

**SPECTRUM MANAGEMENT FOR A  
CONVERGING WORLD:  
CASE STUDY ON THE UNITED KINGDOM**



**International Telecommunication Union**

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The views expressed in this paper are those of the author and do not necessarily represent those of ITU or its membership.

## **1 Introduction**

Until about five years ago, the Government of the United Kingdom practised what could be called a fairly conventional “command and control” form of spectrum management. Allocations were derived from international agreements made at the global and European level; assignments were made using either “beauty contests” or the “first come first served” approach, and the management process was undertaken by a government department, the Department for Trade and Industry (DTI), although implementation was assigned to an agency within the Department, responsible to the Secretary of State, the Radiocommunications Agency (RA). The interests of other government departments, including the Ministry of Defence, were coordinated through a Cabinet Office Committee, co-chaired by a senior Ministry of Defence official and the Chief Executive of the RA, and responsible to government ministers.

Throughout the 1990s, however, the pressure of demand for spectrum increasingly called the traditional framework into question. Extra demand came from many sources, including from the growth of mobile communications, which took off in the 1990s, from other telecommunications innovations, from digital broadcasting terrestrially and by satellite, from new defence capabilities — ever more reliant on communications, from the growth of civil aviation, from new safety of life applications, and so on.

The UK Government responded to the increasing disjunction between new spectrum needs and traditional methods of allocation and assignment by making proposals and bringing forward legislation to change the face of spectrum management. The foundations for these changes were provided by two major pieces of legislation, namely the 1998 Wireless Telegraphy Act and the 2003 Communications Act. These Acts were preceded by a wide-ranging policy debate and followed by major implementation projects, largely completed in relation to the 1998 Act and recently set in train in relation to the 2003 Act.

Because these measures have not been in effect for long, or are still at the design stage, it is not possible to evaluate their effects fully. Accordingly this paper outlines the reforms, sets out their rationales, describes their implementation, where appropriate summarizes the attitude towards them of spectrum users in the public and private sectors, and records the first results in an ongoing process.

## **2 United Kingdom facts and indicators**

The United Kingdom has a population of 60 million, distributed over a land area of 242,000 Km<sup>2</sup>, generating a population density of 245 per km<sup>2</sup>. Its level of GDP per capita in 2002 was USD 25,500, based on purchasing power parity (PPP) exchange rates.

## **3 The communications environment in the United Kingdom**

### **3.1 Legislation**

The UK communications sector is regulated by a variety of Acts, the two most recent of which are the Wireless Telegraphy Act of 1998 and the Communications Act of 2003, as mentioned above. These Acts are of special interest because, as outlined in more detail below, they introduced major reforms into spectrum management — the former permitting the application of administered prices for spectrum and auctions, the latter enabling spectrum trading.

### **3.2 Office of Communications (Ofcom)**

Since 29 December 2003, the principal body responsible for spectrum management has been Ofcom, an independent agency, which on that date took over the function from the Radiocommunications Agency. Ofcom’s duties and powers are described below.

Ofcom is responsible for spectrum management. Its predecessor, the RA, regularly published a Spectrum Strategy Document. Ofcom is also responsible for issuing the various forms of licence and for their enforcement. In relation to the bulk of licensed spectrum, these licences take the form of

apparatus licences, which precisely define the radio station, its location and technical characteristics. Some licences are issued annually, subject to renewal, while others are issued without specific time limitation, but are subject to revocation in certain circumstances.

### 3.3 Terminology of spectrum management in the UK environment

To avoid ambiguity, this paper will use the following terminology to describe different techniques of spectrum management, which corresponds that that used in the UK.

**Command and control:** the Government or its agency makes (or accepts from an international body) the allocation of a band to a particular purpose; spectrum within the band is assigned to a licensee or licensees via an administrative process; a charge may be levied on licensees, normally to cover administrative costs; the licence usually authorizes the licensee to utilize spectrum-using equipment specified as to location, power and other variables, the restrictions being designed to avoid interference with other licensees in adjoining geographical areas or bands.

**Administrative incentive pricing:** allocation and assignment take place as above, but licensees are charged a fee for access to spectrum which depends on some estimate of the value of that spectrum to the economy or to society — typically described as its “opportunity cost” (see below); this is designed to encourage economy in spectrum use; unwanted spectrum might either be returned to the Government or regulator, or there may be provision for the licensee to make it available by sale or lease to others via a market process.

