The Role of Licence-Exemption in Spectrum Reform

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Spectrum policy: what next?

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- WRC-07: the Technological and Market Pressures for Flexible Spectrum Access
- Regulatory and Policy Implications of Emerging Technologies to Spectrum Management
- Spectrum Allocation, Spectrum Commons and Public Goods: the Role of the Market
- The Role of Licence-Exemption in Spectrum Reform
- Emerging Technologies and Access to Spectrum Resources: The Case of Short-Range Systems

Interviews with

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The Role of Licence-Exemption in Spectrum Reform(*)

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Abstract: Spectrum reform initiatives in the US and Europe have identified a need to move away from the traditional "command and control" approach towards flexible and tradable licences and licence-exemption. Current regulatory initiatives are tending to focus on the flexible licensing route, and there is a risk that licence-exemption will be sidelined during the important formative years of this major policy transition. This must not happen; licence-exemption supports innovation and entrepreneurship and is an important second leg of a market-based spectrum management regime. A current case in point is the transition in UHF frequency bands from analogue to digital TV, where licence exempt use of resulting gaps in the spectrum could yield enormous benefits for citizens and consumers.

Key words: spectrum policy, spectrum management, wireless services, deregulation, digital dividend.

There is a growing global consensus that the traditional method of allocating spectrum is outdated and inefficient. In the United States, the FCC's Spectrum Policy Task Force (FCC, 2002) concluded that current spectrum policies were in need of reform. It recognised three spectrum management models:

- "command and control," the traditional method of spectrum management, in which allowable spectrum uses and users are determined by regulatory judgment;
- "exclusive use," where a licensee has exclusive, flexible, and transferable rights to use specified spectrum;

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- "commons," where unlimited numbers of unlicensed users share frequencies.

The recommendation was that use of the latter two should be expanded throughout the radio spectrum, with use of the traditional method being kept to a minimum.

In the United Kingdom, Ofcom's Spectrum Framework Review (Ofcom, 2005) came to comparable conclusions, and in Europe both the Commission and Parliament (EC, 2005a; EP, 2007) have expressed similar aspirations. The same three spectrum management models and the same direction of reform have been identified in each case, although the detailed language differs, as summarised in Table 1.

Table 1 - The three spectrum management models and the direction of regulatory reform

FCC (2002)	*Ofcom (2005)*	*EC (2005a)*
Command and control, the traditional method of spectrum management in the US, in which allowable spectrum uses and users are determined by regulatory judgment.	Command & control, the historical approach where the regulator decides how much spectrum each application should have and allocates and assigns the spectrum accordingly.	Detailed ex-ante administrative decisions. This approach has come under increasing pressure, due to the high technological turnover and the strong demand for wireless applications.
Exclusive use, where a licensee has exclusive, flexible, and transferable rights to use specified spectrum.	Market mechanisms, broadly the use of auctions and trading with liberalisation, to allow the market to modify historical allocations towards those more likely to maximise economic efficiency.	Spectrum markets can improve the efficiency of use of spectrum, since industry is better suited than regulators to identify the highest-value applications.
Commons, where unlimited numbers of unlicensed users share frequencies.	Licence-exempt use. The regulator allows free access to the spectrum, although normally with restrictions on power levels, making it most suitable for short-range devices.	Licence-exempt use, where equipment (typically low-power consumer goods) that fulfils certain technical conditions is used without a licence.
"Existing spectrum that is subject to command-and-control regulation should be transitioned to the more flexible exclusive use and commons models to the greatest extent possible"	"As a light-touch regulator our preference is to move away from central management, allowing market forces to prevail and increasing the use of licence-exemption"	"An EU-wide balanced approach should be sought between all spectrum models. The optimal "mix" between them will depend on various criteria, such as speed to market, protection from harmful interference, quality of service and fostering the internal market and innovation"

However, converting these policy aspirations into practical decisions is very challenging. For example, the packaging of lots has had a strong influence on the outcome of spectrum auctions and hence regulatory judgment is still very much present in a "market-based" approach. Also, existing operators have tended to resist service neutrality. This is usually on technical grounds, although commercial considerations may also play a part. This has made any practical benefits from spectrum trading and liberalisation patchy so far.

In this paper, we are concerned with a different and possibly even more significant challenge: how to determine the right balance between "flexible licensed" [1] and licence-exempt use of spectrum in future.

