density of around 10 RLANs per sq. km. Noting that most commentaries on the subject anticipate outdoor RLANs making up anything from 1% to 15% of the total RLAN population, the peak outdoor RLAN density must be reduced accordingly. However, even with this reduction, outdoor RLANs are expected to present interference potential in environments outside of rural and suburban.

Where the mitigation factors discussed are not present, for example in scenarios such as multiple RLAN use in large open spaces (e.g. conference halls), some interference may be expected to arise. However, other techniques exist to effectively manage interference in such scenarios; for example, property owners limiting access by providing exclusive rights and use of directional antennas.

5.5.5 Transmitting RLAN/Receiving FWA system compatibility

a) Interference scenarios and assumptions

This section examines the potential for interference from transmitting RLANs into receiving FWA systems. Only co-channel interference is considered, as it is expected to dominate over interference from unwanted emissions.

With regard the FWA systems operating in this band, the greatest interest from industry surrounds the potential for operation of so-called ‘Mesh’ systems. Such systems use central base stations (BSs) to communicate with networks of consumer stations (CSs) that are meshed together. These consumer stations are transceivers containing routers that have the ability to carry/route traffic from other nearby CSs.

The assumptions made for FWA and RLAN can be found in Appendix D.

There are four potential interference paths between RLANs and FWA systems, as shown in Table 5.12.

Wanted Link		**Interfering Link**	
Wanted Transmitter	**Victim Receiver**	**Interfering Transmitter**	**Wanted Receiver**
FWA CS	FWA BS	RLAN MT	RLAN AP
FWA CS	FWA BS	RLAN AP	RLAN MT
FWA BS	FWA CS	RLAN MT	RLAN AP
FWA BS	FWA CS	RLAN AP	RLAN MT

Table 5.12: Transmitting RLAN/Receiving FWA system interference paths

For the wanted link, paths with a FWA BS as victim receiver are considered to be the critical paths since (1) they form the network ‘hub’, (2) interference to a wanted FWA CS receiver can be overcome more easily by either re-transmission and/or re-location and (3) a wanted FWA CS receiver will benefit from the mitigation of a lower activity ratio. Of these two paths, the RLAN AP is likely to be the most interfering transmitter, principally because of its location and likely activity ratio.

The interference path examined in the analysis was therefore interference from an RLAN AP into a FWA BS.

Minimum Coupling Loss analysis

Several scenarios have been examined, looking at the interference path with various additional path loss factors beyond basic free space path loss. The scenarios assume:

- For the RLAN AP, a maximum EIRP of 30 dBm, with omnidirectional transmit antenna and a bandwidth of 20 MHz;
- For the FWA BS, an omnidirectional receive antenna, a bandwidth of 20 MHz, a receiver sensitivity of -75 dBm and a C/I of 20 dB.

Table 5.13 describes the full set of interference scenarios examined by Minimum Coupling Loss analysis.

Scenario	Wanted Receiver	Interfering Transmitter	Propagation	Additional Path Loss
(C1)	FWA BS	RLAN AP	Free Space	0 dB
(C2)	FWA BS	RLAN AP	Free Space	10 dB
(C3)	FWA BS	RLAN AP	Free Space	20 dB
(C4)	FWA BS	RLAN AP	Free Space	30 dB

Table 5.13: Transmitting RLAN/Receiving FWA System MCL Interference Analysis Scenarios

Monte Carlo analysis

To examine this interference path in more depth, it is appropriate to use Monte Carlo analysis; several scenarios have been examined:

- A ‘base case’, assuming FWA sensitivity of -75 dBm, indoor RLANs and an RLAN AP activity of 100%
- Increased FWA minimum sensitivity of -65 dBm (equivalent, for example, to a coverage reduction of 70%)
- Operation of outdoor RLANs
- Reduced RLAN activity of 5%.

Each MC scenario was examined with RLAN operation at data rates of both 6 Mbit/s and 54 Mbit/s. Table 5.14 describes the full set of interference scenarios examined by Monte Carlo analysis.

Scenario	Data Rate	FWA Sensitivity	Interfering RLAN AP	RLAN Activity
(D1)	54 Mbit/s	-75 dBm	Indoor	100%
(D2)	6 Mbit/s	-75 dBm	Indoor	100%
(D3)	54 Mbit/s	-65 dBm	Indoor	100%
(D4)	6 Mbit/s	-65 dBm	Indoor	100%
(D5)	54 Mbit/s	-75 dBm	Outdoor	100%
(D6)	6 Mbit/s	-75 dBm	Outdoor	100%
(D7)	54 Mbit/s	-75 dBm	Indoor	5%
(D8)	6 Mbit/s	-75 dBm	Indoor	5%

Table 5.14: Transmitting RLAN/Receiving FWA system MC interference analysis scenarios

The SEAMCAT MC analysis tool makes use of a 'simulation radius' to determine the location area where interfering transmitters may occur around the victim receiver. This simulation radius is based on, inter alia, interfering transmitter density. At higher densities, the simulation radius can become much reduced, so affecting SEAMCAT's results. For the FWA system parameters considered here, this occurs at interfering transmitter densities typical of urban and dense urban environments. The simulation radius has therefore been limited in these environments to a minimum of 1 km. Two sets of results have therefore been produced: a set for rural/suburan environments and a set for urban/dense urban environments.

b) Results and analysis

Minimum Coupling Loss analysis

Figure 5.15 shows the MCL analysis results for scenarios considered.

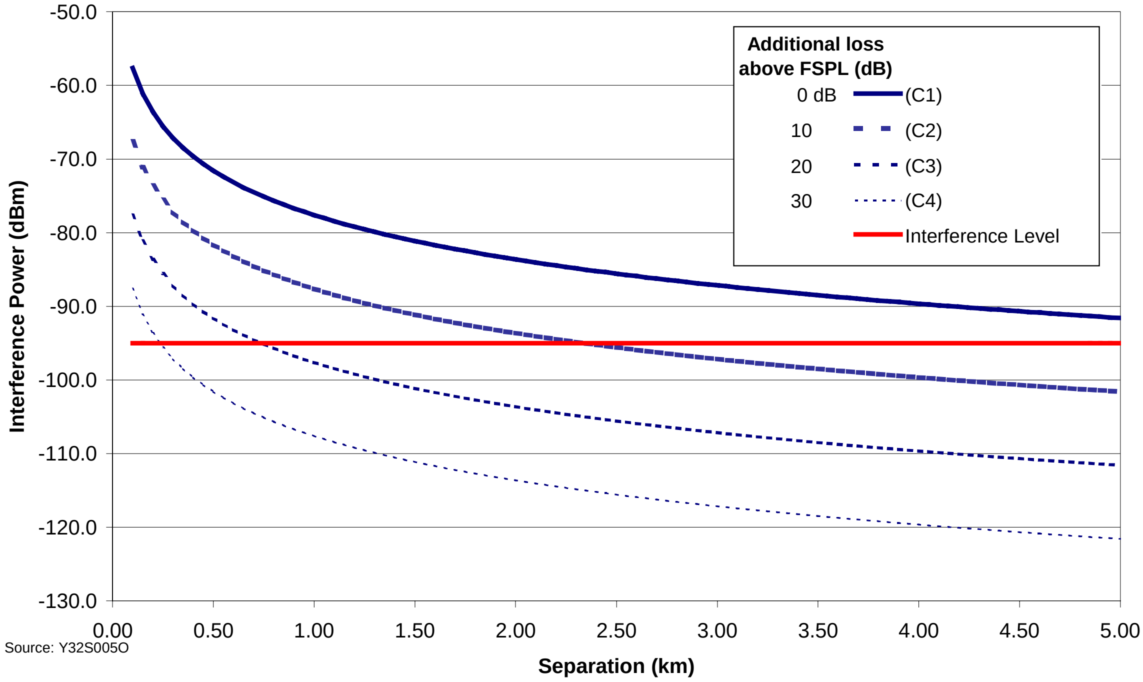

Figure 5.15: Transmitting RLAN/Receiving FWA system MCL interference analysis results

Figure 5.15 shows that considerable co-channel interference will occur on line-of-sight paths unless there is a significant separation distance. The curves with additional losses above free space propagation show that considerable losses are required before reasonable re-use distances are be achieved. However, additional losses for the interference link budget aggregating to at least 35 dB may be expected in practice:

- The Peak to Average Power Ratio (PAPR) of OFDM is typically greater than 6 dBs
- Transmit Power Control is expected to reduce average RLAN EIRP by at least 3 dB
- In practice, actual activity ratios will be much reduced over those assumed provide additional mitigation of up to 13 dB
- Location of equipment indoor (as most RLAN equipment is expected to be) will increase propagation losses by at least 10 dB (i.e. traversing one external wall)
- Manufacturers are claiming significantly lower required C/I ratios; for example, a C/I ratio of 6 dB for a 6 Mbit/s service has been complained (c.f. C/I ratio of 20 dB assumed here).

In practice therefore, required separation distances of less than a few hundred metres are expected. High-density RLAN implementations can be expected to present some problems for FWA system operation therefore, but in most environments sufficient isolation should exist between an interfering transmitter and a wanted receiver, operating co-channel.

Monte Carlo analysis

Figures 5.16 and 5.17 show the results from the SEAMCAT Monte Carlo analysis of the various interference scenarios considered. Two sets of results are given due to the requirement to limit the MC simulation radius to below 1 km in urban/dense urban environments, as discussed earlier.

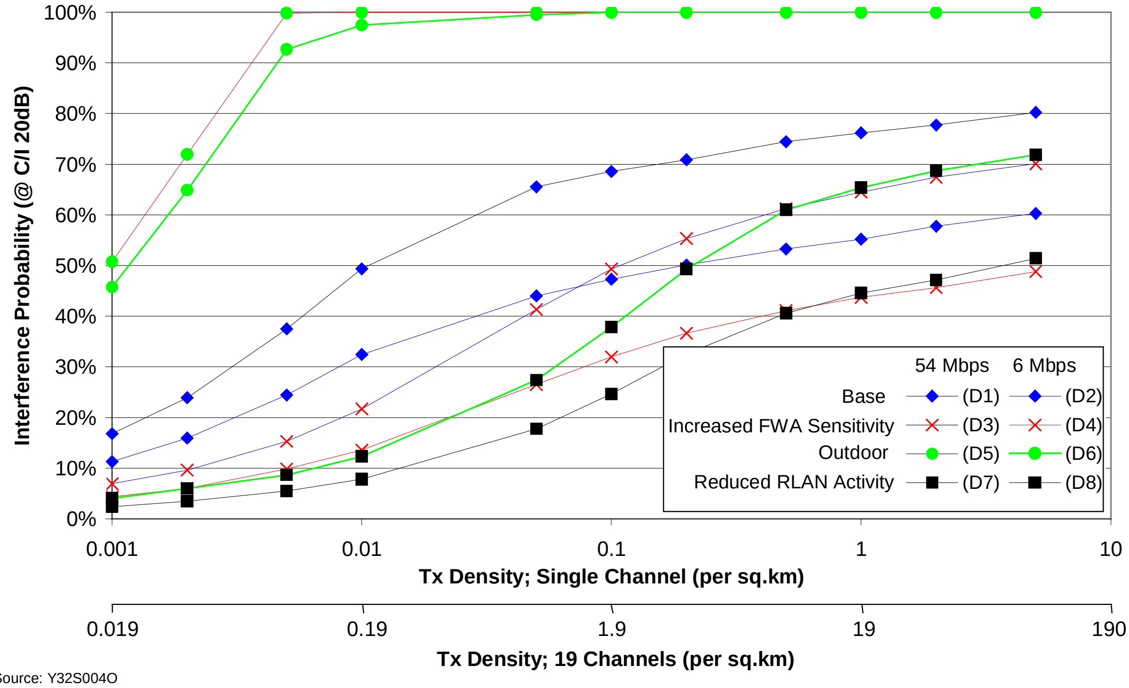

Figure 5.16: Transmitting RLAN/Receiving FWA SEAMCAT MC analysis interference results for rural & suburban environments

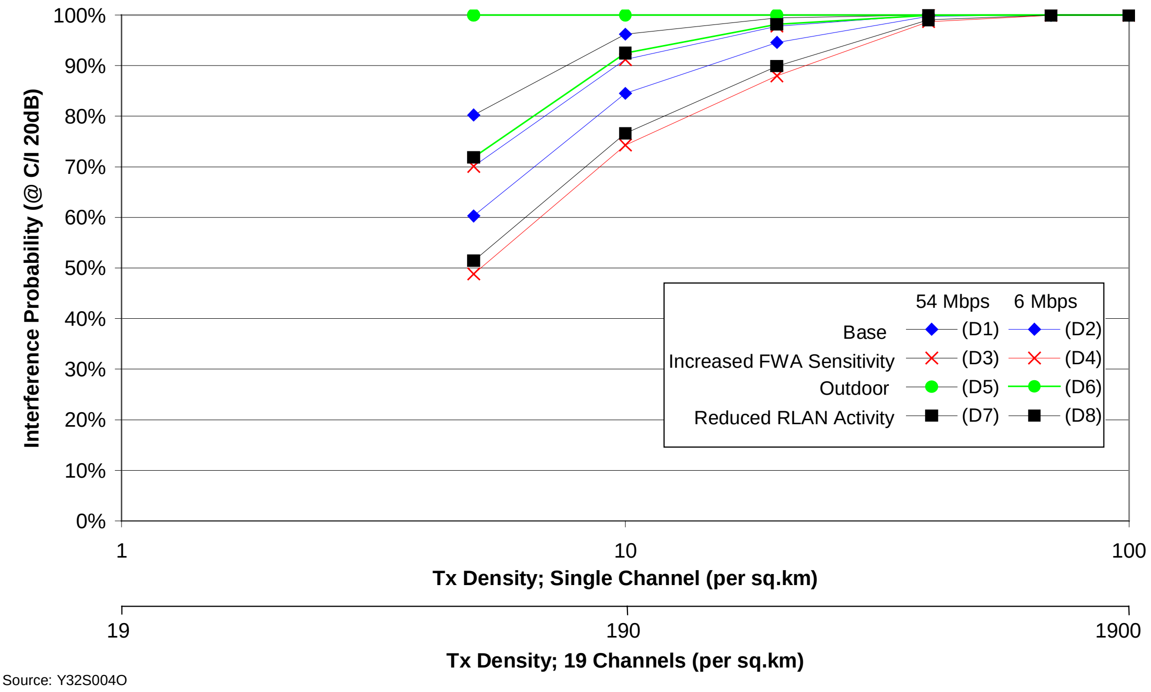

Figure 5.17: Transmitting RLAN/Receiving FWA SEAMCAT MC analysis interference results for urban & dense urban environments

As noted earlier, the results presented in Figures 5.16 and 5.17 should not be considered in isolation; the effect of the various limitations inherent in SEAMCAT, as well as other mitigating factors, should be considered.

SEAMCAT will add an additional 10 dB to the basic propagation loss for the interference from RLANs into the FWA BS, representing a signal travelling through a single external wall. However, additional propagation losses in the urban and dense urban environments are expected for the interfering simulation radii considered. To illustrate the potential effect of additional attenuation in these environments only, simulations have been performed for paths with an average additional 15 dB loss. An average increase of 15 dB in the propagation loss on the interfering link in the urban and dense urban environments reduces the probability of interference, for a 6 Mbit/s signal at 5 transmitters per sq. km, to 42% (with a decreasing reduction at higher densities).

It is also expected that receivers will perform better than those currently modelled. More realistic C/I ratios is one area where significant effects could be foreseen; some manufacturers have claimed C/I ratios of 6 dB for a 6 Mbit/s signal. Such a C/I ratio would reduce the probability of interference to:

- 34% for a 6 Mbit/s signal at 1 transmitters per sq. km

- 40% for a 6 Mbit/s signal at 5 transmitters per sq. km (with a decreasing reduction for higher densities).

Employing both mitigation factors, in the urban and dense urban environments, does not however provide sufficient margin to reduce the interference probability to the levels required. The operation of co-frequency RLANs in the coverage area of a FWA BS, in urban and dense urban environments, does not seem feasible.

Noting that most commentaries on the subject anticipate outdoor RLANs making up anything from 1% to 15% of the total RLAN population, the peak outdoor RLAN density must be reduced accordingly. However, even with this reduction, across all environments, with or without the mitigation factors discussed, outdoor RLANs have to the potential to cause significant interference to co-frequency FWA BSs.

In the rural and suburban environments, if the reduction in C/I is employed with the reduced RLAN activity scenario (which is expected to be more typical in these environments), a 10% interference probability occurs at a indoor RLAN density of 0.5 systems per sq. km. The operation of indoor RLANs in rural and suburban environments does therefore seem practical.