**Primary licence auctions:** this describes a method of assignment of a licence to firms or other organizations when a band is first made available or when it has been returned, for reassignment, to the regulator; instead of an administrative procedure being undertaken, an auction is conducted in which the highest bidder(s) are allocated the licence(s); hitherto, auctions have been conducted for licences associated with specific purposes, such as 3G wireless or broadband fixed wireless access; auctions could, however, attract competitors proposing to utilize the spectrum for a range of different purposes, such as broadcasting and mobile telephony.

**Secondary trading:** under this regime, licences (however first assigned) can be subsequently traded by buyers and sellers, without passing through the regulator’s hands; the transaction may take various forms: change of ownership only, with no variation to the use to which the spectrum is put; reconfiguration, such that the licence is broken up into different parts, by geography, time or frequency, and the parts as sold, or several previously separate licences are combined; and change of use, such that the spectrum to which the licence grants access is employed to produce a service different from its previous one; these three dimension of change can be combined in various ways (e.g. change of owner, reconfiguration *and* change of use); change of use will, however, require a modification of the conventional apparatus-licensing approach, as a new use will require different apparatus — how this will be tackled in the United Kingdom is discussed below.

**Licence-exempt spectrum:** access to spectrum does not require prior authorization; any user satisfying certain conditions — usually relating to the power of the equipment employed — may have access to the band in question; under this approach known also as the “spectrum commons”, there is a greater risk of interference and congestion.

The above mechanisms are summarized in Table 1 below: note also that they are not all mutually exclusive — in particular, primary auctions and secondary trading can be combined with each other, and with administrative incentive pricing.

**Table 1: Characteristics of spectrum management instruments**

	Individual licensing	Initial assignment	Secondary trading	User price
Command and control	Yes	Administrative	No	None (except administrative change)
Administrative incentive pricing	Yes	Administrative	No	Yes (“opportunity cost”)
Primary auctions	Yes	Auction	Not necessarily	Not normally
Secondary trading	Yes	Auction or administrative	Yes	Not necessarily
Unlicensed spectrum	No	None	None	None

Source: Author.

### 3.4 Chronology of reform and legislation in the United Kingdom

The focus of this paper is on the period since 1998, beginning with the Wireless Telegraphy Act of that year, which introduced two major changes: it authorized spectrum auctions and tested conditions for administrative incentive pricing. The following is an extract from relevant sections of the Act:

“3. (1) Having regard to the desirability of promoting the optimal use of the electro-magnetic spectrum, the Secretary of State may by regulations provide that, in such cases as may be specified in or determined by him under the regulations, applications for the grant of wireless telegraphy licences must be made in accordance with a procedure which

[...]

(b) involves the making by the applicant of a bid specifying an amount which he is willing to pay to the Secretary of State in respect of the licence.

[...]

(3) Regulations under this section may make provision with respect to the grant of the licences to which they apply and the terms, provisions and limitations subject to which such licences are issued and may, in particular

(a) require the applicant's bid to specify the amount which he is willing to pay

(i) as a cash sum or by reference to a variable to be determined in accordance with the regulations (such as, for example, his income attributable wholly or in part to the holding of the licence), and

(ii) as the amount of a single payment or as the amount of a periodic payment,

(b) specify requirements (such as, for example, technical or financial requirements, requirements relating to fitness to hold the licence and requirements intended to restrict the holding of two or more wireless telegraphy licences by any one person) which must be met by applicants for a licence,

(c) require any such applicant to pay a deposit to the Secretary of State,

(d) specify circumstances in which such a deposit is, or is not, to be refundable,

(e) specify matters to be taken into account by the Secretary of State (in addition to the bids made in accordance with the prescribed procedure) in deciding whether, or to whom, to grant a licence,

(f) specify the other terms, provisions and limitations subject to which any licence is to be issued,

[...]

(5) A wireless telegraphy licence granted in accordance with regulations under this section shall specify, or specify the method for determining, the sum or sums payable in accordance with the applicant's bid for the licence; and those sums shall be paid to the Secretary of State by the person to whom the licence is issued in accordance with the terms of the licence."

Section 1 of the Act states the following:

"1. (1) In this Act "wireless telegraphy licence" means any licence under the Wireless Telegraphy Act 1949 other than a television licence as defined in section 1(7) of that Act.

(2) On the issue or renewal of a wireless telegraphy licence and, where regulations under this section so provide, subsequently at such times during the term of the licence as may be prescribed by the regulations, there shall be paid to the Secretary of State by the person to whom the licence is issued

(a) such sums as may be prescribed by the regulations, or

(b) if the regulations so provide, such sums (whether on the issue or renewal of the licence or subsequently) as the Secretary of State may in the particular case determine.

[...]

(5) Regulations under this section shall not apply in relation to any licence granted in accordance with regulations under section 3."