In its Spectrum Framework Review, Ofcom (2005) offered some illustrative numbers for the balance between spectrum management models that might be aimed for over the next few years. From a position in 2000 where 96% of spectrum below 60GHz was allocated by Command & Control (CC) and 4% licence-exempt, a potential outcome for 2010 was set out which would reduce CC to 22% by dramatically increasing the use of market mechanisms (flexible licensing) from zero to 71% and marginally increasing licence-exempt allocation to 7% [2].

The CC figures are based on an assessment of practicability, given a policy of moving away from this model where possible to a regime of flexible licensing with market allocation (by auction). The licence-exempt figures are approached in a different way, and are derived from a combination of two approaches - a theoretical calculation of what the demand for short-range communication might be assuming that each person might use up to 100Mbit/s of capacity, and a pragmatic assessment of the occupancy trends of current licence-exempt bands. The illustrative numbers are based on an assumption that by 2010 an extra 200MHz or so of spectrum for licence-exempt applications might be allocated adjacent to the current 5GHz bands.

[1] In this paper we use the phrase "flexible licensing" to refer to the exclusive use / market mechanisms approach.

[2] Percentages were calculated on a weighted basis, so that 100MHz of bandwidth with a centre frequency of 1GHz would score the same as 1GHz of bandwidth with a centre frequency of 10GHz etc.

■ Licence-exemption risks being sidelined

It is not surprising against this background that the current practical focus for spectrum reform in the UK and elsewhere in Europe is on flexible licensing employing market mechanisms rather than on licence-exemption.

For example, the European Commission has made a detailed communication to the Council and Parliament on "a market based approach to spectrum management", while licence-exempt studies are relegated to "future work" (EC, 2005b).

Another example is Ofcom's Digital Dividend Review, which presents the choice on future spectrum allocation as a binary one between a "market-led" approach and an "interventionist" approach (Ofcom, 2006). In this review, licence exemption is considered not as market-led but as a regulatory intervention, and hence subject to a very high burden of proof. However, licence auctions require significant regulatory intervention themselves, particularly in defining the bundles of goods to be traded. It is therefore not appropriate to caricature licence-exemption as interventionist, and auctions as purely market based. Indeed, licensing itself is a regulatory intervention [3].

There is a significant risk that licence-exemption will be sidelined during these formative initial years of spectrum reform for reasons which include:

- Flexible licensing is where the majority of the changes are expected.
- Flexible licensing requires a lot of detailed ground work from the regulators on defining spectrum usage rights.
- The potential economic benefits of flexible licensing can be modelled more readily than those of licence-exemption.
- There are fewer advocates for licence-exemption than for flexible licensing (or even for the status quo), for reasons explained below.

Marginalising licence-exemption will harm consumers and hobble innovation. We show below that there is significant demand for applications based on licence-exempt allocations, and that innovation flourishes in these

[3] The European Authorisation Directive states that "rights of use should not be restricted except where this is unavoidable in view of the scarcity of radio frequencies and the need to ensure the efficient use thereof." It could be argued therefore that licensing is the exception that must be justified by need, not licence-exemption.

bands. A delay, let alone a foreclosure, of these benefits will reduce the total value that can be derived from spectrum use.

Auctions are not the only way of allowing the market to determine the best use of the spectrum; a licence-exempt spectrum commons is also "market-led", since the market decides which applications succeed, not the regulator.

Further, licence-exempt allocations are collective goods, and therefore likely to be underprovided assuming rational actors working in their own self-interest. The regulator therefore needs to take a pro-active approach to achieve the greatest social welfare.

Level of demand for licence-exempt spectrum

A presumption underlying the current relatively low priority given to licence-exemption is that current licence-exempt bands are lightly used and that demand for new spectrum is not high (Ofcom, 2007b).

However, the 2.4GHz band is intensively used, with 250 million Wi-Fi devices sold in 2006 alone and over 1 billion Bluetooth devices in the market. Demand is increasing rapidly, with the 802.11n standard being developed using MIMO and beam forming technology to enable yet more intensive use of this precious spectrum. Any Wi-Fi user will be able to testify to the high number of SSIDs detected in many urban areas. There is very little licensed spectrum as intensively used as the 2.4GHz licence-exempt band.