5.5.6 Transmitting FWA system/Receiving RLAN compatibility

a) Interference scenarios and assumptions

This section examines the potential for interference from transmitting FWA systems and receiving RLANs. Only co-channel interference is considered, as it is expected to dominate over interference from unwanted emissions.

As described earlier, 'mesh' FWA systems are assumed.

There are four potential interference paths from FWA systems interfering with RLANs, as shown in Table 5.18.

Wanted Link		Interfering Link	
Wanted Transmitter	**Victim Receiver**	**Interfering Transmitter**	**Wanted Receiver**
RLAN MT	RLAN AP	FWA CS	FWA BS
RLAN AP	RLAN MT	FWA CS	FWA BS
RLAN MT	RLAN AP	FWA BS	FWA CS
RLAN AP	RLAN MT	FWA BS	FWA CS

Table 5.18: Transmitting FWA system/Receiving RLAN interference paths

Initial studies indicate that, for the wanted link, paths with an RLAN AP as victim receiver are the critical paths since (1) they form the network 'hub', (2) interference to a wanted RLAN MT can be overcome more easily by either re-transmission and/or re-location and (3) a wanted RLAN MT receiver will benefit from the mitigation of a lower activity ratio. Of these two paths, the FWA BS is likely to be the most interfering transmitter, principally because of its location and likely activity ratio.

The interference path examined in the analysis was therefore interference from a FWS BA into an RLAN AP. This interference path has been studied using both Minimum Coupling Loss (MCL) and Monte Carlo (MC) analysis.

Minimum Coupling Loss analysis

As with earlier analysis, several scenarios have been examined, looking at the interference path with various additional path loss factors beyond basic free space path loss. The scenarios assume:

- For the RLAN AP, omnidirectional receive antenna, a bandwidth of 20 MHz, a receiver sensitivity of –85 dBm and a C/I of 20 dB
- For the FWA BS, a maximum EIRP of 36 dBm, with omnidirectional transmit antenna and a bandwidth of 20 MHz.

Table 5.19 describes the full set of interference scenarios examined.

Scenario	Wanted Receiver	Interfering Transmitter	Propagation	Additional Path Loss
(E1)	RLAN AP	FWA BS	Free Space	0 dB

(E2)	RLAN AP	FWA BS	Free Space	10 dB
(E3)	RLAN AP	FWA BS	Free Space	20 dB
(E4)	RLAN AP	FWA BS	Free Space	30 dB

Table 5.19: Transmitting FWA System/Receiving RLAN MCL Interference Analysis Scenarios

Monte Carlo analysis

Again, several scenarios have been examined representing combinations of various parameters:

- Both indoor and outdoor RLAN victim receivers has been considered
- FWA BS activity ratios of 100% and 5% have been examined. With 5% representing a value that could be expected in lower density areas, for example in rural environments
- Lower and upper values for range of FWA BS densities from 0.2 to 3 per sq. km have been examined. The nominal base case value of 1 per sq. km was also examined.

The MC scenarios were examined assuming a FWA BS EIRP of 36 dBm, with no active power control. Table 5.20 describes the full set of intra-RLAN interference scenarios examined by Monte Carlo analysis.

Scenario	RLAN AP Location	FWA Activity Ratio	FWA BS Density
(F1)	Indoor	100%	0.2 per sq. km
(F2)	Indoor	5%	0.2 per sq. km
(F3)	Indoor	100%	1 per sq. km
(F4)	Indoor	5%	1 per sq. km
(F5)	Indoor	100%	3 per sq. km
(F6)	Indoor	5%	3 per sq. km
(F7)	Outdoor	100%	0.2 per sq. km
(F8)	Outdoor	5%	0.2 per sq. km
(F9)	Outdoor	100%	1 per sq. km
(F10)	Outdoor	5%	1 per sq. km
(F11)	Outdoor	100%	3 per sq. km
(F12)	Outdoor	5%	3 per sq. km

Table 5.20: Transmitting FWA system/Receiving RLAN MC interference analysis scenarios

b) Results and Analysis

Minimum Coupling Loss analysis

Figure 5.21 shows the MCL analysis results for scenarios considered.

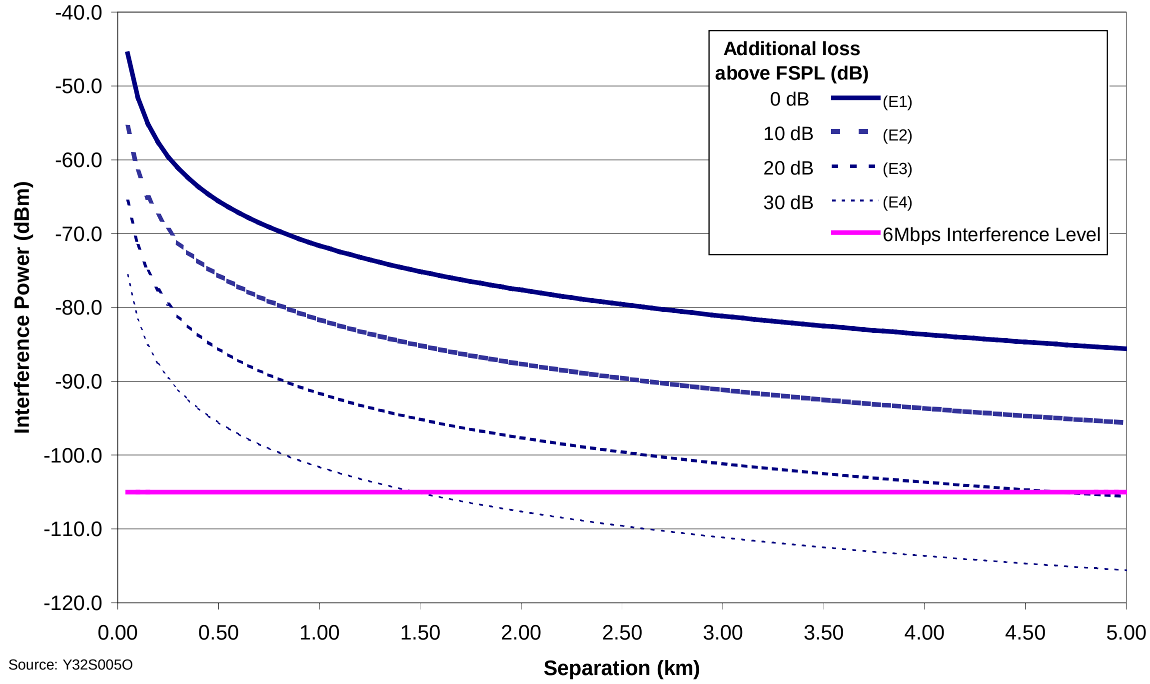

Figure 5.21: Transmitting FWA system/Receiving RLAN MCL interference analysis results

For line-of-sight paths it is clear that severe co-channel interference will occur unless there is a sufficiently large separation distance. Examination of the curves with additional path losses indicates that re-use distances can be reduced if losses above free space propagation occur. Additional losses for the interference link budget aggregating to at least 30 dB can be expected, however:

- The Peak to Average Power Ratio (PAPR) of OFDM is typically 6 dB
- Use of directional antennas to limit the FWA coverage could introduce additional mitigation of 10 to 15 dB, in areas beyond the FWA coverage area
- In practice, actual FWA activity ratios will be much reduced over that assumed providing additional mitigation of up to 13 dB
- The location of equipment indoor (as most RLAN equipment is expected to be) will increase propagation losses by at least 10 dB (i.e. traversing one external wall)
- Manufacturers are claiming significantly lower required C/I ratios; for example, a C/I ratio of 6 dB for a 6 Mbit/s service has been complained (c.f. C/I ratio of 20 dB assumed here).

However, even with such additional losses, separation distances remain significant. Indeed the results indicate that it will not be possible for an RLAN to use the same frequency as an FWA BS in the coverage area of that BS. DFS in the RLAN should permit service to be offered in this case, however reduced capacity can be expected (particularly if operating in a high density RLAN environment).

Monte Carlo analysis

Figures 5.22 and 5.23 show the results, for indoor and outdoor RLANs respectively, of the SEAMCAT Monte Carlo analysis of the various interference scenarios considered.

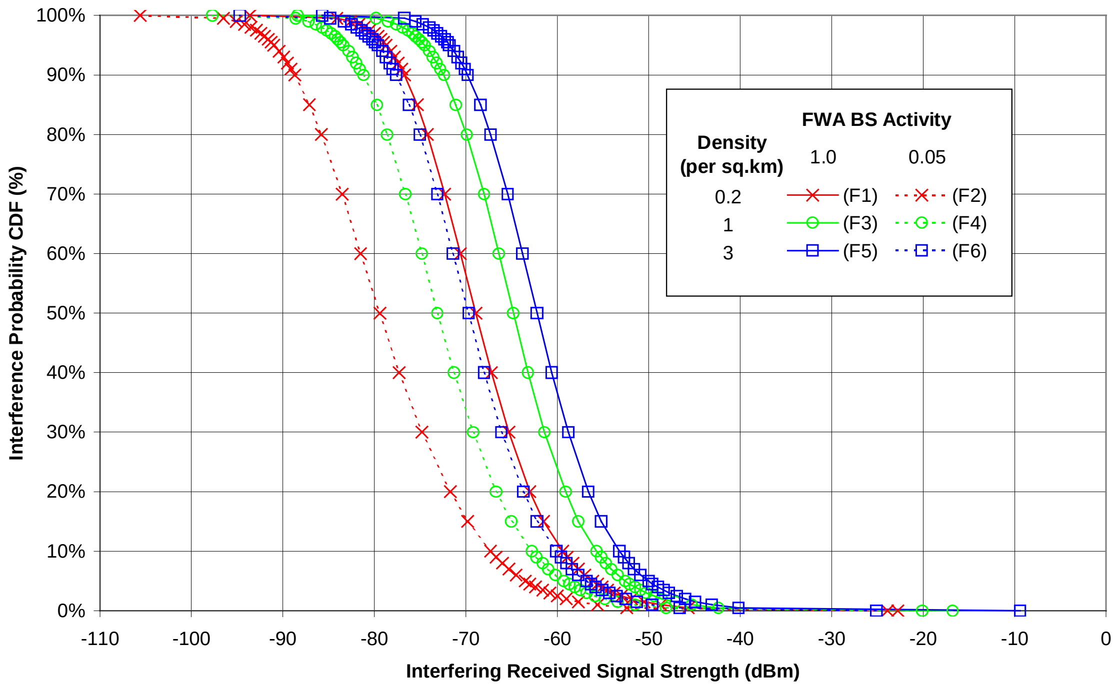

Figure 5.22: Transmitting FWA system/Receiving indoor RLAN SEAMCAT MC interference analysis results

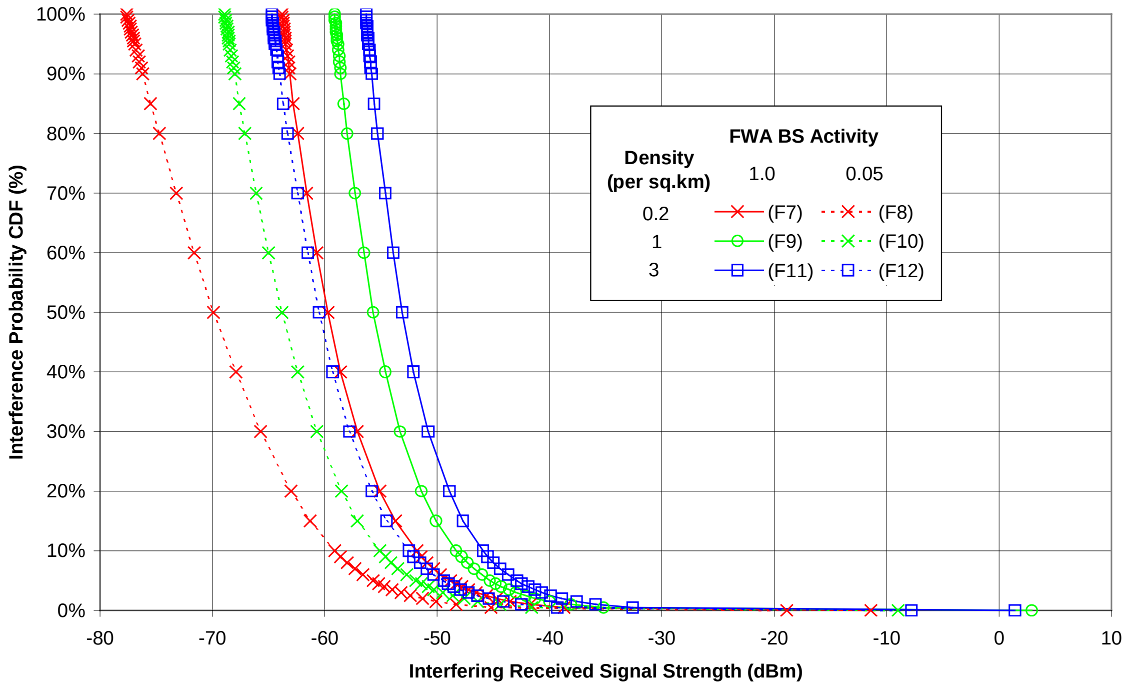

Figure 5.23: Transmitting FWA system/Receiving outdoor RLAN SEAMCAT MC interference analysis results

For a 6 Mbit/s signal, the RLAN receiver interference level is –105 dBm (receiver sensitivity of –85 dBm, with C/I of 20 dB). The figures above show that both indoor and outdoor RLANs operating with such an interference level will not be able to provide service in any of the scenarios examined. As before, a number of mitigating factors can be considered to exist:

- The Peak to Average Power Ratio (PAPR) of OFDM is typically 6 dB
- Manufacturers are claiming significantly lower required C/I ratios; for example, a C/I ratio of 6 dB for a 6 Mbit/s service has been complained (c.f. C/I ratio of 20 dB assumed here)
- Use of directional antennas to limit the FWA coverage could introduce additional mitigation of 10 – 15 dB, in areas beyond the FWA coverage area.

The effect of the latter of these factors is difficult to quantify except that, as shown in the MCL analysis, it should permit re-use of the frequency used by the FWA BS by RLANs operating outside the coverage area of the BS.

Quantifying the effect of the other two mitigation factors is simpler; the PAPR and C/I factors together reduce the interference level, for a 6 Mbit/s signal, to –85 dBm. For indoor RLANs, Figure 5.22 shows that in this case some service is possible, however this will be severely restricted. Additional losses totalling 15 to 30 dB are required before co-frequency operation of RLANs, in the coverage of the FWA BS, becomes viable.

Figure 5.23 shows that, even after applying these mitigation factors, additional losses of the order of 20 to 40 dB, depending on the environment, are required in order that outdoor RLANs can provide a 6 Mbit/s service.

It appears therefore that RLANs will not generally be able to operate co-frequency, co-coverage with FWA BSs, except for indoor RLANs are operating in lower density (suburban and rural) environments.

In urban/dense urban environments, RLANs within a FWA BS's coverage may have difficulty operating even on a non co-frequency basis due to the lack of available channels with which to operate on.

5.5.7 Intra FWA system compatibility

a) Interference scenarios and assumptions

This section examines the interference potential between different FWA systems. Only co-channel interference is considered, as it is expected to dominate over interference from unwanted emissions.

As described earlier, 'mesh' FWA systems are assumed.

There are four potential interference paths between Base Stations (BS) and Consumer Stations (CS), as illustrated in the matrix below.

Wanted Link		**Interfering Link**	
Wanted Transmitter	**Victim Receiver**	**Interfering Transmitter**	**Wanted Receiver**
CS	BS	CS	BS
CS	BS	BS	CS
BS	CS	CS	BS
BS	CS	BS	CS

Table 5.24: Intra FWA System interference paths

Initial studies indicate that, for the wanted link, paths with an BS as victim receiver are the critical paths since (1) the BS is the network 'hub' and (2) interference to a wanted CS receiver can be overcome more easily by re-transmission and, if necessary, re-location. Of the remaining two paths, it is less likely that a CS will interfere directly with an BS, since local site mitigation techniques can be employed on a case-by-case basis. The interference path examined in the analysis was therefore where both the wanted and interfering transmitters are BSs. This interference path has been studied using Minimum Coupling Loss (MCL) analysis.

Minimum Coupling Loss analysis

Several scenarios have been identified, to look at this interference path with various additional path loss factors beyond basic free space path loss. Each scenario assumes a maximum EIRP of 36 dBm, no TPC, omnidirectional transmit and receive antennas, and a C/I of 20 dB.

Table 5.25 describes the full set of intra FWA system interference scenarios examined.