The outcomes of auctions and of administrative pricing are described below. This represented a considerable step forward, but it did not introduce spectrum trading. In 1998, the RA held a consultation entitled *Managing spectrum through the Market*. It set out a broad range of options for the introduction of trading, but led to no immediate action.

In 2001, the Government commissioned an independent study entitled the *Review of Radio Spectrum Management* (published in 2002), which endorsed administrative pricing at opportunity cost levels and strongly supported spectrum trading. The Government's generally favourable *Response to the Review of Radio Spectrum Management* was published in October 2002. Meanwhile the RA conducted another consultation entitled *Implementing Spectrum Trading*.

Most significantly, in 2003 the Communications Act was passed, which made major changes to spectrum management. It formed a new regulatory body, combining the RA and the telecommunications and broadcasting regulators, known as Ofcom. Section 3 of the Act set out Ofcom's duties as follows:

"(1) It shall be the principal duty of Ofcom, in carrying out their functions

(a) to further the interests of citizens in relation to communications matters; and

(b) to further the interests of consumers in relevant markets, where appropriate by promoting competition.

(2) The things which, by virtue of subsection (1), Ofcom are required to secure in the carrying out of their functions include, in particular, each of the following

(a) the optimal use for wireless telegraphy of the electro-magnetic spectrum;

(b) the availability throughout the United Kingdom of a wide range of electronic communications services;

(c) the availability throughout the United Kingdom of a wide range of television and radio services which (taken as a whole) are both of high quality and calculated to appeal to a variety of tastes and interests; (d) the maintenance of a sufficient plurality of providers of different television and radio services;

[...]"

As for more detail, Section 152 *et seq* imposed functions on Ofcom in respect of radio spectrum.

*“152 General functions of Ofcom in relation to radio spectrum*

(1) It shall be a function of Ofcom -

- (a) to give such advice in relation to the use of the electro-magnetic spectrum for wireless telegraphy,
- (b) to provide such other services, and
- (c) to maintain such records,

as they consider appropriate for the purpose of facilitating or managing the use of that spectrum for wireless telegraphy.

it shall be a function of Ofcom, in relation to the use of the electro-magnetic spectrum for wireless telegraphy –

to give such further advice,

to provide such other services, and

to maintain such other records,

as the Secretary of State may, for the purpose of securing compliance with the international obligations of the United Kingdom, require them to provide.

The advice, the other services and the records that Ofcom may give, provide or maintain under this section include advice, other services and records with respect to the use of the electro-magnetic spectrum at places outside the United Kingdom.

The powers of Ofcom to carry out research, or to arrange for others to carry out research, are to be exercisable, in particular, for ascertaining, for the purpose of carrying out their functions under this section, information about –

The demands for use of the electro-magnetic spectrum for wireless telegraphy in the United Kingdom;

The effects, in the United Kingdom, of any such use of that spectrum;

Likely future developments in relation to those matters; and

Any other connected matters that Ofcom think relevant.

*154 Duties of Ofcom when carrying out spectrum functions*

(1) It shall be the duty of Ofcom, in carrying out their functions under the enactments relating to the management of the radio spectrum, to have regard, in particular, to

- (a) the extent to which the electro-magnetic spectrum is available for use, or further use, for wireless telegraphy;
- (b) the demand for use of that spectrum for wireless telegraphy; and
- (c) the demand that is likely to arise in future for the use of that spectrum for wireless telegraphy.

(2) It shall also be their duty, in carrying out their functions under those enactments to have regard, in particular, to the desirability of promoting

(a) the efficient management and use of the part of the electro-magnetic spectrum available for wireless telegraphy;

- (b) the economic and other benefits that may arise from the use of wireless telegraphy;
- (c) the development of innovative services; and
- (d) competition in the provision of electronic communications services.

[...]

*156 Directions with respect to the radio spectrum*

(1) The Secretary of State may by order give general or specific directions to Ofcom about the carrying out by Ofcom of their functions under the enactments relating to the management of the radio spectrum.

*157 Procedure for directions under s. 156*

(1) An order containing a direction under section 156, if it is not one falling within subsection (2) or (3) of that section, must state the purpose for which the direction is given.

[...]

(6) Where under subsection (5) the Secretary of State makes an order containing a direction under section 156 without a draft of the order having been approved, the order shall cease to have effect at the end of the period of forty days beginning with the day on which it was made unless, before the end of that period, it has been approved by a resolution of each House of Parliament.”

In relation to spectrum trading, the Act provides the following:

*“168 Spectrum trading*

Ofcom may by regulations authorize the transfer to another person by -  
the holder of a wireless telegraphy licence, or  
the holder of a grant of recognized spectrum access,  
of rights and obligations arising by virtue of such a licence or grant.’