Expansion into 5GHz, the growth route envisaged in Ofcom's Spectrum Framework Review (Ofcom, 2005), is suitable for some applications but not all. Lower frequencies with better propagation characteristics are better suited for creating cost-effective, robust wireless broadband in rural areas, and self-forming mesh networks in cities and suburbs capable of routing traffic at broadband speeds [4]. Mesh technology creates networks that can cover substantial areas using multiple short-range links.

[4] This becomes increasingly significant as the concept of universal service obligation disappears in a broadband future.

Demand for licence-exempt spectrum is often under-estimated simply because it has fewer and less vocal advocates than the licensed alternative. Some goods and services produce essentially only a consumer surplus, with no producer surplus. The absence of direct producer surplus for individual companies removes the normal impetus for aggressive advocacy. The consumer surplus itself is diffusely allocated since all citizens benefit rather than a specific interest group. Thus, those likely to recognise the true demand for licence-exempt applications are either citizen activists, public interest groups, or a few companies interested in "raising the level of the lake for everyone" and building on top of that innovation platform.

Innovation flourishes in licence-exempt bands

Experience in the 2.4 GHz ISM band - frequencies once known as the "junk bands" - proves the benefits of a licence-exempt allocation. Almost every laptop computer on sale today includes Wi-Fi technology that uses this band, and most mobile devices include Bluetooth.

Technology innovation has been dramatic. Maximum network throughput speed has increased almost fivefold [5]. The 802.11e standard that facilitates multimedia applications has contributed to the rapid growth and positive outlook for networks that support voice and video streams. The draft 802.11n standard promises data throughput rates up to 540 Mbit/s, ten times faster than today's best devices.

This has all happened very quickly: the first 802.11 standards underlying Wi-Fi were ratified in 1999 and 2000 [6]. The worldwide market for wireless local area networks had grown to $2.5 billion by 2005. By 2009, only a decade after its inception, overall Wi-Fi market revenues are forecast to reach $4.8 billion [7].

Licence-exempt allocations encourage entrepreneurs to enter the market, leading to innovation and competition. Usage scenarios are decentralised,

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5 From a maximum of 11 Mbps for 802.11b to 54 Mbps for 802.11g and 80.2.11a.

6 *The Economist* (2004): The basic 802.11 standard was published in 1997. 802.11b was ratified in December 1999, and 802.11a in January 2000. Apple introduced Wi-Fi as an option on its new iBook computers in July 1999.

7 Dell'Oro Group Inc, reported in "Dell'Oro: faster gear to drive Wi-Fi market," *Infoworld*, January 24, 2006. Figures do not include Wi-Fi capabilities embedded in DSL and cable modems.

leading to rapid industry growth. Start-up companies can develop new business models in licence-exempt spectrum where the idea is the primary capital required, rather than a spectrum licence.

Flexible licensing and Licence-exemption compared

Flexible licensed and licence-exempt allocations have complementary strengths and weaknesses:

Flexible licensing	*Licence-exemption*
Licensee controls behaviour of all transmitters in the band	Control is decentralised, and users have to co-exist with transmitters they do not control
Statutory protections from interference from other users	Licence-exempt users have to accept interference from other users, and (in the case of a secondary use) may not interfere with primary users
Spectrum use coordinated by the licensee	Spectrum use coordinated through regulation on devices, and industry standards
Relatively high transaction costs for gaining 'first party' access to spectrum through licensing auction or transfer	Relatively low transaction costs in obtaining 'first party' spectrum access
High cost of entry for service providers and equipment manufacturers	Low cost of entry for service providers and equipment manufacturers
Market in spectrum licenses and devices	Market in devices

To date, capital expenditure in licensed bands has focused on substantial, centralised network infrastructure investments by the licensee. Bands which support licence-exempt use have necessarily seen a more decentralised investment model where equipment is purchased by end users.

Both regulatory models have transaction and administrative costs (BENKLER, 2002; FAULHABER & FABER, 2003):

	Property-based flexible licensed allocation	*Licence-exempt allocation*
Transaction costs	Need to negotiate permission to transmit in a specified band	Minimal direct cost, but some overhead in equipment cost and spectrum usage for coordinating communications
Administrative costs	Definition and adjudication of property rights	Definition and enforcement of the rights to access spectrum

Administrative costs in the flexible licensing model are borne by government, whether as regulator or through the courts: the costs of defining

property rights, running auctions [8], and resolving disputes regarding interference. Industry may also bear costs in standard-setting processes. The transaction cost of spectrum coordination is borne by licensees and sub-licensees.