Scenario	Propagation	Additional Path Loss
(G1)	Free Space	0 dB
(G2)	Free Space	10 dB
(G3)	Free Space	20 dB
(G4)	Free Space	30 dB

Table 5.25: Intra FWA System MCL interference analysis scenarios

b) Results and analysis

Minimum Coupling Loss analysis

Figure 5.26 shows the MCL analysis results for the various scenarios considered.

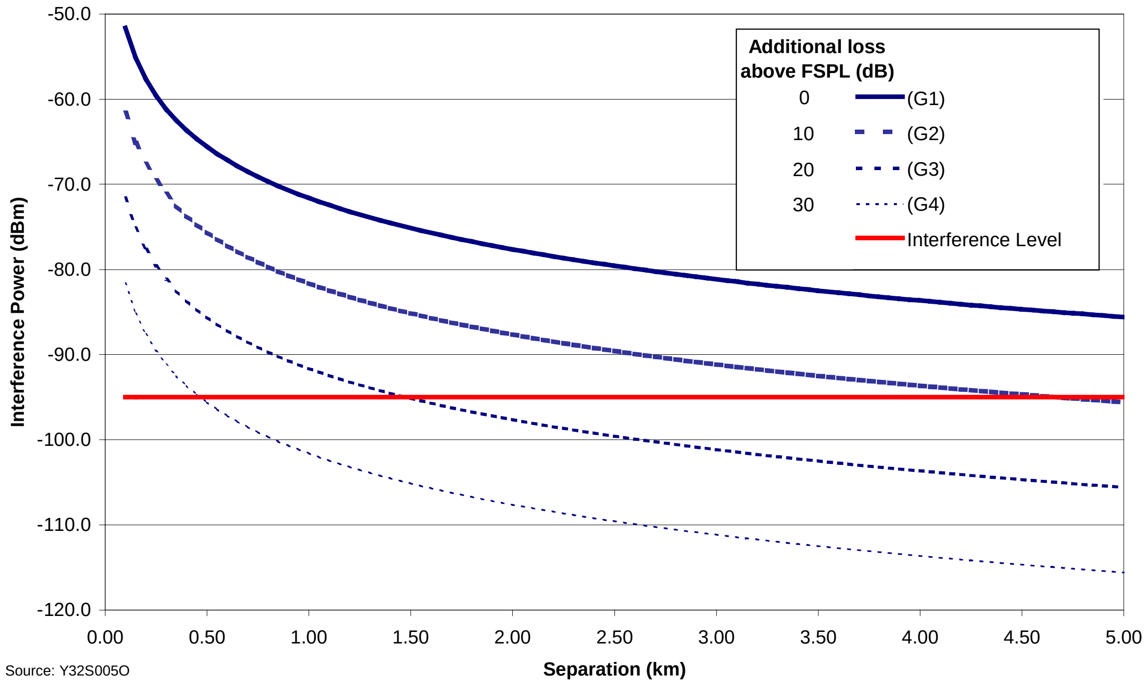

Figure 5.26: Intra FWA System MCL interference analysis results

For line-of-sight paths it is clear that significant co-channel interference will occur unless there is a sufficiently large separation distance. The curves with additional losses above free space propagation show that considerable losses are required before reasonable re-use distances can be achieved. Additional losses for the interference link budget aggregating to at least 20 dB are expected:

- The Peak to Average Power Ratio (PAPR) of OFDM is typically 6 dB
- Use of directional antennas to limit the FWA coverage could introduce additional mitigation of 10 to 15 dB, in areas beyond the FWA coverage area
- In practice, actual FWA activity ratios will be much reduced over that assumed providing additional mitigation of up to 13 dB
- Manufacturers are claiming significantly lower required C/I ratios; for example, a C/I ratio of 6 dB for a 6 Mbit/s service has been complained (c.f. C/I ratio of 20 dB assumed here).

With such additional losses, Figure 5.26 shows that separation distances begin to become manageable. The use of a suitable frequency reuse plan, to ensure that the frequency used at a BS is not reused by adjacent BSs, should permit interference to be managed sufficiently. Use of directional antennas employing down tilt should further enhance this.

5.5.8 5 GHz conclusions

This section has examined various compatibility scenarios in the 5 GHz bands. Densities of use consistent with anticipated take-up of RLANs and FWA have been studied. The conclusions drawn from this analysis are summarised below:

- The sharing between RLANs and other services (EESS, FSS, Radars, Maritime Radionavigation, RTTT, FS) in the 5 GHz bands is feasible, assuming the restrictions on EIRP and outdoor use already placed on HiperLAN operations by existing European instruments.
- The sharing between FWA systems and other services (EESS, FSS, Radars, Maritime Radionavigation, RTTT, FS) in the 5 GHz bands needs further consideration to determine the feasibility of operation.
- Interference between RLANs (RLAN-RLAN interference) is not expected to be significant, with the exception of RLANs used outdoors. Outdoor RLANs are expected to present some interference potential in environments outside of rural and suburban (i.e. in urban and dense urban environments). However this potential will be self-limiting, in that its main consequence will be a reduction of range.
- Sufficient margins do not appear to exist to permit the operation of co-frequency transmitting RLANs in the receiving coverage area of a 5 GHz FWA BS in urban and dense urban environments. However, the operation of transmitting indoor RLANs in the receiving coverage area of a FWA BS in rural and suburban environments does seem practical. Across all environments, outdoor RLANs have to the potential to cause significant interference to co-frequency FWA BSs.
- Receiving RLANs will not generally be able to operate co-frequency, co-coverage with transmitting FWA BSs, except for indoor RLANs operating in lower density (suburban and rural) environments. In urban/dense urban environments, RLANs within a FWA BS's coverage may have difficulty operating even on a non co-frequency basis due to the lack of available channels with which to operate on.
- In terms of intra-FWA interference, the use of a suitable frequency re-use plan, to ensure that the frequency used at a particular BS is not reused by adjacent BSs, should permit interference to be managed sufficiently. Use of directional antennas employing down tilt should further enhance this.

The implications of these conclusions are that:

- At densities consistent with anticipated commercial take-up, RLANs should be able to operate without causing undue interference to either other RLANs, or other services in the bands
- The use of mesh FWA technologies in the 5 GHz bands could be considered, but limitations on use would be necessary, for instance, limiting to rural and sub-urban environments.

5.6 Other Licence-exempt Bands

There are a number of other licence-exempt bands in the UK, as listed in Appendix D, for which technical analysis has not been conducted in this study. These bands exist in various parts of frequency spectrum and are used by a range of SRD technologies. Further technical analysis on a band-by-band basis may be desirable if it were considered that a change in regulation would lead to a greater commercial interest in use of these bands. However, as indicated elsewhere in this report, the use of SRD's to provide third party services is not generally anticipated. In general, however, we expect the general principals arising out of this report will apply to use of SRD spectrum, i.e. systems with homogeneous operating characteristics using 'polite' technologies reduce significantly the potential for interference.

6. ECONOMIC IMPACT ASSESSMENT

6.1 Introduction

A more liberal approach to the regulation of licence-exempt spectrum has the potential to allow new types of services to emerge, with potential benefits for customers. Available evidence suggests that these benefits are likely to be significant, even if they are necessarily difficult to estimate. In particular, within the 2.4 GHz and 5 GHz bands these benefits are very likely to outweigh any realistic costs arising from increased radio interference.

Given that the costs and benefits of any change in the regulatory regime are complex and affect many parties, we break the assessment into a number of simpler steps:

- First, we compare allowing the use of licence-exempt spectrum for public access systems with the regulatory status quo on the assumption that interference problems are minimal. By making this assumption we can temporarily ignore the distinction between complete deregulation and a light regulatory regime. We construct an order of magnitude estimate of the economy-wide benefits likely to be generated from allowing public access RLAN provision
- Second, we consider the extent to which the likely take-up and supply of services would in fact lead to congestion and interference problems. Drawing on the technical analysis of section 5, for RLANs, we find that these problems are limited in the 2.4 GHz and 5 GHz bands and very unlikely to outweigh the benefits identified in the first step. Therefore, we can conclude that there is a strong case for deregulation for these bands regardless of the optimal form of any residual regulation
- Third, we consider whether the regulatory measures required to mitigate interference would lead to a significant erosion of the benefits identified in the first step. In practice, there are relatively simple measures that can be taken to limit the potential for interference without significantly restricting the ability of providers to introduce innovative new services that create entirely new demand. This suggests that total deregulation is not desirable.

6.2 General framework

We will assess the impact of regulatory change in terms of consumer and producer surplus. Any change in overall economic welfare is given by the sum of the changes in consumer and producer surplus.

Consumer surplus generated by a product or service is the sum of all net benefits enjoyed by its consumers. The net benefit enjoyed by one particular consumer is the difference between the market price and the maximum price the consumer would be willing to pay for each unit of the product or service used. Drawing a standard demand curve, consumer surplus is simply the area between the demand curve and a horizontal line at the market price (see Figure 6.1).

The producer surplus is measured by the difference between price and marginal cost for each unit of the product/service, multiplied by the total quantity supplied. The case of constant unit cost is shown in Figure 6.1. In this case producer surplus equals the total profit earned by suppliers.

In a perfectly competitive environment, competition will drive price down to the level of minimum average costs, and economic profits and hence producer surplus are equal to zero. Even if competition is less than perfect, but by and large effective, economic profits will be competed away and correspondingly producer surplus will be small. Thus, assuming that the supply of services is sufficiently competitive, the economic welfare from a regulatory change will be captured by the change in consumer surplus.

Often services produced in one sector are not directly consumed by end-customers, but form intermediate inputs into other sectors. Telecoms services are clearly vital intermediate products to every sector of the economy. In this case, a welfare assessment would also have to take into account the competitive conditions in the downstream markets in which the services under consideration are used as inputs. However, providing these other sectors are reasonably competitive, the ultimate use to which services are put does not affect our welfare analysis. It makes little difference whether consumers of a service are end-customers or else producers of other products and services acting effectively as agents for their own customers. We need only look at the overall demand curve for the particular service we are considering without distinguishing the nature of the demand. Again, provided that market conditions are sufficiently competitive, we can safely ignore profits generated in downstream sectors. The assumption of a sufficiently competitive supply of services is commonly made in welfare analysis.

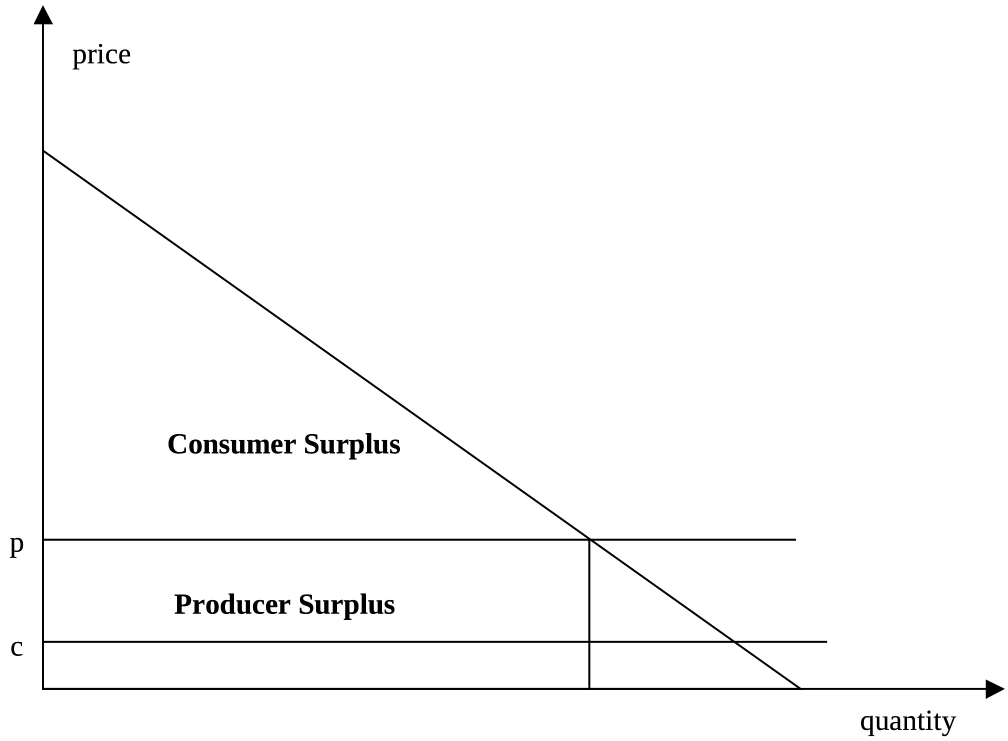

Figure 6.1: Consumer and producer surplus

Generally, a change in regulatory conditions may have two distinct impacts:

- The consumer and producer surplus generated by existing services may change, for example due to a change in the price and the quantity consumed of those services; and/or
- It may lead to the introduction of entirely new services, and generate consumer and producer surplus from meeting these new demands.

As we will see, often the latter will be much larger than the former. Therefore, potential and actual benefits from the introduction of new services are a very important element of the economic welfare effects of liberalising the use of licence-exempt spectrum.

Consider first the welfare benefits of increased competition. Figure 6.2 illustrates the case of a simple linear demand curve and constant average cost *c* (in this case, the same as the long-run marginal cost or the unit cost). Suppose that a new service is very similar to existing ones and can therefore be represented by the same demand curve (the downward sloping line). Increased competition as a result of the new substitute service exerts downward pressure on price and aligns it more closely with cost. This generates a consumer surplus benefit for customers. In the example, assume that increased competition results in a price reduction from p_0 to p_1, leading to a corresponding increase in the quantity supplied from q_0 to q_1.

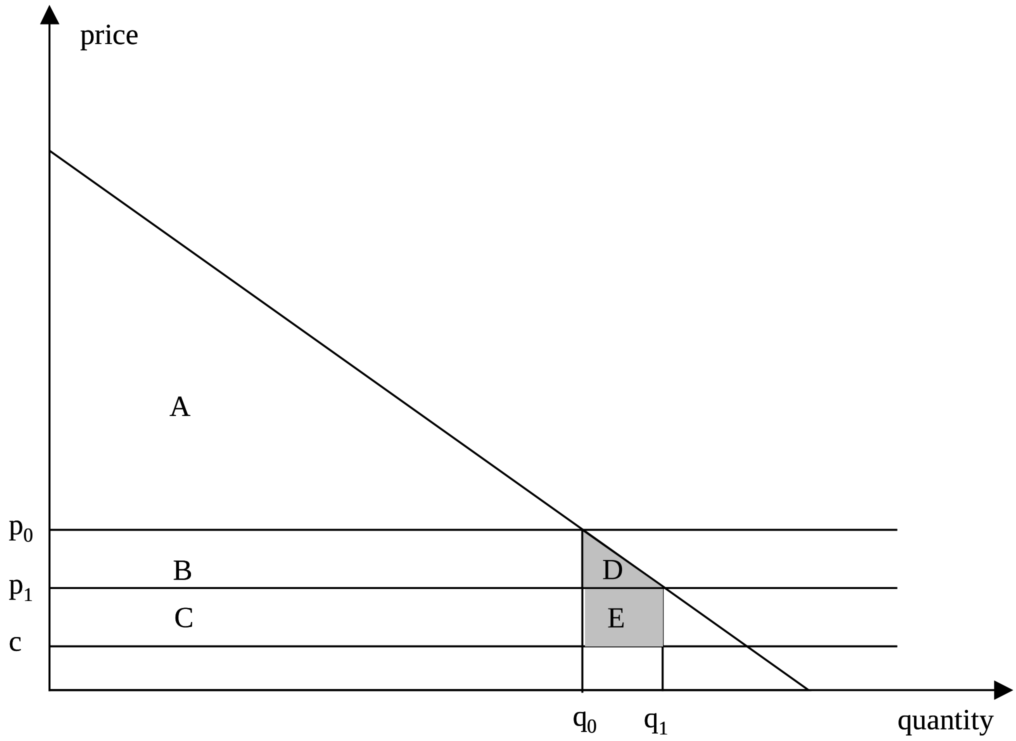

Figure 6.2: Welfare effects of increased competition

At the initial price, consumer surplus is captured by the area A, measuring the extent to which consumer valuation of the service exceeds price. Producer surplus is equal to B+C – quantity supplied multiplied by profit margin. The price reduction from p_0 to p_1 results in consumer surplus increasing to A+ B+D. Producer surplus falls to C+E. Most of the gain in consumer surplus (i.e. B) is simply redistributed profit implying a corresponding reduction in producer surplus. The net benefits from increased competition are thus measured by the area D+E.

Now consider benefits from introducing an entirely new service that appears in the form of consumer and producer surplus from satisfying new demand, as shown in Figure 6.3.