In accordance of this clause, in November 2003, Ofcom issued a *Spectrum Trading Consultation*, discussed in more detail below.

To summarize the situation, the United Kingdom has had in place since 1998 a system of administrative incentive pricing for spectrum which is now likely to be revised and extended (see below). Three spectrum auctions have been carried out since 2000, including the very large scale third-generation (3G) licence auction. A consultation is now in progress on secondary spectrum trading. If the latter is implemented, as seems likely, the largest proportion of the most valuable UK spectrum will be tradable by 2007, with the bulk of the remainder subject to administrative pricing.

The Communications Act has also introduced a new decision-making framework, introducing a “converged” regulator, Ofcom, for broadcasting, telecommunications and spectrum (for all purposes) subject only to — it is expected — occasional direction by the Secretary of State in spectrum matters.

In the following four sections, we discuss in more detail:

- administrative incentive pricing;
- the UK experience of spectrum auctions;
- current proposals for spectrum trading;
- the role of licence-exempt spectrum.

## 4 Administrative incentive pricing

The approach set out in the 2002 *Review of Radio Spectrum Management* (and largely accepted by the Government) is to view spectrum as an input into a range of processes providing goods and services both sold for commercial purposes (such as mobile telephony) and meeting collective or social needs (such as defence). Given the increasing scarcity of spectrum, it was vital to ensure that this resource is used efficiently. The method recommended to achieve this aim was the price system: users of spectrum would be guided to combine spectrum efficiently with other inputs by having to pay a price for spectrum, just as they do for other inputs.

However, two separate uses of the price system were recommended in the *Review*. For commercial services, spectrum (more accurately spectrum licences) would trade in a market, and find a market price. As a result, spectrum of any kind would gravitate towards those firms or organizations which could make the best use of it, as they would value it highest. The *Review* concluded, however, that it was premature to expose all spectrum to trading, and desirable for spectrum required for certain public services purposes to be reserved and allocated administratively. However, in order to encourage economies in the use of spectrum on the part of users gaining access to it in this way, they would face an administrative price, designed to reflect its potential value to the country.

For the purpose of this approach, the value would be calculated, conceptually, by asking the following question: if a particular licence were not employed in its current use, where else would it be used, and what resulting saving in cost would arise as a result of redeploying it there? If the administrative incentive pricing (or AIP) were set at that price, then, if the current user retained it, it would be an indication that that user valued it more highly than the next most efficient user. In other words, the AIP is intended to reflect the “opportunity cost” — the value to the country of the same spectrum in its next most efficient use. In principle, this approach to AIP generates an outcome similar to the outcome of the market for tradable spectrum, as the process of price setting in a competitive market ensures that prices equal the value placed on the asset by the next more efficient use. Thus, both AIP and trading generate similar outcomes, but by a different process.

Should all non-traded spectrum be subject to AIP? The *Review* argued that it should, except in cases when international agreements, for example through NATO for defence spectrum, or the International Civil Aviation Organization (ICAO) for aeronautical spectrum, made the spectrum unavailable for other users — in which case it would have a zero opportunity cost (and no AIP).

The approach also carried the implication that AIP should be positive only in geographic areas of potential congestion where demand exceeds supply at a zero price. As a result, spectrum used for radio broadcasting might have a positive AIP in metropolitan areas, where the population could sustain a large number of radio stations, but a zero value in rural areas, where the audience could contain fewer stations.

The approach to establishing AIP as set out above was first employed in a consultancy report for the RA by Smith-NERA in 1996. As described in a subsequent report on AIP, Smith-NERA proposed a method for setting prices based on opportunity costs. The approach focused primarily on assignment within frequency bands. Prices were calculated for mobile services (i.e. PMR, PAMR and cellular services) and fixed links and were intended to result in a more efficient assignment of spectrum to these services. The allocation of spectrum to these services was assumed to be fixed.

In addition, Smith-NERA suggested that mobile and fixed link prices could in principle be used to benchmark prices for other spectrum that could be used by either mobile or fixed link services respectively. In these cases spectrum allocations were assumed to be flexible.

The following hypothetical example can serve illustrate the Smith-NERA method. Let us assume that radio spectrum is characterized as three bands (a, b, c) in the interval [0,1]. Further assuming there are three competing uses for radio spectrum: I, II and III. The allocation of spectrum is as follows: Use I is allocated frequency band a, Use II is allocated frequency band b, and Use III is allocated frequency band c. In each Use area, users (firms) compete to provide final goods and services to consumers. We shall also assume that the users differ in their abilities to produce final goods and services, with some users being more efficient than others.