The costs for licence-exemption arise both in the administrative process of defining and enforcing technical standards to manage congestion and harmful interference, and in the "cost" of bandwidth devoted to negotiating access among receivers rather than to transferring data. Some costs are embedded in the cost of equipment, and reduced efficiency of communications. Administrative costs are borne by government in the regulatory process, and by industry in the standard-setting process. There is an opportunity cost if the spectrum use entailed by regulation is not the most efficient one. If there is little spectrum scarcity, transaction costs decrease; administrative costs remain, but may be reduced since standard-setting and compliance may be less onerous.

The two models imply different industry economics. The flexible licensing approach favours a network-centric service provider model, while licence-exemption favours an equipment-centric end-user model. The former implies more centralised spectrum management while the latter is more distributed and decentralised.

Current mobile communication and broadcasting services employ a service-provider model which facilitates co-ordinated decisions about network management. Emerging intelligent radio systems, however, will make it increasingly feasible to decouple frequencies and radio networks, and to ensure coordination in a decentralised way. With licence-exempt spectrum, it is possible to build up a network from end-user equipment that can be linked in an ad hoc, wireless mesh. This supports viral, edge-based growth and offers an alternative for the future to the service-provider-based model.

The end-user model is unlikely ever to replace completely the service provider one, but it is more consistent with the way new technologies are developing, and with many market trends in the information society [9]. It is

[8] These costs are set off against the (hopefully larger) revenue gained through auctions.

[9] This decentralised model for access can be compared with the innovative network models for content distribution and telephony, based on peer-to-peer technology, developed by BitTorrent, Skype and others.

therefore short-sighted to focus only on flexible licensing in the current spectrum reform debate.

■ Two models are better than one

The choice between flexible licensing and licence-exemption is a choice between regulatory models. Any regime choice will bias outcomes. In a flexible licensing regime, the pace of innovation and development will be controlled by licence holders rather than end-users or equipment suppliers. In a licence-exempt regime, on the other hand, end-users and device manufacturers drive innovation. Neither model is intrinsically better than the other, nor is the choice between them straightforward; diversity in regulatory models is therefore the best bet.

Either licensed or licence-exempt allocations can result in increased social welfare, but the combination of the two will result in a greater citizen benefit than each individually. For example, a public park enhances the value of surrounding owned and leased properties, and the use by residents in those properties increases the utility of the park.

The licence-exempt band at 2.4GHz sits right next to licensed services and huge benefits have been created. In the United States, some wireless Internet services have been provided around 2.5GHz using licensed bands, and others have successfully used licence-exempt technology around 2.4GHz. Cellular service providers like T-Mobile USA have created services that combine licensed cellular and licence-exempt operation [10], demonstrating the value of a blend of licensed and licence-exempt allocations.

The right approach to spectrum management is a judicious mix of licensed and licence-exempt uses in all major frequency bands (e.g. below 1 GHz, between 1 and 3 GHz, 3-10 GHz, 10-60 GHz, above 60 GHz).

[10] The HotSpot @Home service.

The limitations of projections of economic value

The flexible licensing and licence-exemption models are sufficiently different that economic analysis is of very limited help in picking between them. Licensed spectrum has few operators, and well-defined prices; licence-exempt has huge numbers of operators, and no market prices for spectrum services.

Despite the difficulties of long-term prediction, forecasting of economic value has been proposed as a key tool for regulators to employ, alongside public consultation and analysis of likely congestion, in choosing between the flexible licensing and licence-exemption models for new spectrum allocations (CAVE & WEBB, 2004). This approach has been used by Ofcom (2007a) in its Licence-Exemption Framework Review, and supported by an in-depth study to develop methods to estimate the future economic value of licence-exempt applications through to 2026 (Indepen *et al.*, 2006).

The Indepen et al. study models the expected benefits of a few wireless communications applications on a socio-economic basis rather than from a supply-side, techno-centric view. This is useful since it attempts to capture the true consumer benefits of licence-exempt applications. Nevertheless, the framework and methodology proposed are likely to under-estimate these: the approach is rooted in the current situation and tends to use conservative measures of economic benefits.

Only ten known applications are taken into account and novel applications that might well emerge in the future (even the near future) are not valued. Also, innovation brings more benefits than originally imagined by pioneers: innovation is likely to create positive externalities. However, it is impossible to predict when and how these benefits will be realized – particularly over a span as long as twenty years. CAVE & WEBB (2004) summed it up very well: "It is necessary but impossibly difficult to look ahead."