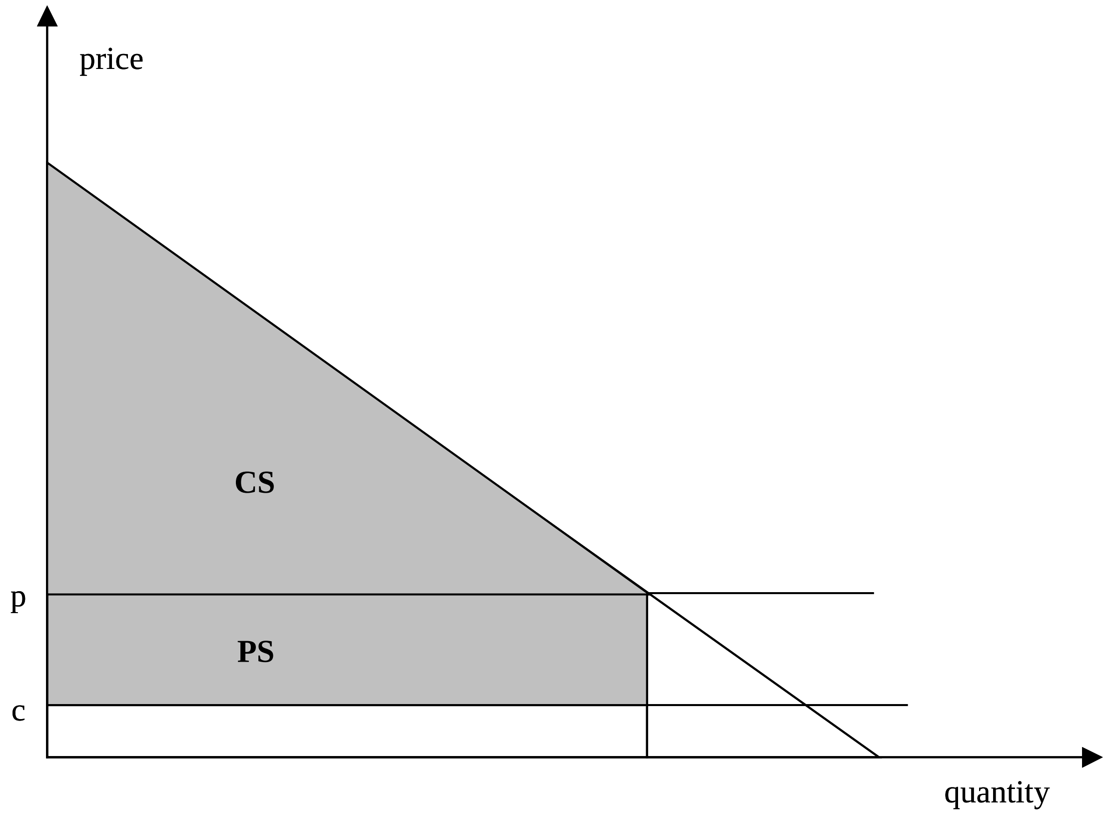

Figure 6.3: Welfare effects from the introduction of independent new services

As the new service satisfies previously unmet demand, the net benefit is measured by the *entirety* of the consumer surplus (CS) and producer surplus (PS) associated with serving a new market at price p (given average cost of c). A simple stylised example will help to understand the order of magnitude of these effects.

Assume that a new service is introduced, which is unrelated to existing services. The unit cost of providing the service is £100. The service is offered at a price of £200, at which 1,000 people subscribe. The most anyone is prepared to pay for the service (known as the choke price) is £1,200. The consumer surplus generated by this service is therefore:

$$CS = \frac{(£1,200 - £200) * 1,000}{2} = £500,000.$$

The producer surplus is:

$$PS = (£200 - £100) * 1,000 = £100,000.$$

Therefore, the total surplus is: TS=CS+PS=£600,000.

Now assume that another essentially similar service is being introduced. Assume that as a result the price falls by 10% from £200 to £180. This increases demand by 20 units, so now 1,020 people subscribe to the service. The new level of consumer surplus is

$$CS = \frac{(£1,200 - £180) * 1,020}{2} = £520,200$$

$$PS = (£180 - £100) * 1,020 = £81,600$$

Consumer surplus has increased by £20,200 and producer surplus has fallen by £18,400, so the total welfare change is a gain of £1,800.

If price were competed down to the level of cost, total demand would be 1,100, total consumer surplus would be £605,000, total producer surplus would be zero. This would imply a welfare gain of £5,000 relative to the initial situation.

Comparing the welfare effects from improved competition and satisfying previously unmet demand we find that the benefits from additional competition tend to be small relative to the benefits flowing from meeting entirely new demand, which are potentially very large.

Recent empirical studies confirm that the benefits of new services can be very large. Hausman has estimated the loss in consumer surplus from the delayed introduction of cellular telephony and voicemail services [23] - which measures the net benefits that could have been created had these services been introduced earlier – and the consumer surplus gains from the introduction of a new cereal brand [24]. Whilst cellular telephony and (perhaps to a smaller extent) voicemail services are likely to satisfy previously unmet demand, the main effect of introducing a new cereal brand is likely to be an increase in competition. As Table 6.4 shows, the welfare impacts differ by orders of magnitude – independent new services can generate large welfare gains relative to products that are similar to, and may to a large extent substitute for, existing ones.

Service	Effect on consumer surplus	Per capita impact
Delayed introduction of voice messaging	$1.10 - $1.27 billion	$4.42 - $5.10
Delayed introduction of cellular telephony	$33.5 - $49.8 billion	$134.51 - $199.97
Introduction of Apple-Cinnamon Cheerios	$66.8 - $78.1 million	$0.268 - $0.314

Table 6.4: Estimated welfare impact from the introduction of new products/services, (1994 US$)

These figures may understate the welfare gain, as they do not include producer surplus. On the other hand, the figure for voicemail services does not take into account the welfare loss resulting from decreased demand for substitute services such as the use of traditional answering machines thus overestimating the overall consumer surplus loss [36].

6.3 Relationships with existing services

From our industry interviews it is clear that the current restrictions on the use of licence-exempt spectrum for public access systems are preventing the introduction of new services. Over the immediate horizon, the most immediate impact from a removal of the public access restriction would be the introduction of public access RLANs at 2.4 GHz and 5 GHz. However, in the longer term, regulatory change could lead to a wide variety of new services that are necessarily difficult to anticipate.

These new services will have a variety of impacts on economic welfare depending on their relationship with existing services. According to their relationship with existing services (both in the licensed and the licence-exempt bands), we may characterise new services as being:

- Substitutes for existing services
- Unrelated to and independent from existing services
- Complements to existing services.

As shown in Figure 6.5, the introduction of new services has both:

- Direct effects on consumers and producers of these services and any other services that are complementary or in the provision of which the new services are inputs
- Indirect effects through increased competition improving allocative, productive and dynamic efficiency (for a more detailed discussion of these dimensions of efficiency see [25]).

We have already discussed so-called *allocative efficiency* benefits of new services and lower prices for existing services in the previous section. However, there may also be other indirect benefits flowing from increased competition due to service innovation.

There may be *productive efficiency* gains resulting from impact of competition in reducing of costs and removing internal inefficiencies. In order to compete effectively, technological improvements or changes in management structures may be required. These cannot be achieved instantaneously. Similarly, *dynamic efficiency* benefits will arise only in the long run, as firms need to innovate and develop new products and services in order to stay competitive. Productive efficiency gains and dynamic efficiency are interrelated as technological improvements are often the result of innovation to stay competitive, and managerial incentives to innovate are sharpened by competitive pressure. A regulatory environment that encourages competition through the introduction of new services will encourage both productive and dynamic efficiency. For example, Aghion et al. [26] conclude that increased competitive pressure may stimulate innovation because it reduces managerial slack in which managers delay efforts required to introduce the new products and services.

Although these indirect effects are extremely important in the long term, there is no easy means of estimating the impact of regulatory change on these dynamic aspects of the competitive process. Therefore, we note that there are important additional benefits of allowing the introduction of new services on the competitive process that are not reflected in the usual consumer and producer surplus measures, but that these effects cannot be quantified.

The relative importance of direct and indirect depends strongly on how new services relate to existing services. For example, if a new service is a close substitute to an existing service, then the impact of overall consumer and producer surplus is likely to be modest. In particular, if the new service simply replaces a very similar existing service, then the gain in consumer surplus from consuming the new service will be closely matched by that lost from ceased consumption of the old service; producer surplus may simply be redistributed from one supplier to another. The principal benefit may be through indirect effects due to increased competition in cases where competition was previously insufficient to erode economic profits.

If the current supply of services is effectively competitive, new substitute services will generate little or no benefit; they will simply replace existing one, attracting away demand for current suppliers. In the presence of scale economies, this may even lead to welfare losses as it could increase unit costs (a problem that has been discussed in the industrial economics literature under the heading of excess entry).

By contrast, new services that are distinct from existing services and provide genuine innovations generate additional consumer and producer surplus rather than simply redistributing consumer and producer surplus. This will result in strong direct effects.

If a new service is complementary to existing services, then it will not only provide benefits in its own right, but also increase demand for other services. For example, technologies such a Bluetooth may be strongly complementary with 3G mobile services, increasing the range of 3G applications and devices that can be offered.

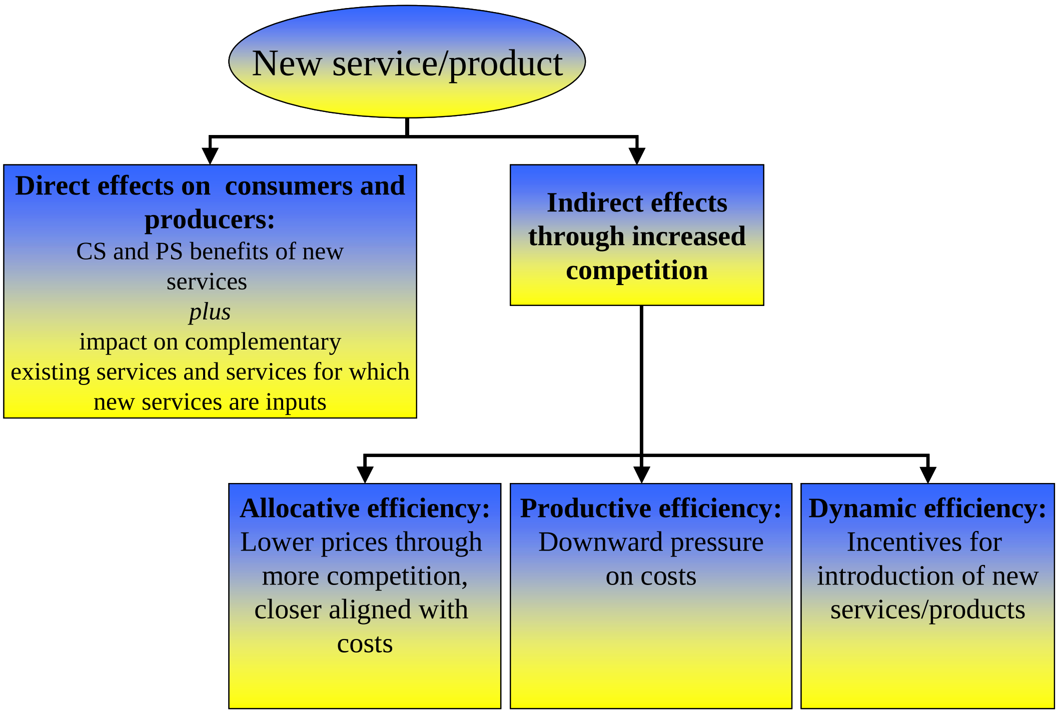

Figure 6.5: Effects from introducing new services

Although it is difficult to anticipate what future new services might look like, we can expect that the larger the direct benefits, the smaller the indirect benefits through increased competition and vice-versa. This is because, in order to increase the intensity of competition, new services need to be a close substitute for existing ones. This implies that most of the demand for the new service comes at the expense of demand for existing services. Conversely, where a new service is unrelated to existing ones, there are large direct benefits from satisfying entirely new demand without any negative impact on demand for existing services. However, this implies that there is little or no impact on competition, and indirect benefits are small.

Our examples in the previous section (considering perfect substitutes and entirely new services) show that the direct benefits tend to exceed indirect benefits by orders of magnitude. However, the impact is more difficult to illustrate if the new service is an imperfect substitute (as would be likely in practice). In this case, there will be welfare gains from customers being able to purchase a service that provides a closer match to their requirements. Some of these customers may previously have bought other services whilst others may be new. Therefore, the demand for the new service to some extent reduces demand for existing services. There is a somewhat larger welfare gain than in the case of perfect substitutes, though smaller than in the case of independent services.

In the case of new services that are complementary to existing services, there are further welfare gains through the positive impact on the value customers place on existing services, as shown in Figure 6.6. The introduction of a new service may increase the valuation of an existing service, causing an outward shift of the demand curve. With unchanged prices and costs in the provision of the existing service, consumer surplus increases from A to A+C, and producer surplus increases from B to B+D. Thus, net benefits of C+D accrue *in addition* to the gains in consumer and producer surplus associated with satisfying previously unmet demand.

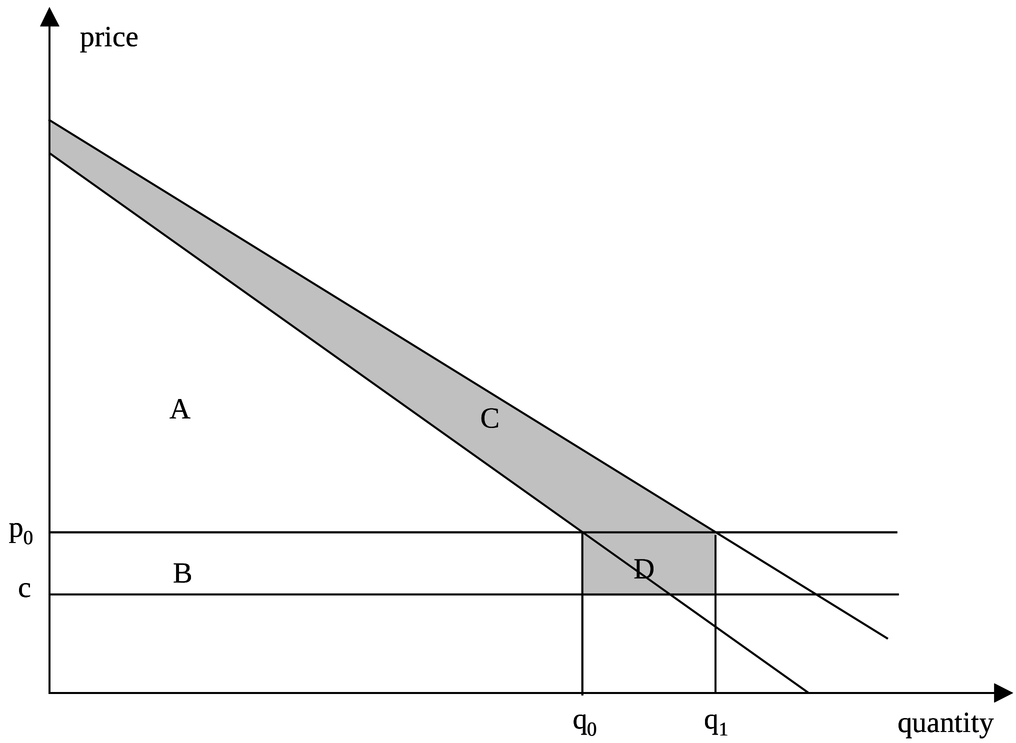

Figure 6.6: Welfare effects on complementary services

6.4 Congestion and interference costs

Opening up access to licence-exempt spectrum may potentially lead to increased levels of congestion and interference for both existing and new users. This potentially has economic costs, in terms of reduced quality of service for users of services and increased costs for providers of services. These problems could affect both new and existing services, though the problems may be somewhat different in nature in the two cases.

For example, allowing new services to use a particular frequency band might lead to interference which reduces the value of, and therefore demand for, an *existing service*, even if the supplier of the new service puts in place technologies that mitigate the impact of interference on its users. This is represented in Figure 6.7 by an inward shift of the demand curve and an increase in average cost from c_0 to c_1. As a result of the loss in service quality, demand at an unchanged price level falls from q_0 to q_1. Consumer surplus falls from A+B to B, and producer surplus is reduced from C+D+E to C. The cost of opening up access is given by the loss in welfare, i.e. the sum of A, D and E.