The Smith-NERA approach first posed the question: what should be the price of spectrum to ensure an efficient assignment? Prices were estimated by calculating the impact of a hypothetical marginal change in spectrum on the costs of an “average firm” assuming the level of output and service quality were kept constant. For example, suppose a firm operating in Use I were provided an extra unit of spectrum. The marginal benefit would be equal to the cost savings the firm would enjoy were it to have the additional unit of spectrum.

Smith-NERA recommended that the price of spectrum be set equal to the estimated marginal benefit in a sector. This recommendation would result in the most efficient firms using spectrum in each sector. There would be efficiency in the assignment of spectrum within each sector. However, productive efficiency would not be satisfied across all the sectors, as this requires that the marginal benefit values to be equal across the different sectors.

In Table 2, a hypothetical set of estimated marginal benefits for the different frequency bands in each use sector is presented. These values assume that output and service quality in each sector is fixed and would be based on a firm of average efficiency in each use sector. In the example in Table 2, the price of frequency band *a* would be 100 and the price for *b* equal to 60. For the purposes of our example, we can think Use I as being mobile and Use II being fixed links. The marginal benefit for Use III was not calculated.

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**Table 2: Estimated marginal benefits**

Uses	Frequency bands		
	<i>a</i>	<i>b</i>	<i>c</i>
I	100	-	-
II	-	60	-
III	-	-	-

Source: Author.

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The Smith-NERA approach thus far is *partial*, as it does not make comparisons between different categories of spectrum use, and it focuses on the potential gains stemming from changes in assignment within a sector.

The extension of the mobile and fixed link prices to other spectrum bands/uses can also be illustrated using the example given above. Assume that band *c* can be used by mobile services i.e. Use I in addition to Use III. Smith-NERA assumed that the value of band *c* to mobile services was the same as that for band *a*. The situation was as shown in Table 3 below.

**Table 3: Spectrum prices based on the marginal benefit in Use I**

Uses	Frequency bands		
	<i>a</i>	<i>b</i>	<i>c</i>
I	<b>100</b>	-	100
II	-	<b>60</b>	-
III	-	-	-

Source: Author.

The price for frequency band *c* was set at 100, based on the estimate for Use I in frequency band *a*. Note that if the value of band *c* to all users for Use III was substantially below 100, then this would have the effect of clearing band *c*.

If the value of band *c* or Use III was greater than 100, then some reassignment of spectrum between Use III users is possible. The extent of any reallocation of spectrum would depend on whether and how many Use III users had a value of spectrum less than 100, and on the ability of the spectrum manager to reallocate spectrum. (Note that the pricing shown in Table 3 does not allow for the possibility that the allocation of band *c* spectrum to Use I may reduce the marginal value of frequency band *a* in Use I.)

The application of AIP following Smith-NERA resulted in lower prices than those proposed: the Government set the prices below the values estimated by Smith-NERA (by at least 50 per cent), and the estimated values were modified further to take account of other factors (typically in a downwards direction).

The effect of reducing the prices depends on how prices were derived initially. For mobile and fixed link services the substantial reduction in prices may mean that some less efficient users would continue to use the spectrum, thereby reducing the extent of improvements in the efficiency of spectrum assignments (as compared with the situation in which the full Smith-NERA prices were set).

In the case of services/bands to which mobile or fixed link prices were applied, the reduction in prices has the effect of lowering the strength of incentives to reassign and reallocate spectrum. The impact on efficiency depends however, on the marginal value of spectrum in the current use. If this value were less than the fixed or mobile price applied to the spectrum, then the Smith-NERA prices may have been set too high and the reductions made by government may have had a beneficial effect. This would not be the case if the marginal value in the current use exceeded the fixed-mobile price.

The consultancy report noted above attempts to extend the original method by considering the possible reallocation of spectrum to different purposes. Essentially, the original report focused on the margin of substitution between a given band and alternative, non spectrum-based inputs producing the same outputs. The new approach considers the implications of an additional margin of substitution — between one band and another. A list of AIP in force in 2002 is given in the Annex hereto (it was subject to minor modifications in 2003).

In 2002, the Government indicated a willingness to extend the regime more broadly – essential to all areas not covered by binding constraints on alternative uses. These would include a greater proportion of defence spectrum, maritime and aeronautical spectrum's (except for certain bands) and broadcasting. It commissioned the consultancy study referred to above to make proposals on the coverage and level of AIP.

The obligation to pay AIP for spectrum has met with considerably varied responses from those organizations which have to pay it. Private sector bodies would prefer not to pay, although the amounts charged to date (rising over four years to one half of the original estimate of the opportunity cost) have been low, and the coverage small. It seems reasonable to predict therefore, that the likely

outcome of the current review — raising AIP to the full estimate of opportunity cost and extending the coverage — will be poorly received.