A further difficulty arises when valuations of putative licensed and licence-exempt allocations are compared. The assumptions and methods used are likely to be very different for valuing the two allocation types, and comparison will be fraught with difficulty. In sum, a test for licence-exemption which is based on comparing estimates of the economic value derived from licensed and licence-exempt approaches looks rational, but is largely arbitrary.

Given such uncertainties in calculating the prospective value of competing allocation types, setting aside spectrum for licence-exempt applications only when the economic value of these applications strictly exceeds the value of a licensed allocation (Ofcom, 2005) is not a well-founded basis for regulatory choice. If regulatory expediency demands such comparisons, then licensed and licence-exempt should be considered equally viable as long as their putative values are of the same order of magnitude.

Despite these limitations, the Indepen et al. study reaches a positive conclusion on the value of licence-exempt applications, noting:

> "Certain LE applications, such as short range radars, RFIDs in retail and public access Wi-Fi could generate economic benefits for the UK which are substantially greater per MHz of use than the highest value licensed applications."

Still, there is a risk that once numbers are available from an economic model such as this, they will be compared superficially with numbers derived in a completely different way for licensed applications. Indeed Ofcom (2007a) uses figures from the Indepen et al. study to suggest that even Wi-Fi at 2.4 GHz may have a lower economic value than a licensed cellular alternative. This could be taken to imply that if the 2.4 GHz band had not already been made licence-exempt, it would not be made so today. Given the phenomenal success and user benefits of Wi-Fi, Bluetooth and so on (not to mention microwave ovens), this cannot be right.

Rather than relying on largely meaningless 20-year estimates of revenues and benefits, we suggest that regulators compare the nearer-term costs of creating and operating under licensed and licence-exempt regimes in a particular band. Both BENKLER (2002) and FAULHABER & FABER (2003) discussed differences in transaction and administrative costs between the two allocation types, though without providing numerical examples.

While also uncertain since they pertain to putative allocations, set-up and overhead costs are front-loaded and less likely to be sensitive to the imprecision of long-run analysis, and administrative costs are less sensitive to the vagaries of innovation. In many cases, licensed allocations of compact bands may have lower costs than licence-exemption; conversely, licence-exemption may have lower costs when spectrum is to be used in an opportunistic way with evolving rules in "messy" bands where transferable

property rights may be difficult to define up front, expensive to trade, and costly to rationalize in negotiation with many other licensed band occupants.

Difficulties with congestion criteria

Congestion has been proposed as a criterion for deciding between licensed and licence-exempt use (CAVE & WEBB, 2004; Ofcom, 2007a). In some cases, such as very high frequencies with very short range propagation, this approach yields common sense results: licensing is not necessary. While congestion has a relatively well-defined meaning in network management, it is difficult to define for spectrum policy purposes, particularly in bands where the frequency is neither very high nor very low. Congestion is sometimes defined as the situation in which spectrum demand exceeds available supply, and sometimes it is used interchangeably with harmful interference.

Since congestion is typically used in licence-exemption analyses, there is an implication that licensed allocations do not suffer from congestion. That might be correct as a matter of definition, since a spectrum licensee can increase the price of access (or, in the case of cellular networks, drop calls) until demand matches supply. Since spectrum access is not priced in licence-exempt bands, this mechanism is not available. However, spectrum demand is managed in this case by declines in quality of service rather than by increases in price. The number of users grows until interference deters additional access. Further, congestion, defined as harmful inter-user interference, is only a problem if there's an expectation of guaranteed quality of service – and there is no such expectation in licence-exempt bands [11].

The amount of coordination required for many concurrent users of a spectrum band is an alternative criterion to congestion tests for allocation decisions. If little or no coordination is required, license-exemption is indicated. Such an approach would yield the same result as Ofcom's congestion analysis for very high frequencies where there is a large amount of capacity (Ofcom, 2007a, Section 6), but would also allow regulators to consider bands such as UHF where capacity is scarce. It also provides a

[11] Licence-exempt allocations suffer from a Catch-22: if there are so few users that there is no mutual interference, then the band is adjudged to be under-used, and a wasteful allocation; on the other hand, if there are so many users that there is mutual interference, it's deemed to be congested, unusable, and a wasteful allocation.

framework for incorporating band rules like power control and politeness that improve coordination.