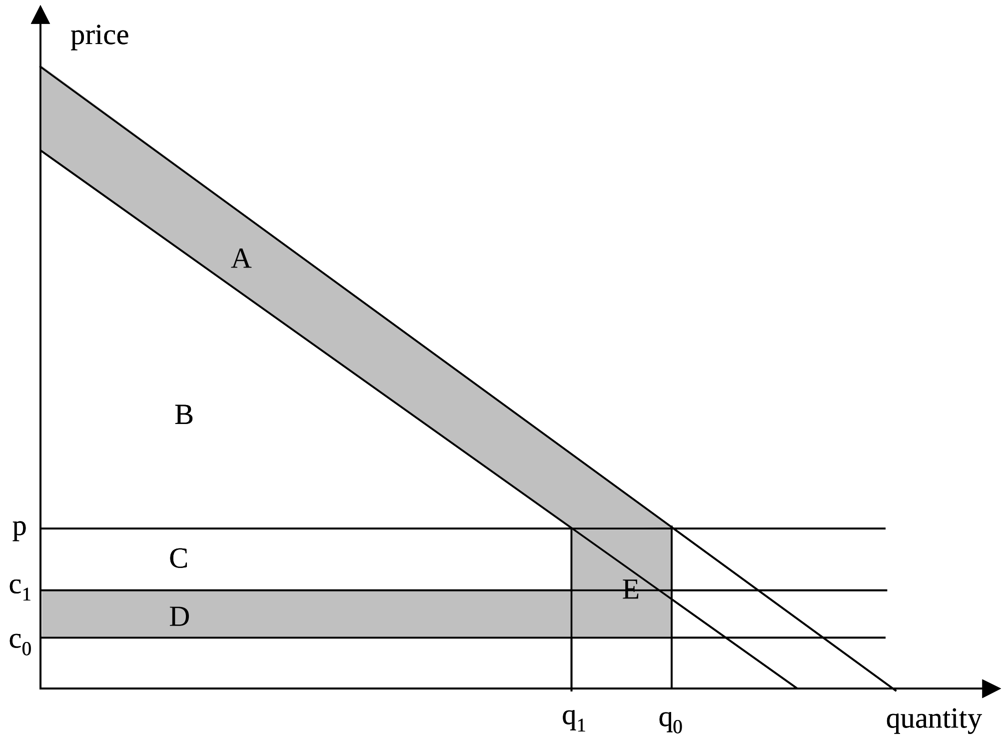

Figure 6.7: Cost of opening up access

There are a variety of factors that affect the magnitude of the economic cost of interference, including regulatory restrictions, the nature of the technologies used and their take-up. These factors can be expected to vary substantially across different spectrum bands.

There are, however, a number of reasons to support the view that the economic costs of interference caused by changes in the regulatory framework may be modest. Unlike many other resources, current technology has the potential to allow radio spectrum to be used in a non-rivalrous way in which one user has at most a modest impact on the service quality experienced by other users. 'Polite' technologies that scan for least congested channels and minimise the chance of interference will impose a smaller cost (if any) on other spectrum users. In order to limit interference, operators may be able to invest in better technology (e.g. devices that automatically scan for the least congested channels and adjust power levels to the specific requirements), or increase the number of access points, but with an increase in the cost of providing a service.

Spread-spectrum technologies and channel management techniques can allow quality of service to degrade progressively as usage of a band becomes more intensive. This means that although there may still be interference between users, the economic costs of that interference may be reduced. In particular, rather than there being a probability that a service is unavailable at a certain time, service quality will be reduced. For example, RLANs may fall back to slower transmission speeds in an adverse radio environment. Technologies of these types reduce the risk of non-availability of services and the impact of interference on the value of services to users.

This is the basis on which at present most consumers experience Internet access services.

Although not directly relevant to the debate about public access services, it is important to remember that new services may sometimes be close substitutes for existing ones using the same band. In this case, interference problems may be mitigated by demand for existing services falling as new services are introduced. This is likely to occur where services are upgraded.

Despite these considerations, there is a limit to the extent to which spectrum can be used in a non-rivalrous way. At some point, if usage and take-up are sufficiently great, interference problems may become significant even between polite technologies, as has been considered in the technical assessment.

In this regard, it is important to distinguish between the interaction amongst users of new services and the interaction between old and new services. Equipment manufacturers and service providers have strong commercial incentives to ensure that new services can be offered with a reasonable quality given expected levels of take-up. Concerns about the quality of services are more important for services provided on a commercial basis, even if they are delivered using licence-exempt spectrum.

Indeed, many industry respondents stated that they would not wish to introduce services that cannot be expected to be of a reasonable quality, in particular where negative user experience would undermine the value of an existing brand. However, most respondents said they would not anticipate significant problems with the QoS level, given available technologies and the fact that in most cases the need to negotiate access to a particular property with the property owner will limit the number of providers in each particular place. This may mean that, through technology choice and commercial negotiations, new services will not interfere with each other, and may suffer little or no interference from existing services.

However, the same incentives may not exist to minimise any interference from new services *to* old services. Therefore, situations could arise where interference is asymmetric, as shown in Figure 6.8 below. In this case, restrictions may be required on new services to correct the externality they impose on users of old services.

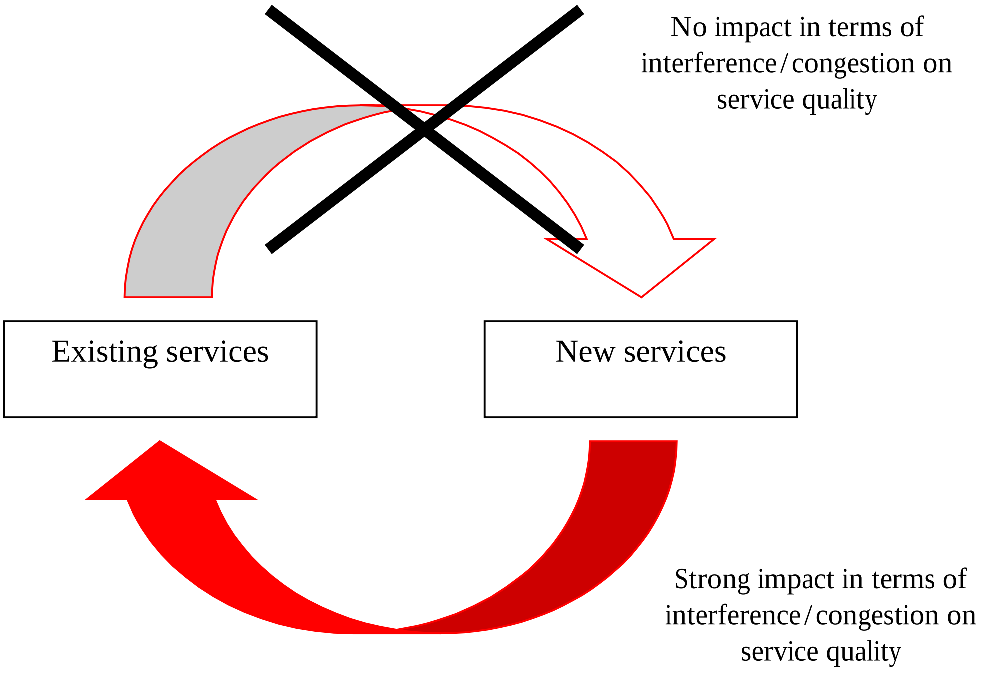

Figure 6.8: Asymmetric impact of new services

A further concern is that new services using licence-exempt spectrum may provide a substitute for services using licensed spectrum. For example, fixed line operators may have incentives to provide public access services over licence-exempt spectrum that could at the margin compete with broadband mobile services or fixed wireless access provided over licensed spectrum. As these services use different bands, licence-exempt spectrum could become congested while, in the extreme, leaving freed-up licensed spectrum lightly used. This would be inefficient and wasteful.

Moreover, a further consideration in this case is the extent to which competition from operators using licence-exempt spectrum would result in 'cherry-picking' and thereby jeopardise the ability of licensed operators to comply with license obligations (e.g. build-out requirements or universal service obligations). These wider effects may be considered an economic cost of relaxing access restrictions on public services.

Overall, it can be seen that there are good reasons to expect the economic impact of interference between new services using frequency hopping and spread spectrum technologies to be limited. However, at the same time providers of new services have poor incentives to protect the users of old services in the same band from interference. This gives a strong rationale to a band-by-band approach to setting radio standards in line with how the band is currently being used and likely future developments.

6.5 The role of regulatory policy

A welfare-maximising spectrum management strategy should aim to allow access to every service that generates net benefits, i.e. where the benefits from the introduction of the new service (taking into account the impact this would have on demand for and competition between existing services) exceed the costs that result from congestion and interference. This would normally be achieved by making those seeking access to spectrum face the opportunity cost they impose on other actual or potential users. This general principle is reflected in the overall spectrum management strategy as set out in the June 2001 Consultation Paper of the Radio Spectrum Management Review, which states that the "*review's overarching principle is that all spectrum users should face some form of price reflecting the opportunity cost of the spectrum use, thus providing incentives over the long term towards efficient use*" [27].

In the case of licensed spectrum, this opportunity cost-based price is charged either through spectrum auctions, administrative pricing or, possibly in the future, spectrum trading. If with the opening of licence-exempt spectrum there were a possibility of charging the users or providers in the affected frequency bands fees that reflect the opportunity cost of the spectrum use then this regulatory change would *unambiguously* increase welfare. However, due to the nature of the services being provided, an economic charging mechanism cannot be implemented in a cost-effective way for licence-exempt spectrum. Whilst in the licensed spectrum bands there are a limited number of operators whose property rights are well defined, licence-exempt spectrum is used by a large number of (mostly unidentified) users without clear property rights. This makes it difficult for a regulatory authority to assess the likely cost caused by additional users providing services in the same frequency band. Spectrum trading mechanisms whereby new users would have to 'buy' the right to use spectrum from existing users will not work because existing users do not have any property right that would allow them to exclude new users, and even if they did would be too numerous for a trading mechanism to be viable. This is because a new user would have to negotiate with, and compensate all existing users who might suffer from congestion and interference.

This inability to apply opportunity cost pricing principles to licence-exempt spectrum, means that we must at least consider the possibility that congestion and interference related costs could overturn the benefits of new services. However, it is also the case that there are market-based incentives to mitigate interference problems.

We would expect that providers would not wish to use licence-exempt spectrum that is currently used very extensively and where control of interference might be a problem, or use licence-exempt spectrum if they expect that congestion and interference will become a significant issue in the near future. Prospective users can be expected to develop commercial services using licence-exempt spectrum only where current and expected future use allows them to control interference in order to maintain reasonable quality of service. The homogeneity of systems and technologies is an important determinant of the ease with which polite technologies can be deployed to minimise interference problems. This implies that public service providers:

- Are unlikely to have strong incentives to develop services in bands in which there are at present a wide variety of heterogeneous technologies, as this could limit the effectiveness of polite technologies in controlling interference problems

- May not wish to use licence-exempt spectrum in currently unused bands unless they can reasonably expect that future use will be sufficiently homogeneous and will have sufficiently predictable interference characteristics to guarantee the effectiveness of polite technologies and the ability to maintain a certain level of service quality.

This limits the extent of serious interference problems to situations where public service providers would be able to use 'smart' technologies that escape interference from, but interfere with existing systems. However, simple restrictions on the nature of applications and usage should be sufficient to minimise this potential danger.

6.6 Estimating the welfare impact of introducing Public RLANs in the UK

Quantifying the total welfare impact likely to arise from opening up current license-exempt spectrum to new services is very difficult as:

- We have only limited information about the services that will be introduced in the future, mainly because such services are not developed yet
- The likely take-up and pricing of such services is highly uncertain.

Nevertheless, it is still possible to give a broad-brush estimate of the possible welfare benefits that might stem from the use of licence-exempt spectrum to provide specific services such as public access RLAN by looking at pricing in those limited examples where such services have already been introduced in other countries and making plausible assumptions about take-up. Clearly, the overall welfare consequences of permitting public access services can be expected to be larger than those arising just from one specific service such as RLAN. Indeed, the most significant welfare impact may arise from accelerating the introduction of new services that do not yet exist and which we cannot easily anticipate.

In our welfare analysis, we assume competitive markets, i.e. that price equals cost and so there are no excess profits made. In this case, producer surplus is zero (or small) and we can concentrate entirely on consumer surplus. This assumption is reasonable given the likely nature of the services likely to be offered over licence-exempt spectrum. Entry into providing these services should be relatively easy, with little sunk investment required. Rolling out a hot-spot RLAN network is largely a question of installing access points (which are already commodity items) in appropriate locations and connecting these to appropriate backhaul connections (for example using ADSL). The cost and effort required to set up hot-spot RLAN provision is minimal in comparison with, say, installing a mobile base station. Equipment manufacturing is likely to be competitive. For example, there are already many suppliers of 802.11b RLAN equipment.

Below we attempt to quantify the welfare effects of the introduction of public access RLAN services. The approach we will take in assessing the welfare impact of these new services will be to estimate consumer surplus at observed prices and to ignore producer surplus. The potential problem with this approach is that if we base our consumer surplus calculations on observed prices that are higher than cost due to imperfect competition, we *underestimate* total welfare because we do not account for producer surplus (the difference between price and cost times the quantity supplied).

Public RLAN services are already operational in the US and Scandinavia. Public RLANs are typically located at public 'hotspot' areas, such as airport lounges, hotels and coffee shops and provide high-speed Internet access to their subscribers. Public RLANs are at present primarily aimed at serving business customers (much as early mobile telephony services). Indeed, a recent survey by Telia Mobile in Sweden confirmed that "*almost 90 per cent of corporate travellers would like to access e-mail from hotels, airports and other public areas*." [38]

There is good reason to expect there to be similar demand for these services in the UK. Internet access is currently available from UK airports and quality hotels. At both Heathrow and Gatwick, ISDN connections can be used in the business centres; airport hotels also have comparable services. Even though prices are relatively high (the charge for ISDN Internet access at both the Gatwick Business Centre and the Radisson Edwardian Hotel at Heathrow is £10 per half-hour), travelling business people use these services, confirming that there is demand in the UK for Internet access in such locations.

6.6.1 Relationship with mobile services and impact on existing users

At present it is very unclear whether public RLAN services are substitutes or complements to broadband mobile. At present, the development of RLAN services in Europe is driven mainly by telecoms operators. Telia Mobile introduced HomeRun to the Swedish market in 1999, a public wireless 802.11b LAN service, which has been introduced in airports, railway stations and hotels across Sweden. Telia has explained that it sees RLANs as complements to 3G [28]:

"*By means of franchising our public RLAN offer, ISPs can deliver high speed Internet access virtually anywhere, while a cellular operator can complement their data service offerings to 3G levels and beyond at a fraction of the time/cost associated with next generation deployment. Investing in a HomeRun license means additional revenues for the franchisers and a better service for the user; our goal is to make the HomeRun brand synonymous with mobile computing.*"

Sonera also offers a RLAN service, available both in public areas and as an extension of corporate intranets. In Austria, mobile operator ONE is rolling out public area RLANs in order to extend their planned UTMS service [29]. Other European mobile operators that are planning to develop RLAN services include Telenor and Telefonica. By and large, our industry interviews suggest that public RLANs are perceived as an extension of, and being complementary to, rather than substitutes for broadband mobile services, even though some uncertainty exists about a potential cross-over point. Nevertheless, there is a widely held view that public RLANs "*represent a huge opportunity to offer* *consumers the true mobile broadband experience which 3G appears unlikely to deliver*” [30].

However, mobile operators may also want to offer RLAN services for defensive reasons as these services may be a potential competitor to 3G – a substitute rather than a complement. Some evidence of this is suggested by purely fixed operators (such as BT) also planning to offer RLANs, presumably in limited competition to broadband mobile services.

Given this uncertainty about the interrelationship between RLANs and broadband mobile, we have not tried to take account of any knock-on effects of allowing public access RLANs on broadband mobile demand. At this point in time, it is impossible to know whether RLAN take-up would increase or decrease demand for broadband mobile.

Similar, we have not explicitly calculated any potential welfare loss arising from reduced QoS for short-range devices. Any such impact can be expected to be *de minimis* in the 2.4GHz and 5GHz bands. The only material usage of SRDs in these bands is telemetry and telecommand applications in the 2.4GHz band. However, these applications are primarily used in commercial and industrial contexts, for example for radio tagging in warehouses. Such commercial users should be able largely to control the radio environment in which their SRDs operate. Even at present it is possible for such users to install private RLAN systems that could in theory affect the operation SRDs. However, there is every incentive for these users to avoid such problems.

Allowing public access systems cannot be expected to affect this situation materially provided that there are restrictions on high power outdoor systems. First, industrial and commercial users of SRDs in the 2.4GHz band are likely to have an effective private radio management right, in the sense that any public access provider would require their permission for putting public access points into their premises. Clearly if regulations were to allow wide-area FWA type systems this could compromise this effective management right, but we do not recommend such a change. Second, our industry survey strongly suggests that the obvious target areas for roll-out of commercial public access services using unlicensed spectrum are mostly indoor facilities such as coffee shops, airports and other indoor public spaces where the usage of SRDs for commercial/industrial telemetry and telecommand is likely to be extremely limited.