Public service broadcasters have been particularly vociferous in their objections to paying AIP for spectrum. They argue that their coverage obligations leave them no latitude over spectrum needs, hence AIP will not encourage economy in spectrum use. They also argue that AIP may hamper the objective of analogue switch-off in TV broadcasting, which the Government hopes to achieve by between 2006 and 2010. In its *Response to the Review of Radio Spectrum Management*, the Government was notably cautious over AIP for broadcasters.

Finally, for public sector bodies producing non-marketed services, AIP are a cost which cannot be recovered by raising charges. If the same level of output is to be maintained, they may need to be compensated by higher funding from the Treasury. This raises the possibility that AIP are simply a reciprocal transfer of money between two government departments, with no incentive effects. Care must be taken to prevent this outcome.

## 5 UK Spectrum Auctions

As well as AIP, the 1998 Wireless Telegraphy Act authorized spectrum auctions. The first of these was carried out in 2000, with spectacular results. That first round of auctions raised around GBP 23 billion — well above the highest expectations.

The items under auction were five licences for the provision of 3G (also known as Universal Mobile Telecommunications System, or “UMTS”) services. The logic behind offering five licences was to add at least one new player to the market, in addition to the four existing GSM operators, Vodafone, Cellnet (later MMO<sub>2</sub>), One2One (later T-Mobile) and Orange. The regulator took steps to ensure that the new entrant would be able to roam on at least one existing GSM network, as it rolled out its facilities. It was recognized that the existing licensees had strong reason to seek 3G licences — to benefit from the economy of scope in the provision of 2G and 3G services and to hold on to their generally profitable 2G customers.

The licences were not identical. Two “large” licences, A and B (see Table 4), were accompanied by three small ones, with the largest licence, A, reserved for new entrants.

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**Table 4: The UMTS licences in the UK**

Licence	Paired spectrum MHz	Unpaired spectrum MHz	Total spectrum MHz	Minimum opening bid GBP million	Winner	Winning bid GBP million	GBP million/MHz (paired)
A	2 x 15	5	35	35	TJW	4385	292
B	2 x 15	0	30	30	Vodafone	5964	398
C	2 x 10	5	25	25	BT	4030	403
D	2 x 10	5	25	25	One2One	4004	400
E	2 x 10	5	25	25	Orange	4095	410

*Source:* Radiocommunications Agency, UK.

The auction process used was a simultaneous ascending one. In the first round, each bidder made a bid for the licence of their choice. To remain in the auction, each bidder had either to hold the top bid on one licence or to raise the bid on any licence by the minimum increment. The auction ended when only five bidders were left standing, with each paying their winning bid for the licence in question.

There were initially 13 bidders when the auction started on 7 March 2000, including the four existing operators and nine entrants. When it closed on 27 April after 150 rounds, licences went to the four

incumbents and to TSW, which began 3G services in 2003 under the name of “3”. Table 5 shows the pattern of bidding in the auction, with some bidders jumping from one licence to another, others, notably Vodafone, sticking on one or two licences throughout.

**Table 5: Pattern of bidding for UMTS licences in the UK**

Bidder	Final bid In round	Number of times bid for license					License Won
		A	B	C	D	E	
TJW	131	12	5	12	12	10	A
Vodafone	143	-	34	-	-	-	B
BT	149	-	23	8	13	27	C
One2One	146	-	-	12	16	13	D
Orange	148	-	16	-	-	8	E
NTL Mobile	145	23	-	12	13	4	
Telefonica	129	5	1	12	20	6	
Worldcom	117	4	-	14	15	7	
One-Tel	97	2	-	9	10	5	
Spectrumco	95	20	1	3	4	1	
Epsilon	94	-	-	13	9	6	
Crescent	90	-	-	8	13	6	
3G UK	89	3	-	8	10	10	
Total bids		69	80	111	135	103	

Source: Radiocommunications Agency, UK.

A review of the auction carried out by the UK National Audit Office (*Auction of Radio Spectrum for the Third Generation of Mobile Telephone*) pronounced favourably on the procedures adopted. The large sums raised however, to the tune of around ten times the amounts forecast at the outset, attracted much comment. It was asserted, variously, that bidders continually revised their business plans for 3G as the auction continued, on the basis of other bidders’ behaviour, engendering herd-like behaviour; that the bids for 3G captured expected future 2G profits, as an operator unable to offer 3G service would lose 2G business (note that this is not very plausible as the overall level of bids was set not by one of the incumbents but by the entrants — it was competition among them for the fifth licence which forced prices up), and that the restrictions placed on use of the spectrum and a resale of the licence forced investors into a knife-edge “all or nothing” decision.