Criteria for selecting Licence-exempt *vs* Licensed

Choosing between licensed and licence-exempt allocations is difficult. It requires a judicious combination of economic, technical, and regulatory judgments.

- Where little or no coordination among independent band users is required to prevent harmful interference, licence-exempt (with appropriate rules) is an appropriate allocation.
- Choose between licensed and licence-exempt allocations on the basis of estimates of set-up and operating costs rather than forward-looking estimates of speculative long-term consumer benefits.
- Licence-exempt applications result in consumer benefit, rather than producer surplus. Measures of consumer benefit should be sophisticated enough to recognise the time spent on activities as well as the money spent on them [12]. Licensed valuations should explicitly separate out the values attributed to producer surplus and to consumer surplus, so that consumer-surplus-only comparisons can also be made.
- Comparisons with licensed valuations, if used, should carefully consider any differing underlying assumptions, since the effects of these can easily dwarf differences between the applications themselves.
- Take into account the value of having a combination of licensed and licence-exempt applications in the same "spectrum neighbourhood", and of a combination of licence-exempt applications in different bands.
- Recognize the innovation value and social benefit of licence-exempt applications.

Economic projections can never replace the need for strategic policy judgments by the regulator. The benefits of licence-exemption are enjoyed today in many cases because of historical decisions made to allow experimentation in Industrial, Scientific and Medical (ISM) bands such as

[12] Only about 0.2% of consumer spending in the U.S., for example, went for Internet access in 2004 yet time use data indicates that people spent around 10% of their entire leisure time going online (GOOLSBEE & KLENOW, 2006). This suggests that conventional consumer surplus calculations significantly understate the value of internet assets.

that at 2.4GHz. However, a real danger with the current focus on flexible licensing is that a system is established under which forward-looking allocations like this might never be made again.

■ Case Study - The UHF Digital Dividend

The transition from analogue to digital television which is taking place around the world provides an opportunity to re-allocate some of the UHF spectrum which is currently employed for broadcasting. Once the analogue services are switched off at the end of the transition, the spectrum allocations used by the remaining digital broadcasts can if necessary be reconfigured so as to clear some spectrum (the "Digital Dividend") for other uses.

This is an area of very active work in the US, with two main threads. First, in April 2007, the FCC released a Report and Order and Further Notice of Proposed Rulemaking which addresses rules governing wireless licences in the 698-806 MHz Band (more commonly referred to as the "700 MHz Band") (FCC 2007). This spectrum currently is occupied by television broadcasters in TV channels 52-69 and is being made available for wireless services, including public safety and commercial services, as a result of the digital television ("DTV") transition. The DTV transition is due to end in February 2009, releasing the clear spectrum for other applications from that date at the latest.

Second, in October 2006 the FCC issued its First Report and Order and Further Notice of Proposed Rulemaking concerning Unlicensed Operation in the TV Broadcast Bands (FCC, 2006). This is commonly referred to as the "white space" issue, and concerns unused localised spectrum within the bands still to be employed for broadcasting. This notice indicated the FCC's intention to allow licence-exempt operation, and sets out a schedule with laboratory and field test results to be published in summer 2007; a second Report and Order specifying final requirements for devices operating in the TV bands in the autumn of 2007; and equipment to be permitted for retail sale from the planned end of the DTV transition in February 2009.

Broadly speaking, the intention is to use service and technology neutral auctions to allocate most of the cleared spectrum in the 700MHz band, with some being reserved for public safety, and for licence-exempt operation to be allowed in the white space.

In the United Kingdom, Ofcom issued its "Digital Dividend Review" consultation in December 2006 (Ofcom, 2006). This sets out proposals for the equivalent DTV transition in the UK, referred to as the "digital switchover", which is due to be completed in 2012. In this case there are fifteen 8 MHz channels to be cleared for other uses (channels 31-37, 39-40 and 63-68), as well as "interleaved channels" usable on a localised basis within the spectrum to be retained for broadcasting (equivalent to the white space).

Broadly speaking, Ofcom's proposals are for service and technology neutral auctions both for the cleared channels and also for interleaved channel capacity.