6.6.2 Calculating consumer surplus

Our surplus estimates are based on the publicly available data on prices and/or subscriber numbers of existing public RLAN services offered by Jippi and Sonera (Finland), Telia (Sweden) and MobileStar (US).

MobileStar had access points in 500 Starbucks coffee shops around San Francisco, Seattle, New York and Texas, with plans to install a further 3,500, as well as American Airlines Admiral clubs and 19 different hotel chains. It describes itself as the leading broadband provider for travelling business people [39].

To obtain estimates of the possible consumer surplus generated by public RLANs in the UK we have to form a view about future demand. For simplicity, we assume that demand for public RLANs is linear. Clearly, as demand curves are generally assumed to be convex, consumer surplus is *underestimated* as a result of a linear approximation. This is illustrated in Figure 6.9 in case of the actual demand curve consumer surplus is the sum of area A and B. However, if we use the linear approximation that goes through the actual price-quantity point *(p*,q*)* the consumer surplus is reduced to area A.

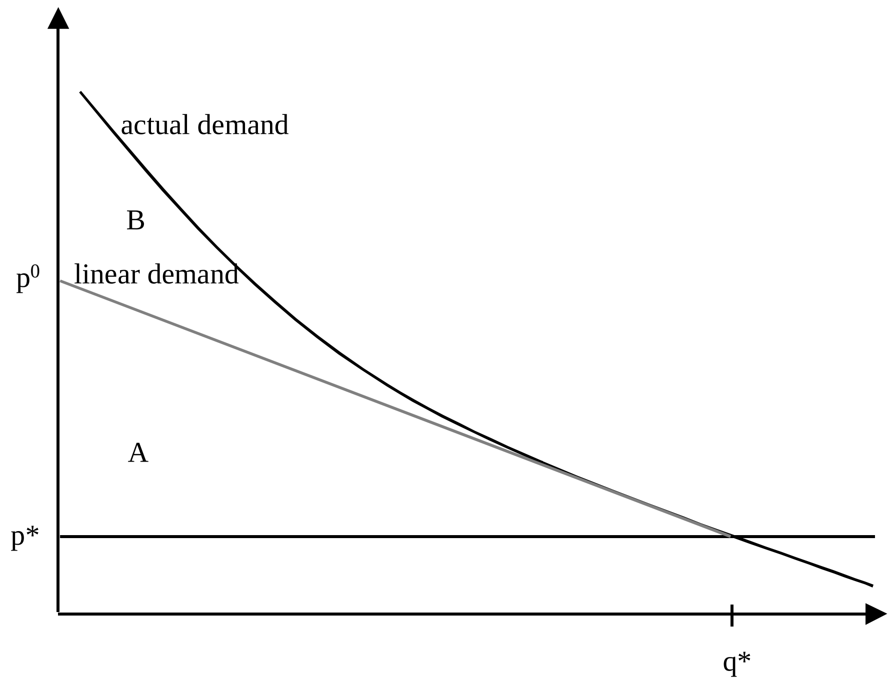

Figure 6.9: Linear vs. convex demand

In order to estimate area A we need information on the future (long-run) price (*p**), subscriber numbers (*q**) and the choke price (p^0), which is the highest price at which there is some positive demand for the service. Alternatively, information on the choke price can be substituted with information on the elasticity of demand at (*q*,p**) as this information would enable us to derive the choke price using the formula $p_0 = p*(1+1/e)$, where *e* is the elasticity of demand at price *p**.

We have obtained subscription charges for the services of Telia in Sweden [39], MobileStar [31] in the US and Jippi Freedom [32] in Finland (see below). These charges are for unlimited Internet access through nationwide RLAN systems.

Service	Monthly subscription
Telia HomeRun	£98.43
MobileStar	£41.12
Jippi Freedom	£31.49

Table 6.10: Public RLAN subscription charges

We assume that the long run price of public RLAN services is equal to the lowest of the observed prices, that is £31.49. At this price the service is likely to be commercially viable; we have no reason to believe that Jippi Freedom is making substantial losses at this price. Furthermore, growth in subscriber numbers will lead to scale economies in terms of billing, customer management and other central overheads.

The costs of rolling out a hot-spot RLAN service are generally modest. For example 802.11b access points for private networking are currently available at around £500 or less, which would be amortised over the effective life of the equipment. 802.11b LAN cards for PCs are currently priced at little more than £100. For a mobile or fixed operator, there will be substantial scale economies integrating billing with other services and so the incremental costs of these activities will be modest. Therefore, the main deployment cost is likely to be provision of backhaul links to connect up access points. Typical ‘coffee shop’ deployments of RLANs in the US have used ADSL to provide these backhaul links. At present in the UK, the wholesale price of BT’s IPStream S connection is £780 p.a. (excl. VAT) with a connection charge of £260 (excl. VAT). As a rough rule of thumb, these assumptions would imply that an RLAN service might be profitable at a price around £30 per month once the number of subscribers exceeded twice the number of access points. Unlike most other telecoms services, public RLANs do not require substantial sunk investments and it is feasible to deploy these services even if the target market is small.

Therefore, we consider that there are strong reasons to expect the long-run price of the service to be below the current Jippi Freedom price. This would imply that we are calculating an overall *lower bound* on consumer surplus. We have been able to obtain subscription numbers only for Jippi Freedom. Their customer base was approximately 3,000 subscribers in October 2001 [32]. However, this figure hardly provides any information about possible UK subscriber numbers as the service is currently at an early stage of take-up. Therefore, we have taken Gartner’s forecasts [34] of the number of notebooks with integrated 802.11b equipment shipped in the US in 2005. Assuming the same per capita equipment usage we have calculated user forecast in the UK, as shown in Table 6.11 below.

User type	Integrated notebook shipments in 2005, USA	Integrated notebook shipments in 2005, UK equivalent
Small and medium business	6,530,000	1,400,000
Large business	4,920,000	1,060,000
Education	739,000	159,000
Home	2,970,000	637,000
Total	15,200,000	3,250,000

Table 6.11: Forecasted notebook shipments, US and UK

We have assumed that only 50% (around 1,600,000 people) of the future users will subscribe to public RLAN services while the other 50% will use the equipment exclusively to access private systems. At this point, it is somewhat unclear what type of conditional access technology will become widespread for public access RLANs. On some systems it is currently possible to authenticate users using a SIM card, but PCs currently being shipped with integrated RLANs do not usually incorporate this solution. However, this may change if public access systems become widespread. Alternatively, service providers might adopt a software-based solution to conditional access in order to exploit the installed base of PCs with in-built RLAN capabilities.

At first sight our forecast of 1.6m subscribers might appear large compared with Jippi Freedom's current 3,000 subscribers. However, the *pattern* of take-up of public RLAN services is likely to be similar to that of mobile telephony, even if the long-run level of penetration is lower. In particular, early adopters are likely to be business customers with less intense users adopting later as prices fall.

A recent report by Analysys has forecast at least 20 million *public* WLAN users in Western Europe by 2006, with more than half of these in the UK, France, Germany and Sweden. This suggests a UK penetration of around 5 million. Therefore, we do not consider our working assumption of 1.6 million subscribers by 2005 to be particularly aggressive. Again, we are calculating a *lower bound* on consumer surplus.

Obtaining the choke price is a more difficult task. In the absence of any exploitable data we assume two different choke prices. The first choke price used is the most expensive observed price (£98.43). We also use an elasticity estimates for mobile calls to approximate the elasticity of demand and thus obtain a choke price estimate (assuming that the demand characteristics for public RLAN may be similar to those of mobile phone usage). In a previous project [35] we have estimated price elasticity for mobile originated calls to be equal to –0.62, a figure which falls within the usual range of estimated telephone demand elasticities in the literature [23]. An elasticity of –0.62 corresponds to a linear demand curve where the choke price is £82.28.

Given the information on prices and subscriber numbers we have calculated consumer surplus. Table 6.12 contains the corresponding estimates.

	Scenario 1	Scenario 2
Price (£)	31.49	31.49
Subscribers	1,600,000	1,600,000
Choke price (£)	98.43	82.28
Consumer surplus (£million/month)	53.55	40.63
Consumer surplus (£million/year)	642.62	487.59

Table 6.12: Consumer surplus estimates for public RLAN systems

Therefore, we expect the consumer surplus that results from the introduction of public RLAN services to be around £500 million per annum. (Note that the use of 2005 forecast data leads to our consumer surplus forecast relating to the year 2005.)

6.6.3 Cost of congestion and interference

Interference would raise the costs of providing the service and/or decrease demand for it. For example, if in Scenario 2 the cost and, assuming effective competition, therefore the price were to increase by 10%, the benefits from introducing public RLANs would be reduced to £429m per annum. This implies a welfare loss of £58.6m per annum due to interference compared with Scenario 2, but the overall net welfare gain is still very substantial and positive. In addition, one would have to assess the costs caused by interference to existing users.

However, there is no reason to believe that the introduction of public RLAN systems in addition to private systems, which can operate within the current regulatory framework, would result in additional congestion or interference. Assuming that the equipment used for the provision of public RLAN services would have to meet the same standards as private RLAN equipment, removing the public service restriction on unlicensed spectrum would only have an impact on interference and congestion to the extent that the take-up of such services pushes transmitter density to a level at which interference becomes a problem.

Both the technical analysis and the industry interviews suggest that this is not expected to be a problem in the affected frequency bands. We would not expect the introduction of public RLANs to increase transmitter density to a level at which interference becomes problematic (i.e. to a density that exceeds the density that might be achieved in hot-spots such as the City of London), not least because public RLAN providers have a strong incentive to adopt technologies and negotiate commercial arrangements that guarantee a certain minimum QoS. Therefore, is extremely unlikely that interference could ever raise costs or reduce service quality or adversely affect existing users to an extent where the deployment of public RLANs (in addition to private RLANs) would result in a net loss in economic welfare.

6.6.4 Other costs and benefits

For reasons of simplicity, certain costs and benefits have not been considered in the above analysis.

Firstly, we have overlooked the dynamic aspects of demand for a new product. We assume that demand is static, that is, the demand curve does not move over time. This may seem an unrealistic assumption, but it is standard practice in consumer welfare calculations. As a result, the estimate overstates benefits for early years of the take-up process.

Secondly, we have ignored any potential producer surplus – the welfare gain to operators should they be able to price the service above costs. This means that we are implicitly assuming a perfectly competitive market. This has two implications:

- If the price we use for Jippi Freedom indeed equals cost and in the UK operators will be able to price above cost, then the CS estimates are larger than actual CS figures will be. However, in this case CS would be partly substituted by PS and the deadweight loss is likely to be negligible. For example, if in Scenario 2 the cost is 31.49 and the operator has a 10% price-cost margin the CS is reduced to £429m per annum while the PS is £56.7m per annum thus resulting in a deadweight loss of £1.8m per annum.
- If the price we use for Jippi Freedom is higher than the actual cost (as competition is currently imperfect) and the UK operators will be able to set the same price then our CS estimation is correct. Moreover, total welfare is higher than the consumer surplus as there is also some producer surplus. This is in line with our approach of estimating a *lower bound* for the overall welfare impact.

Overall, however, the impact of changes in competitive conditions is likely to be small relative to the total welfare impact of public RLANs, and given the considerable uncertainty about future demand and prices should not affect our estimate.

As already discussed, we do not take account of any interaction with 3G services.

6.6.5 Conclusion

We can draw the following conclusions:

- Given reasonable take-up and pricing assumptions, allowing the introduction of RLANs generates a very substantial consumer surplus in the order of £500 million per annum
- The overall impact on economic welfare is likely to be of a similar order to this, regardless of whether market conditions are effectively competitive or not
- It is extremely unlike that interference costs could be sufficiently large to outweigh this scale of benefit.

Given the difficulty in quantifying these net benefits, we do not believe that it would be reasonable to try to allocate these to affected groups. However, the following table gives a qualitative assessment of the likely impacts.

Affected party	**Benefits**	**Costs**	**Net benefits**
End users	Use of newly introduced public services	Charge for public services Possible interference	Positive (corresponding to part of the total consumer surplus, which is in the order of £500m p.a.)
Public service providers	Increase in revenue as a result of accessing new spectrum and offering new services	Operating costs	Non-negative, but small if competition is effective
Public service customers	Use of newly introduced public services	Charge for public services	Positive (corresponding to part of the total consumer surplus, which is in the order of £500m p.a.)
Equipment manufacturers	Revenues from equipment to support new services	Operating costs	Non-negative, but small if competition is effective

Table 6.13: Welfare impact of the introduction of public RLAN

6.7 FWA and RLAN

Our analysis highlights an important distinction between new services that meet entirely new demands and those that simply substitute for existing services. As we have seen, there are strong reasons to expect the consumer surplus generated by the former to be much greater than that generated by the later. Where there may be a conflict between services, in the sense that available spectrum cannot accommodate all of them without congestion, it is economically efficient to allow the highest value services and prohibit lower value services. Often this will mean favouring innovative services over those that simply substitute for existing services that can be provided in other ways.

This general principle is relevant to the potential for using the 2.4GHz and 5GHz bands to offer FWA type systems. There are strong reasons to expect the benefits of offering RLANs to be greater than those of FWA systems as:

- FWA systems may simply substitute for services that could otherwise be provided over fixed infrastructure. Although it is certainly true that deployment of FWA services might increase competition, the welfare benefits are limited, not least as fixed services may in any case be price regulated if they are not effectively competitively supplied. In contrast, RLAN systems can satisfy a demand for mobile nomadic access that would otherwise be unmet
- There is a choice of bands available for FWA systems, not just the 2.4GHz and 5GHz bands.

The technical analysis suggests that co-frequency interference between RLAN and FWA could be a problem. To the extent that it is infeasible to operate both types of services within the same band, our analysis suggests giving preference to RLAN applications.

6.8 Light regulation

Overall there appears to be little reason for concern over future congestion and interference, and therefore little justification for restrictions above and beyond those that are currently in place with regard to the system characteristics of the equipment deployed in licence-exempt bands. Nevertheless, we briefly discuss the economic principles that should govern the design of a ‘light’ regulatory regime in which the current public access restriction is dropped, but alternative (and perhaps additional) restrictions on specific services may be introduced.

Where an economic charging mechanism is not viable or cost-effective, broad-brush rules may be used to limit access to the resource. These rules should aim to replicate as much as possible the efficient outcome that would result if economic charging were possible. In particular, these rules should:

- Provide appropriate incentives to minimise interference where it is easy to do so (e.g. by adopting polite technologies), especially where heterogeneous technologies use the same spectrum

- Encourage the development of new services that are most likely to be complementary to or independent from existing ones as these services are most likely to create large welfare benefits.

The current regime of banning public access systems appears not to meet these objectives as:

- Public services are not necessarily more likely to create interference problems than private services, in particular given that public service providers are likely to be very concerned about service quality
- Public services by and large create larger benefits than private services.

Indeed, the assessment above provides a very strong case for removing the current public service restriction on the use of licence-exempt spectrum. However, it does not address what (if any) restrictions on the use of licence-exempt spectrum should remain.

By definition the decision where the regulatory regime should draw the 'fault line' between services that can and cannot use licence-exempt spectrum cannot be based on a detailed assessment of the costs and benefits of each potential type of use; if this were possible, an economic charging mechanism could be implemented. However, it is possible to base such a decision on general conclusions with regard to the welfare impact of particular types of services, and on an understanding of how congestion and interference can be minimised without holding back the development of new services.

In particular, access restrictions should specify system characteristics that minimise interference (e.g. limiting power output or banning outdoor use) or maximise the opportunity for service providers of adopting polite technologies (e.g. making sure that the technologies deployed are sufficiently homogeneous within bands). Such system characteristic requirements are already in place and should remain.

We have above identified services that are least likely to generate net benefits. In particular services that are close substitutes for existing services using licensed spectrum could lead to an overall welfare loss by causing interference without providing a genuine innovation. Whilst it may be difficult to establish rules that discriminate against such services, it is important to examine what types of services would be discouraged by particular restrictions. For example, a ban on outdoor provision of public access services might not only help to minimise interference problems, but also discourage services that offer wide area coverage and are therefore most likely to be substitutes for cellular mobile services (current GSM/GPRS and even more so future 3G services).