This last point reflects the fact that the licences were for 25 years, with no provision for resale in the interim. A licence which was not used would simply have to be handed back with no payment in return. Licences also carried network roll-out conditions, departures from which could lead to their withdrawal.

The next licence auction conducted in the UK, this time for fixed wireless broadband licences, took place six months later, and resulted in a completely different outcome. Forty-two licences were made available, three in each of fourteen regions, with reserve prices of between GBP 4 million for Greater

London and GBP 100,000 for Northern Ireland. The auction opened and closed quickly, with six bidders taking sixteen licences in seven of the regions. The remainder were left unsold.

The RA's *Summary Report on 28GHz Auction* noted that deteriorating stock market sentiment in the previous six months had depressed bids for what was a commercially untested service. On a brighter note, the Agency highlighted that, contrary to fears expressed after the 3G auction, the fact that prices paid were at or a little above the reserve price demonstrated that auctions do not inevitably lead to spiralling bids.

The RA made subsequent attempts to re-auction the remaining licences, and in 2002 changed the licence conditions to allow a broader range of uses. The RA's third auction took place in June 2003. Fifteen regional licences at 3.4 GHz were auctioned to provide public fixed wireless access, especially to SMEs and high-usage residential customers. After 41 rounds, thirteen went to one company, PoundRadio, for a total of GBP 6.3 million, while Red Spectrum and Public Hub each paid GBP 330,000 for one licence. The process attracted little publicity.

The United Kingdom's experience has thus run the gamut of outcomes, from unexpectedly high to unexpectedly low. To evaluate the processes properly though, more experience will have to be gathered, ideally in an environment of post-auction trading.

## **6 Spectrum trading**

The auctioned licences described above were tied to a particular use, and essentially took the form of apparatus licences. Licensees received authorization to locate specified equipment of given power in specified locations. As discussed in Section 2, spectrum trading can take various forms. The introduction of trading, in which the use of the spectrum is fixed, is consistent with apparatus licensing; the licence simply changes hands. Reconfiguration of the licence by time and space presents relatively few problems to the approach: the apparatus has been licensed to avoid interference, and disaggregating a licence or aggregating licences should have no major impact. When a change of use is contemplated though, the apparatus licensing approach does not work, as a change of use will almost by definition involve a change of apparatus. This is why spectrum trading permitting change of use imposes such fundamental changes on the regime of spectrum management. According to exponents of market-based spectrum management methods though, change of use is necessary to provide the flexibility in spectrum allocation necessary to ensure that it is efficiently used and to avoid bottlenecks and artificial shortages resulting from "command and control" methods.

These considerations underlie Ofcom's *Spectrum Trading Consultation* of November 2003. In essence, tradable rights are to be created, defined in a number of technical and commercial dimensions. In relation to technical rights, Ofcom distinguishes transmission rights and interference. Commercial rights include licence term and conditions for licence termination.

In relation to transmission, Ofcom

"[...] is proposing is that WT Act licences which have been adapted for spectrum trading would define the right to transmit in terms of transmitted power or equivalent isotopically radiated power (eirp)  $e$  and a "spectrum mask". The right to transmit may also be specified in terms of conditions experienced at a defined geographic and/or frequency boundary. Together, these conditions should be broad enough to be technology-neutral, but sufficiently tightly defined that geographic boundaries could be managed effectively."

Ofcom further notes that:

"Protection from undue interference is of critical importance to users of the spectrum. Ofcom intends to publish guideline levels of interference for each licence class, and to establish a mechanism for ensuring that disputes regarding interference from third party radio equipment can be considered in a timely manner.

In a more liberalized environment there may be a greater chance of undue interference as a result of users making changes to the use of their licences. While there may be more activity in resolving interference issues, Ofcom will endeavour to ensure that it remains possible to achieve satisfactory

protection for all spectrum users, on the basis of the proposed mechanisms for approving proposed changes of use and for resolution of disputes.

In an environment where licensees may wish to trade their right to use spectrum, Ofcom may need to provide a more structured approach to resolving disputes which arise in relation to interference, and to provide clearer guidance as to when and how it will seek to resolve such disputes.”

In the United Kingdom, spectrum licences have traditionally been finite, but indefinite. The Government has exercised its right to give notice to licensees sometimes offering to transfer them, at the Government's expense, to another band. Such arrangements are part and parcel of the command-and-control model, in which decisions about the abandonment of technologies and re-use of spectrum are taken by administrative means.