In Europe as a whole, the Radio Spectrum Policy Group (RSPG) published an opinion on the digital TV transition in February 2007 (RSPG 2007). It encourages all European administrations to take actions to enable the development of "new services fostering growth and innovation" in the Digital Dividend, but also sounds a note of caution warning that they must not "conflict with national and European content legislation aiming at promoting cultural diversity and media pluralism".

Also a mandate has been given by the EC to the CEPT for technical studies to be completed before the end of 2007 in three important areas for the Digital Dividend (ERO, 2007):

- compatibility issues between "cellular / low-power transmitter" networks and "larger coverage / high power tower" type of networks;
- the technical feasibility of harmonising a sub-band of UHF bands IV and V for mobile applications (including uplinks);
- a preliminary assessment of the feasibility of fitting new/future applications/services into non-harmonised spectrum of the digital dividend (namely to so-called "white spots" between allotments).

In spite of these technical studies on new possibilities, in most of mainland Europe there is currently a greater emphasis on continued broadcasting use of the Digital Dividend, rather than on flexible licensing or licence-exemption.

The Digital Dividend is a prime example of a situation where licence-exemption risks being sidelined, especially in Europe. Doing so would miss a once in a lifetime opportunity for reconsideration of an important spectrum resource.

The potential for licence-exempt operation in UHF frequencies below 1 GHz

Providing licence-exempt devices with access to spectrum below 1 GHz will allow the manufacture and sale of devices featuring lower power, lower cost, more reliable, and relatively longer-range communication capability. These devices would take advantage of the favourable physical propagation characteristics of this spectrum by, for example, easily going through walls to enable inter-home mesh networking and better in-home coverage in municipal wireless networks.

The potential for a market at least equivalent to Wi-Fi and Bluetooth at 2.4 GHz would exist for the licence-exempt use of UHF spectrum. Possible applications include:

- self organising, mesh connected community and campus networks,
- in-home multi-media distribution,
- local coverage extension for digital broadcast networks – e.g. DTT and DAB [13],
- remote patient monitoring and elderly care,
- game play,
- people, animal and asset tracking,
- industrial automation and control,
- home automation and control,
- security covering whole homes, larger properties, communities and campuses,
- public safety.

Most of these applications would require much less infrastructure when compared to the existing shorter range ISM band solutions at 2.4Ghz or 5GHz, thus creating a significant benefit to the user.

Mesh networks

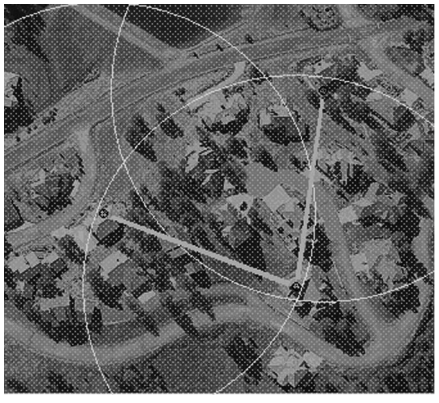
Neighbourhood mesh networks can increase choice and extend internet access to lower income groups by enabling shared network access. They grow organically; they do not require any infrastructure; they are robust and

[13] The coverage of new digital broadcast networks, such as DAB and DTT is often constrained by lack of capital or a need to avoid interference. Enabling the use of low cost, home-area fillers on a licence-exempt basis may provide an economically viable means of extending coverage, for example, by allowing portables and second sets to be used conveniently.

fault tolerant; no centralised management is necessary. Thus they empower the individual by facilitating choice and competition at the edge of networks, features which are often absent in rural and some suburban areas. However there are important challenges in being able to provide the necessary range, scale, and capacity using existing 2.4 GHz and 5 GHz licence-exempt spectrum, as illustrated in this example [14].

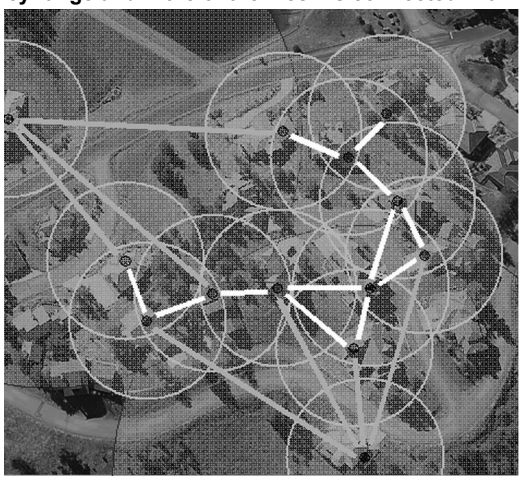
Figure 1 - 5 GHz: Bandwidth is good but measured range (circle) is poor. Range is not sufficient to bootstrap mesh until installed percentage is quite high (in this diagram ~50%)

Figure 2 - 700 MHz: Much better range. Three 2 MHz channels can bootstrap a neighbourhood with ~3-5 Mbps



[14] The diagrams in this section are based on those used by Jawad Khaki, Microsoft, in his keynote speech to the IEEE DySPAN conference in Dublin on 19 April 2007.