However, for licence-exempt bands that are currently used extensively (especially for SRDs), economic consideration suggest that it may well be appropriate to continue the status quo of banning public services. This is because public service providers should not have an incentive to use spectrum that is already being used by a wide variety of different technologies *unless* they expect to be able to manage interference both due to and imposed on existing users. However, in such circumstances, new technologies is likely to have a strong asymmetric impacts, affecting but not being affected by existing technologies, and a blanket prohibition on public services using these bands might be the most appropriate solution. As such a solution would only affect technologies that are likely to have an asymmetric impact – otherwise there would be no incentive to use heavily used licence-exempt bands regardless of whether this would be permitted by the regulatory framework – it would act very much as a safeguard.

7. ANALYSIS AND CONCLUSIONS

7.1 Introduction

This section of the report presents a summary of the results of the Mason and DotEcon study on a band-by-band basis, drawing conclusions for each frequency band under consideration. Following this, we draw overall conclusions on the optimal design of regulatory policy for future management of licence-exempt spectrum.

7.2 SRD spectrum (433 MHz, 868 MHz, 173 MHz, 458 MHz, 2.4 GHz, 5.8 GHz)

As indicated earlier in this report, the spectrum used for SRD applications is predominantly designated on a pan-European basis (433 MHz, 868 MHz, 2.4 GHz, 5.8 GHz), with the exception of 173 MHz and 458 MHz, which are 'UK only' bands.

Considering the deregulated nature of short range devices (meaning that there is no way of knowing where SRD installations are being introduced), the SRD community considers a pan-European approach to the regulation and use of SRD applications is particularly important, in view of the circulation of devices around Europe and overseas products being sold in the UK. This approach is already being implemented through the development of ERC Decisions on designation of spectrum and free circulation of devices within Europe.

In terms of the licensing framework, the SRD community responding to this study considered that there might be some negative impact on the installed SRD base arising from a change in regulation governing use of licence-exempt spectrum in the UK. This was primarily due to the uncertainty created by a change in regulation (for instance, whether the regulatory change would lead to increased interference in the spectrum used by SRD applications), and also the threat that removing the public prohibition on use of licence-exempt spectrum might encourage the introduction of public systems operating at higher power and radiating over a wide outdoor area, hence affecting existing SRD installations over a large operating area.

As described in Figure 4.1 of this report, however, the majority of service providers who responded to this study considered that the most attractive commercial opportunity lay in providing public access services in hot spots rather than over a wider area. Hot spot provision of services would imply that public systems such as 2.4 GHz public access RLANs would operate under the same technical conditions as current private RLANs. Assuming this to be the case (i.e. same EIRP limit, transmit power control etc), then the conclusion can be drawn that the potential for congestion to occur in a particular band is not directly related to the question of whether public systems are allowed to operate, but rather is related to the density of devices operating in a given area, irrespective of whether they are public or private. The extent to which these devices will interfere is directly related to the technical conditions under which they are allowed to operate and hence, in setting appropriate regulatory limits on radiated power and other relevant system co-existence parameters, the probability of interference can be minimised.

From the responses to the industry survey, there was little evidence to support that a change in regulation would result in SRD applications being used for the provision of new ‘commercial’ services or create significant new service opportunities, although there is some suggestion that certain applications could be exploited on a commercial basis, for example networked telemetry to provide third party security or asset tracking systems. The exception to this is in the use of 2.4 GHz and 5 GHz RLANs and Bluetooth, where commercial opportunities are considered to exist. These applications are therefore addressed in more detail in the following sections of the analysis.

7.3 The 2.4 GHz band

The 2.4 GHz band is currently used for a range of applications on a licence-exempt basis, including SRDs, RLANs and Bluetooth. Other applications also currently use the band on a licensed basis (e.g. fixed wireless access and outside broadcast links).

A number of previous technical studies have indicated that there may be potential for congestion to occur in the 2.4 GHz band in high-density areas, due to the number of different applications using the band. Other studies have highlighted a particular co-existence issue in the 2.4 GHz band being that of RLANs and Bluetooth operating in close vicinity.

It is noted, however, that some of the earlier assumptions on the growth in use of the 2.4 GHz band for some applications (e.g. for fixed wireless access) have proved to be unfounded (e.g. with the main 2.4 GHz service provider, Atlantic Telecom, currently in receivership) [41]. This should therefore allay some of the earlier congestion concerns, which largely surround interference to/from licensed FWA systems.

In considering the other co-existence issues, it can be noted that RLAN-RLAN interference is to a large extent controlled by the equipment itself, since devices are designed to co-exist with other devices in the same area. Addressing the particular issue of RLAN-Bluetooth co-existence, it is noted from the industry responses to this study that most Bluetooth manufacturers also produce 2.4 GHz RLANs and, therefore, it is in their commercial interest to overcome any potential interference issues. Analysis of this in section 5 shows that the RLAN-Bluetooth interference potential is relatively limited anyway.

An important point to note from the responses to this study was that a number of other countries outside of the UK are already allowing commercial use of the 2.4 GHz band (e.g. Scandinavia and the USA), which is already driving a market for business travellers carrying 2.4 GHz RLAN cards. There is therefore a risk of the UK being at a competitive disadvantage compared to these other countries if this commercial opportunity is further delayed.

It was also noted that in countries where public access RLANs at 2.4 GHz are already allowed (e.g. USA, Finland, Sweden), there appear to be no reported problems of congestion occurring (this is despite indications that, in the USA at least, competing RLAN providers are offering services in the same public ‘hot spots’ in some instances (e.g. MobileStar and Wayport). Operating experience also demonstrates that various technical solutions exist to overcome RLAN QoS issues in hot spots, (e.g. deploying more access points, adaptive antennas, access point location).

All operators/service providers who were interviewed for this study indicated that the commercial opportunities offered for proving public access RLAN services in the 2.4 GHz band would be potentially attractive, if regulation were to be changed. The level of interest varied from those who saw it as a major commercial opportunity to those who saw it as a mixed opportunity (some user benefit but costs incurred in supporting and maintaining the service).

In terms of consumer benefit, the economic analysis suggests that a lower bound on the consumer surplus associated with the introduction of public RLAN services is in the range of £500 million per annum. Given that we expect the supply of such services as well as the supply of equipment required by service providers to be reasonably competitive, this consumer surplus figures consumer benefits also reflect the economy-wide benefits from eliminating the public access restriction on the use of licence-exempt spectrum.

It is therefore considered that a change in regulation to remove the restriction on public access RLANs in the 2.4 GHz band should be a priority for the RA to address.

7.4 The 5 GHz band (5150 – 5350 MHz, 5470 – 5725 MHz, 5725 – 5875 MHz)

The 5 GHz band is potentially divided into three 'sub bands', which are commonly referred to by industry as bands A, B and C, in line with the work of the 5 GHz advisory group (5GAG). The 5GAG recommended that use of the three sub-bands should be as shown in Table 7.1.

Band Abbreviation	**Frequency (MHz)**	**Use**
A	5150 - 5350	RLAN Indoor systems Max EIRP 200mW
B	5470 - 5725	RLAN Outdoor and indoor systems Max EIRP 1W Possible FWA applications, depending on sharing studies
C	5725 - 5875 (ISM band)	Short range devices Currently max EIRP 25mW It is recommended that consideration is given to raising the EIRP in Band C for outdoor devices installed on permanent structures to 2 Watts and possibly 4 Watts (following co-existence studies with other services)

Table 7.1: UK 5 GHz advisory group: Recommendations on use of the 5 GHz band

The results of the technical analysis for this study indicate that, for co-existence of 'like' technologies (e.g. RLAN-RLAN), the probability of interference remains acceptable unless a very high density of indoor RLANs, or a lesser density of outdoor RLANs, is assumed. This indoor density is unlikely to be reached in practice, however, even in highly populated urban areas such as the City of London (where, in any case, the deployment of private RLANs is more likely to be the main driver of transmitter density). Thus, the *additional* deployment of RLANs for public access services is unlikely to have a significant impact on the expected level of congestion and interference.

For co-existence between RLAN and FWA, there is a higher likelihood of interference occurring, depending on the scenario and the technical conditions. The analysis indicates that operation of mesh FWA systems is feasible as long as coverage is limited to rural and suburban areas. Further studies on the compatibility between FWA and services other than RLAN in specific bands are needed before concluding on whether to permit mesh FWA in bands at 5 GHz.

From the industry responses to this study, it is apparent that reaping economies of scale in 5 GHz RLANs is still some way off. The USA is leading the market in 5 GHz products with one manufacturer having recently announced launch of 802.11a products. Other manufacturers are expected to follow with 802.11a products over the coming year. The timing of HiperLAN product launch appears to be somewhat less certain, with indications being that this will be a little way behind 802.11a. The ongoing harmonisation efforts between HiperLAN and 802.11a were noted along with discussions surrounding access to spectrum (notably in relation to the agenda item for the upcoming World Radio Conference (WRC2003) on global identification of spectrum for RLANs. It is assumed that these ongoing initiatives will lead to increasing levels of harmonisation between the different regional solutions solutions, to achieve global economies of scale.

Although it appears likely that 802.11a products will become more widely available in 2002, it likely that these will remain 'premium priced' products compared to 2.4 GHz RLANs, at least until 2004/2005. It is for this reason that the majority of operators/service providers who responded to this survey tended to suggest that, depending on regulation, they would be more likely to be interested in launching public RLAN services at 2.4 GHz initially, rather than 5 GHz, since products were already widely available.

In view of the overlap between the commercial opportunities at 2.4 GHz and 5 GHz, it can be concluded that regulatory changes to enable public access services in these bands should ideally be taken forward in tandem. In regards to timing, however, it is noted that there are some technical issues to solve concerning use of the 5 GHz band (e.g. in current differences between the European and USA standards, and precise use of the spectrum bands A, B and C). This would imply that a further consultation on these technical issues might be required. At 2.4 GHz, since products are already available and in use, the main issue to address is the public/private distinction and whether this should be removed.

The results of this study suggest that there would be advantages to the UK in removing the public/private distinction for both the 2.4 GHz and 5 GHz bands for devices currently covered by the existing exemption regulations. Systems with other characteristics, such as mesh FWA, may need to continue to be individually licensed. The study also suggests that there might be risks to the UK in not taking this step (e.g. in loss of commercial opportunities compared to other countries where 2.4 GHz public access RLANs are already being offered to the public).

7.5 3G ‘TDD’ (2010 –2025 MHz)

The main issue affecting determination of an appropriate regulatory regime for the 3G TDD spectrum at 2010 – 2025 MHz is lack of certainty surrounding completion of technical specifications, and subsequent equipment availability. It appears that this is still some way off. Initial 3G launch is expected to be in the FDD portion of the 3G licensed spectrum.

For this reason, there appears to be some concern with industry that regulatory decisions on use of the 2010 – 2025 MHz portion of the 3G spectrum should be delayed until market developments are clearer.

However, the considerations raised by this study would indicate that, in general, moves towards more liberalised access to licence-exempt spectrum will bring benefits to the UK and therefore it would appear that, in time, access to the 2010 – 2025 MHz spectrum could be enabled for both public and private systems, operating under the same technical conditions to guarantee co-existence.

In view of the ongoing developments in the 3G specifications, it would appear that a further technical consultation on the 2010 – 2025 MHz portion of the 3G spectrum will be required in due course in order to confirm appropriate technical conditions for its use.

7.6 DECT (1880 – 1900 MHz)

It is noted that commercial use of the DECT spectrum has been allowed for a number of years under the TAct ‘Cordless Class Licence’ and the WTAct ‘Public Access Cordless Licence’. Take-up of this has been difficult to predict.

Overall, the results of the industry survey for this study indicate that there is not a strong commercial interest in providing DECT public access cordless systems. However, if such systems were to be introduced, the main regulatory consideration lie in setting appropriate technical conditions to ensure co-existence between all DECT applications using the 1880 – 1900 MHz spectrum. Since this spectrum is designated on an exclusive basis to DECT, the co-existence with other systems or services can be discounted, other than compatibility with adjacent services.

The ETSI DECT specifications already comprehensively set the characteristics of the DECT radio interface to allow it to co-exist with other DECT devices and to enable interoperability (between equipment of different manufacturers). This is demonstrated in the technical analysis of section 5. It could therefore be concluded that the technical regulations governing use of the DECT spectrum should be in accordance with the existing specifications, as is the current case with the PACT licence.

If the UK regulatory regime for other licence-exempt spectrum is changed to enable public access provision, effectively removing the public/private distinction in these bands, it is assumed that regulatory regime for use of the DECT spectrum could be aligned with this without hindering the existing DECT user base. This is on the assumption that the technical conditions for use of the DECT spectrum align with the existing DECT specifications.

7.7 Conclusions

On the basis of this study, the following conclusions can be drawn:

1. The results of the industry survey indicate that commercial interest does exist in using the 2.4 GHz band for public access RLAN's in hot spot areas. Most respondents supported that the RA should remove the public/private distinction for the 2.4 GHz band for devices currently covered by the existing exemption regulations as soon as practical (at the same time or sooner than 5 GHz).

2. Commercial interest in offering public access RLAN's in hot spots is currently more focussed towards the 2.4 GHz band since equipment is widely available for this band. Commercial 5 GHz systems may still be a little way off, implying that, in regulatory terms, it would not make sense for the RA to remove the public/private distinction for the 5 GHz band before doing it for the 2.4 GHz band (since the interest in providing public access systems is currently focussed on the latter). The higher performance characteristics of 5 GHz devices would tend to imply that there will be some migration to these devices from 2.4 GHz, once economies of scale are reached.

3. In countries where public access RLAN's at 2.4 GHz are already in operation, for example, USA and Scandinavia, there appear to be no reported problems of widespread interference occurring or poor Quality of Service being an issue (despite indications that, in the USA at least, competing RLAN providers are offering services in the same public 'hot spots' in some instances.

4. Operators who are already providing public access RLANs have experience in managing QoS and there are a number of ways that this can be achieved. On a commercial level, there is the potential to reach an exclusive operating arrangement with the relevant site owner (e.g. airport lounge owner or coffee shop), or, if more than one operator covers the same area, there is scope for co-operation between operators in the location of access points, for instance, to ensure effective co-existence. On a technical level, the location of access points, installing additional access points or certain antenna solutions can all be used to improve QoS to the customer.

5. 2.4 GHz radio LAN cards are now widely available and business travellers are starting to use them. This implies that the UK may be disadvantaged if

regulation is not changed (since travellers would not be able to roam onto public RLANs whilst in the UK).

6. Providing users with roaming between radio LANs of different providers is technically possible but needs commercial agreements to be put in place. This is already being discussed within industry bodies (e.g. the GSM Association).

7. Since most public ‘hot spots’ are largely indoors, this reduces the potential for interference, since building penetration loss provides additional isolation. By far the majority of those responding to the industry survey for this study confirmed that their commercial interest was in the provision of ‘tetherless’ data systems in selected locations rather than providing larger areas of contiguous coverage.

8. Earlier indications of the growth in use of the 2.4 GHz band for certain applications (i.e. FWA) have proved optimistic. This is likely to reduce the earlier concerns over congestion occurring in the 2.4 GHz band. However if wider spread FWA use was to re-emerge in future then this may increase congestion concerns.

9. Most manufacturers in the Bluetooth market are also active in designing RLANs – hence it is in their interests to solve any compatibility problems without the need for regulation.

10. The technical analysis conducted for this study indicates that interference/congestion would only occur if a very high density of RLAN use were reached. It is considered that these densities are unlikely to occur in practice. In any event, the cause of congestion if it occurred would be due to the density of RLAN usage and not directly related to the public/private question (since it is not envisaged that the introduction of public RLANs would drive demand to such an extent that the very high densities assumed in the modelling would be reached). Interference between ‘like’ technologies is managed by the equipment itself, since RLANs (both 802.11a and HiperLAN) are designed to co-exist with other like devices in the same area.

11. The results of the technical modelling indicate a higher probability of interference occurring between mesh FWA systems (using higher EIRPs) and RLANs sharing the same spectrum. The operation of FWA systems could be regulated by the RA depending on the nature of the technical conditions set for use of the 5 GHz band (e.g. the Interface Regulations could set a low EIRP limit, or prohibit use of highly elevated antennas for instance). However, it may be difficult to control FWA deployment to rural and suburban environments via this route. It is also possible that the RA could adopt the same model for FWA at 5 GHz as was adopted at 2.4 GHz, in that this type of service is considered to remain out with the general Licence-exemption and can only be provided under individual operating licences by which the RA can control their geographic distribution. The results of the technical analysis suggest that, ideally, technical regulations for the 2.4 GHz and 5 GHz bands should be set to encourage ‘homogenous’ use of the spectrum (i.e. setting the same technical restrictions for

all systems using the spectrum, public or private) since this will encourage even distribution of systems across the available bandwidth.