Figure 3 - Dual Frequency Network: As more clients come online, links form in high-frequency range and more of the mesh is connected with high-bandwidth



A combination of higher and lower frequency licence-exempt bands maximises spectrum utilization, and reduces the need for coordination by minimising the number of longer-range [15] links.

Licence-exempt use of the Digital TV "White Spaces"

A particular feature of the digital TV transition is that even within the spectrum nominally to be retained for broadcasting, there are many vacant "white spaces" or "interleaved channels". In most areas, this capacity is in fact greater than the amount of spectrum that will be cleared completely. For example, in the UK, fifteen 8 MHz channels are to be cleared, and thirty-two 8 MHz channels are to be retained for broadcasting. At any one transmitter site, only six of these channels will be used for broadcasting, leaving up to 26 potentially vacant. Clearly there are overlap areas where 12 of the 32 channels will be in use, and there are also professional radio microphone and talk-back systems which are currently allowed to use these vacant channels on a very localised basis. But the reality is that no matter where the reader happens to be, a scan of the UHF TV band with a spectrum analyser would reveal many unused channels.

[15] Note that even the longer-range links are still quite short, of the order of 100m.

The criteria outlined above for choosing between licensed and licence-exempt indicates that a license-exempt allocation would be suitable in the UHF TV band:

- Low transmission power limits (for example, 100 mW) would limit range and require minimal coordination that can be easily handled by current licence-exempt technology.

- Allocating the interleaved channels to licensed use would entail significant costs in setting up auctions with limited proceeds, given that available white space varies by geography, and that new licensees would have to coexist not only with broadcasters but also licensed radio microphone systems. Overhead costs are likely to be lower for a licence-exempt allocation.

- There will be licensed allocations in the adjacent cleared broadcast channels, which when combined with a licence-exempt allocation will create a whole greater than the parts.

- The mesh example above demonstrated the value of combined operation in longer- and shorter-range licence-exempt bands.

- In the United States, a consortium has submitted proposals [16] to the FCC for licence-exempt use of these white spaces using portable devices that will detect and avoid broadcasts and radio-microphones, providing the consumer benefits and potential applications discussed above. Microsoft (NARLANKA, 2007) and Philips (CHALLAPALI, 2007) have both submitted to the FCC prototype devices which demonstrate the effectiveness of the detect-and-avoid techniques. Similar proposals have also been submitted by Microsoft, Philips and Intel to Ofcom in response to its Digital Dividend Review [17]. Innovation in this band is just beginning. Indeed, as would be expected with licence-exempt applications, the best use has probably not been invented yet.

[16] Comments in proceeding 04-186 of Dell, Microsoft, Google, HP, Intel and Philips, submitted on 31 January 2007, and Reply Comments submitted on 2 March 2007, available online from the FCC at http://gullfoss2.fcc.gov/prod/ecfs/comsrch_v2.cgi

[17] Available online via Ofcom's website.

■ Conclusions

The flexible licensing and licence-exempt regulatory models complement each other, and a combination is more valuable than either individually. Licenses are just one kind of spectrum-related market; a licence-exempt allocation creates a market in device technologies in which manufacturers compete with each other to provide affordable innovation directly to end-users.

There are vacant channels between broadcast television stations. This spectrum can be used by licence-exempt devices without harming television viewing.

A licence exempt allocation of these bands would be the most productive way to use this spectrum because licence-exempt spectrum:

- it is a proven way to generate technical and commercial innovation;
- it promotes healthy diversity in markets and regulatory models;
- it complements the work regulators are already doing to introduce market mechanisms through flexible licensing.

A broad cross-section of society would benefit, including rural and inner-city residents seeking affordable Internet access, entrepreneurs starting up digital communication businesses, cities and companies seeking to foster growth and productivity, and citizens who want to create community networks.

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