12. In terms of the relationship between FWA services in dedicated spectrum (e.g. 3 GHz, 10 GHz, 28 GHz) and services that could be provided in licence-exempt bands using 5 GHz mesh FWA technology, the exact relationship and service crossover will depend to a large extent on individual FWA business plans. Services using dedicated FWA spectrum are provided under individual operating licences and hence the operators benefit from an ‘exclusive’ assignment of spectrum which they can plan in order to optimise network capacity and minimise in-band interference. Since the technical modelling in this study has indicated that there is a higher probability of interference between mesh FWA systems (using higher EIRPs) and RLANs sharing the 5 GHz band, this would tend to imply that the RA should continue to regulate the licensing of FWA (i.e. that this type of service is not covered by the general Exemption Regulations). To the extent that RLAN and FWA services in the 5GHz band may conflict, RLAN services should have greater priority.

13. Overall, the industry survey for this study indicated that respondents believed that regulation on use of licence-exempt spectrum should be limited to technical conditions to allow systems to co-exist. This will continue to encourage innovation whilst also creating the potential for new public access services to cater for tetherless data access for nomadic users.

14. The economic analysis suggests that the consumer surplus associated with the introduction of public RLAN services is in the range of £500 million per annum. Given that we expect the supply of such services as well as the supply of equipment required by service providers to be reasonably competitive, this consumer surplus figures consumer benefits also reflect the economy-wide benefits from eliminating the public access restriction on the use of licence-exempt spectrum. Even though it is impossible to break down the quantification by affected group, Table 7.2 provides a qualitative assessment.

Affected party	Benefits	Costs	Net benefits
End users	Use of newly introduced public services	Charge for public services Possible interference	Positive (corresponding to part of the total consumer surplus, which is in the order of £500m p.a.)
Public service providers	Increase in revenue as a result of accessing new spectrum and offering new services	Operating costs	Non-negative, but small if competition is effective
Public service customers	Use of newly introduced public services	Charge for public services	Positive (corresponding to part of the total consumer surplus, which is in the order of £500m p.a.)
Equipment manufacturers	Revenues from equipment to support new services	Operating costs	Non-negative, but small if competition is effective

Table 7.2: Welfare impact of the introduction of public RLAN

15. Even though this figure overstates the consumer benefits from public RLAN figures for the early years of the take-up process, it might be regarded as an indication of the cost of delay in opening licence-exempt spectrum for public access services. In particular, given the developments in the 2.4 GHz band in other countries, there could be immediate benefits from removing the public access prohibition.

16. In order to maximise the gains from the introduction of new services, access restrictions should focus foremost on measures that help to minimise the potential for interference. This is not only important for existing users but also for prospective users as *expected interference* can be a strong disincentive to investment and innovation. This suggests that access restrictions should continue to be based on system characteristics.

17. There is no reason to expect that public access systems would cause a significant increase in the probability of interference relative to a continuation of the status quo. Whilst interference problems can arise with extremely high transmitter densities, such a situation is unlikely to emerge even in hot spots such as the City of London (where, in any case, it would more likely be private RLANs than a considerable deployment of public RLANs that are responsible for a high transmitter density).

8. RECOMMENDATIONS

Based on the conclusions of this study, the following recommendations can be make, as an input to the RA's policy determination in this area.

1. From the industry response to this study, there appears to be an immediate need for action in the 2.4 GHz and the 5 GHz bands to remove the public/private distinction for devices currently covered by the existing exemption regulations.

2. The timing of action in relation to the 3G TDD spectrum from 2010 – 2025 MHz is less certain until equipment specifications are confirmed.

3. The results of this study suggest there is no reason to discriminate between public and private systems in licence-exempt spectrum – assuming both conform to the same characteristics in order to ensure sufficient homogeneity of technology.

4. It would appear that there are some technical issues, which need to be solved concerning access for mesh FWA to the 5 GHz spectrum and so a further technical consultation in this area may be required.

5. In managing interference, the licence-exempt nature of bands such as 2.4 GHz has fostered innovation in technology development and the development of advanced radio technologies able to co-exist effectively with other like devices in the same area. There are a number of commercial incentives in avoiding interference in such an environment:

   - Co-ordination of Bluetooth and RLAN equipment because most manufacturers produce both
   - If system characteristics are the same, a public RLAN provider is likely to require an agreement with the property owner in whose property the service will be provided. This ensures co-ordination and avoids externalities that might otherwise lead to interference.

APPENDIX A

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APPENDIX B

GLOSSARY OF TERMS

3G	Third Generation
AP	Access Point
BS	Base Station
CEPT	European Postal and Telecommunications Conference
CS	Consumer Surplus
CS	Consumer Station
CTM	Cordless Telephony Mobility
DECT	Digital Enhanced Cordless Telecommunications
DFS	Dynamic Frequency Selection
DSSS	Direct Sequence Spread Spectrum
DTI	Department of Trade and Industry
EESS	Earth Exploration Satellite Service
EIRP	Effective Isotropic Radiated Power
ERC	European Radiocommunications Committee
ERO	European Radiocommunications Office
ETSI	European Telecommunications Standards Institute
FHSS	Frequency Hopping Spread Spectrum
FS	Fixed Service
FSPL	Free Space Path Loss
FSS	Fixed Satellite Service
FWA	Fixed Wireless Access
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communications
HiperLAN	High Performance Local Area Network
IR	Interface Regulation
ISDN	Integrated Services Digital Network
ISM	Industrial, Scientific and Medical
ISP	Internet Service Provider
ITU	International Telecommunications Union
LAN	Local Area Network
MAN	Metropolitan Area Network
MC	Monte Carlo
MCL	Minimum Coupling Loss
MNO	Mobile Network Operator
MSS	Mobile Satellite Service
MT	Mobile Terminal
OBTV	Outside Broadcast Television
PACT	Public Access Cordless Telecommunications
PAPR	Peak to Average Power Ratio
PBX	Private Branch Exchange
PC	Personal Computer
PDA	Personal Digital Assistant
PMR	Private Mobile Radio
PS	Producer Surplus
QoS	Quality of Service
RA	Radiocommunications Agency

RFA	Radio Fixed Access
RFID	Radio Frequency Identification
RLAN	Radio Local Area Network
SEAMCAT	Spectrum Engineering Advanced Monte Carlo Analysis Tool
SI	Statutory Instrument
SIM	Subscriber Identity Module
SRD	Short Range Device
TDD	Time Division Duplex
Tx	Transmitter
UK	United Kingdom
UMTS	Universal Mobile Telecommunications System
USA	United States of America
UTRA	UMTS Terrestrial Radio Access
WEP	Wired Equivalency Protocol
WLL	Wireless Local Loop
WT	Wireless Telegraphy

APPENDIX C

TECHNICAL ANALYSIS ASSUMPTIONS

5 GHz RLAN Assumptions

The various RLAN standards around the world (ETSI, IEEE, ARIB) are undergoing some convergence and it is expected that, following this, the main technical characteristics will be very similar. The following characteristics for HiperLAN2 are taken from ETSI TS 101 475 v1.1.1 and are those used for a general 5 GHz RLAN during the analysis.

Parameter	Value	Note
Maximum EIRP	30 dBm or 23 dBm	Depending on regulatory requirements
Transmission Bandwidth	20 MHz	
Operational Frequencies	8 carriers centred on 5,180 MHz and above 11 carriers centred on 5,500 MHz and above	Carriers are spaced at 20 MHz intervals
Power Control	3 dB step size Max received power: -30 dBm	
Receiver Sensitivity	Between -85 dBm and -68 dBm	Depending on bit rate (these values correspond to 54 Mbit/s and 6 Mbit/s)

Table C.1: RLAN technical characteristics

Other key assumptions made for the technical analysis are shown in Table C.2.

Parameter	Value/Assumption	Note
C/I	20dB	
AP/MT location	Indoor	Unless specified otherwise
Wanted Coverage	Indoor: 40m Outdoor: 200m	
MT activity	5%	
Antenna	0 dBi omnidirectional	Unless specified otherwise
Out of band/spurious emissions	Not considered	In-band interference is assumed to be dominant

Table C.2: RLAN interference analysis assumptions

5 GHz Mesh FWA System Assumptions

The following characteristics for FWA Mesh systems are taken from a draft version of IEEE 802.16, Standard Air Interface for Fixed Broadband Access Systems, Media Access Control Modifications and Additional Physical Layer for 2-11 GHz.

Parameter	Value	Note
Maximum EIRP	36 dBm	
Transmission Bandwidth	20 MHz	
Operational Frequencies	5470 – 5875 MHz	Carriers are spaced at 20 MHz intervals
Receiver Sensitivity	-75 dBm	Similar to RLAN

Table C.3: Mesh FWA system technical characteristics

Other key assumptions made for the technical analysis are shown in Table C.4.

Parameter	Value/Assumption	Note
C/I	20dB	Same as RLAN
Wanted Coverage	1 km	Unless specified otherwise
Antenna	BS & CS: omnidirectional	Unless specified otherwise
Out of band/spurious emissions	Not considered	In-band interference is assumed to be dominant

Table C.4: Mesh FWA interference analysis assumptions

APPENDIX D

LICENCE-EXEMPT BANDS IN THE UK

Licence-exempt Bands For Consideration

Analogue Cordless Telephone	CT1	1642 - 1782 kHz (b) 47.45625 - 47.54375 MHz (m)
Digital Cellular Telephones	UMTS Licence-exempt	2010 – 2025 MHz
Digital Cordless Telephones	DECT	1880 - 1900 MHz
HIPERLANs	5 GHz	5.150-5.350 GHz, 5.470-5.725 GHz and 5.725-5.875 GHz.
PMR 446	PMR 446	446.00625 - 446.09375 MHz
RLANs	2400 MHz	2400 to 2487.5 MHz
Short Range Device Bands	SRDs	See attached Table

Frequency Bands used by Short Range Devices

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
9 to 180 and 240 to 315 kHz	RFID Anti-theft alarms Inductive communications (e.g. hearing aid loops) Metal detectors	Radionavigation Fixed Maritime Mobile Broadcasting	Inductive applications only Band is heavily used by established licensed services Unsuitable for short range wideband wireless applications. ETSI Standard EN 300 330, CEPT/ERC Rec 70-03 UK Interface Requirement 2030
300 to 2000 kHz	Medical Applications	Radionavigation Maritime Mobile Broadcasting Fixed Land Mobile Radiolocation Amateur	Inductive medical applications only Band is heavily used by established licensed services Unsuitable for short range wideband wireless applications. ETSI Standard EN 300 330, UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
2 to 30 MHz	RFID Anti-theft alarms Railway applications Medical Applications General Telemetry & Telecommand (T&T) Model Control	Radionavigation Maritime Mobile Broadcasting Radio Amateurs Land Mobile Met-Aids Fixed	Below 27MHz, inductive applications only. Band is heavily used by established licensed services including broadcasting. Unsuitable for short range wideband wireless applications. ETSI Standard EN 300 330, or EN 300 220 CEPT/ERC Rec 70-03 UK Interface Requirement 2030 **NOTE:** Frequencies up to 26 MHz may increasingly be used by third party provided line based telecommunications services (e.g. DSL & PLT) and subject to ongoing studies.
34.9 to 35 MHz 35.3 to 35.5 MHz	Social alarms Databouys Model control	Radiolocation Space research	Shared with MoD and civil radar systems EN 300 220 UK Interface Requirement 2030
40.66 to 40.7 MHz	General purpose telemetry & telecommand. Model Control	Mobile	Shared with MoD Unsuitable for short range wideband wireless applications. EN 300 220 CEPT/ERC Rec 70-03 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
49.82 to 49.98 MHz	General purpose SRDs	Mobile	Use as one of the main consumer bands. Typical applications include domestic baby monitors, remote control for toys, cheap walkie-talkies, etc. EN 300 220 UK Interface Requirement 2030
161.275 MHz	Marine alarms	Maritime Mobile	SRD application limited to marine applications EN 300 220 UK Interface Requirement 2030
173.1875 MHz 173.2 to 173.35 MHz 173.5875 to 173.6 MHz 173.7 to 174 MHz 173.35 to 175.1 MHz	Lone worker alarms General purpose telemetry & telecommand. Industrial telemetry & telecommand Fixed alarms General purpose telemetry & telecommand plus voice Medical & biological Radio microphones Hearing aids	Mobile	Some sharing with HO/SO for the Emergency Services Up to 10 mW erp, 12.5/25 kHz channels Wide band permitted between 173.2375 and 173.35 kHz. EN 300 220 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
402 to 405 MHz	Medical T&T	Met-aids Space operation Fixed Mobile	Band used for radio sondes. Medical applications limited to very low power implants. EN 300 220 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
417.9 to 418.1 MHz	General telemetry & telecommand	Mobile Fixed services Radio Amateurs	History of interference problems between SRDs and licensed services. The SRD band is likely to be withdrawn if TETRA services. EN 300 220 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
433.05 to 434.79 MHz	General purpose telemetry & telecommand Model control telemetry	Fixed Mobile Amateur	History of interference problems between SRDs and licensed services. Not suitable for applications requiring high duty cycle. For wideband applications a maximum of 10% DC is imposed. The ERO/MG and SE PT 24 are looking at the feasibility of introducing 100% narrow band channels at the band edges. Primary services transmit high powers compared with SRDs. EN 300 220 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
458.5 to 458.95 MHz 458.96 to 459.1 MHz 458.5 to 459.5 MHz	Industrial/Commercial telemetry & telecommand Social Alarms General purpose alarms Lone worker alarms Fixed alarms Medical T&T Model control	Fixed services Mobile Paging	458.5 to 458.95 MHz is the main band in the UK for narrow band T&T EN 300 220 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
862 to 870 MHz	Cordless Audio Devices Radio Microphones General purpose telemetry & telecommand Social Alarms General purpose alarms	Fixed services Mobile	FM PT 37 recommended this band for SRD applications and also the phasing out of CT technologies in this band, including CT 2 (864 to 868 MHz). SE24 currently studying compatibility issues concerned with FHSS technology in 862 to 870 MHz band. It is unlikely that SRDs will be allowed below 863 MHz. A FHSS tracking system has been licensed in the band EN 300 220 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
1389 to 1399 MHz	CCTV Domestic Videosenders	Fixed Mobile	Radioastronomy services have to be protected. Only CCTV allowed. EN 300 440 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
2400 to 2483.5 MHz	CCTV Domestic Videosenders Movement detection & alert. Railway applications Automatic Vehicle Identification Short range indoor data links General telemetry & telecommand RLANS	ENG/OB Fixed services Mobile	This band is heavily used by services, which are after global harmonisation. The SRD/RFID Industry use this band for tagging/logistic purposes, to keep track of items on a global basis, such as shipping containers, airline baggage, etc. The wholesale industry are looking for 4 Watt systems in order to trace produce from the grower/manufacturer all the way through the distribution chain to the retail outlet. The higher power is required because passive tags are required and read/write ranges up to about 2 metres. EN 300 440, EN 300 761, ETS 300 328 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
5725 to 5850 MHz	Road transport & traffic telematics General purpose telemetry & telecommand Short range indoor data links. Movement detectors CCTV	Radiolocation Radio Amateurs Mobile Fixed satellite	There are some trial systems for Road Toll applications. Government has to decide on whether to implement the road charging system in the UK. There are some private schemes. If road tolling is implemented then other applications will either need to avoid the band 5805 to 5815 MHz or will need to be planned to avoid interference. EN 300 440 CEPT/ERC Rec 70-03 ERC/DEC/(92)02 UK Interface Requirement 2030

Frequency Range	Typical Licence-exempt SRD Applications	Shared with licensed services	Comments
10.577 to 10.597 GHz	Short range indoor data links Movement detection (e.g. traffic light sensors)	Fixed Mobile	EN 300 440 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
10.675 to 10.699 GHz	Short range indoor data links Movement detection	Earth exploration satellite Radioastronomy Space research	SRD use restricted to indoor use only EN 300 440 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
13.5 to 14 GHz	Movement detection	Radiolocation Radionavigation Space research	Government use. SRD use for movement detection agreed only EN 300 440 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
24.15 to 24.25 GHz 24.25 to 24.35 GHz	Movement detection (e.g. traffic light sensors) Speedmeters Radar level gauges	Radiolocation Radio amateurs Fixed services Law enforcement speedmeters	Civil use has to avoid the band below 24.15 GHz. EN 300 440 CEPT/ERC Rec 70-03 UK Interface Requirement 2030
63 to 64 GHz 76 to 77 GHz	Road transport & traffic telematics	Fixed services Radiolocation	Vehicle to road side and vehicle to vehicle communications Vehicle radar or traffic monitoring. EN 300 674, 301 091 CEPT/ERC Rec 70-03 ERC/DEC/(92)02 UK Interface Requirement 2030
60 to 63 GHz 122 to 123 GHz 244 to 246 GHz	General purpose devices		Future development