However, greater clarity is needed when licences become tradable. Some argue that such licences should be perpetual, but the view taken by Ofcom is that “this would present difficulties for the management of spectrum, which has to have regard to considerations such as spectrum efficiency, international agreements and harmonization, public policy and competitive matters”. On this basis, Ofcom proposes that they should have a rolling term with a standard (but not invariable) notice period of five years. Durations of newly issued spectrum licences (primary assignment) would be chosen on merit, with the possibility of a longer initial term.

In relation to licence termination, Ofcom will retain the right to terminate licences for breaches of conditions, but may reserve the right to give notice of termination on other grounds — for example to counter excessive fragmentation of a band or deal with market failures in relation to spectrum licences. This important issue will have to be resolved in more detail before trading begins.

In order to introduce trading quickly, existing licences will have to be converted to tradability. The Government indicated in its October 2002 *Response to the Review of Spectrum Management*, that this would not involve recovering licences from existing incumbents and auctioning them. As a result conditions in existing licences will have to be changed, in ways which benefit existing licensees, whose assets will then become tradable.

This raises the vexed question of capital gains; the conferment of which may be a major and visible consequence of the introduction of trading. Such gains can be “taxed” in various ways, some of which jeopardize the benefits of trading by discouraging the realization of the gains.

In Ofcom’s plans the extent of windfall gains is limited by a proposal under which licensees of tradable spectrum would continue to pay administrative spectrum prices described above. This proposal is supported by other arguments, but one consequence is to reduce the capital value of spectrum, just as the capital value of land is introduced if the occupant has an obligation to pay an annual rent on that land.

Ofcom proposes a gradual transfer to spectrum to tradability over the period 2004-2007, as set out in Table 6.

**Table 6: Phasing of the introduction of trading**

Year	Licence class	Comment
2004	Analogue PAMR	Subject to the conclusions of the consultation currently underway on the future use of L-band and Band III spectrum (which includes bands currently used for PAMR).
	National paging	Spectrum possibly under-utilized – change of use configuration will be permitted.
	Data networks	Change of use and reconfiguration within the constraints of UK adoption of future possible harmonization for asset tracking.
	Fixed wireless access	Reconfiguration and change of use permissible within fixed services.
	National and regional PBR	Exclusive geographically defined channels – change of use within land mobile will be permitted.
	Common Base Stations	As national and regional PBR above.
	On-site PBR	As national and regional PBR above.
	5.8GHz Band C	Change of ownership only will be permitted from the end of 2004.
	32GHz	Currently vacant, tradability and flexibility in use will be permissible from the date of issue.
	Scanning telemetry	National channels use by utilities. Reconfiguration and change of use will be permissible.
	Fixed terrestrial links	Tradability and reconfiguration permissible – but not change of use owing to interference to neighbouring links.
	Sound broadcasting	Transfer of ownership of analogue sound broadcasting WT Act will be permissible. In addition, limited aggregation and partition of digital sound broadcasting WT Act licences will be permissible, to allow some trading of interference rights subject to fulfillment of Broadcasting Act obligations.
2005	Wide area PBR	Assignments in this category are shared, so trading will require recourse to MASTS (due to be completed in 2005) to monitor changing nature of use.
	Digital PAMR	Delayed until the completion of reassignment exercise in conjunction with the MoD.
	Programme-making and special events	Introduction of SMO-style programme-making licences in 2005 or later.
2006	Emergency services	Delayed until questions regarding the future organization and assignment of spectrum for emergency services have been resolved.
2007	Television broadcasting (analogue and digital)	Tradability in television broadcasting delayed until frequency plan of digital switchover, including international coordination considerations, anticipated by end 2007.
	2G and 3G mobile spectrum	Delayed subject to sufficient clarity over re-farming of 2G spectrum and release of 3G expansion spectrum.
	Aviation and maritime communications	Agreement by 2007 on tradability for ground-based aviation and maritime coastal communications rights of use. Changes of use will be permitted within the constraints of international harmonization and agreements, safety of life considerations, and with the agreement of sector regulators CAA and MCA.

	Radionavigation (radar)	Agreement on tradability of radio navigation rights of use between 2007 and 2009. Tradability and changes of use permitted within the constraints of international harmonization and agreement of sector regulators.
<b>Other</b>	Mobile satellite	Tradability subject to introduction of Recognized Spectrum Access.
	Satellite shared with terrestrial services	Tradability subject to introduction of Recognized Spectrum Access.

Source: Ofcom.

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## 7 Unlicensed spectrum

As the last topic of this paper we will look at the final mode of spectrum management, one which eschews licensing completely, making the spectrum licence-exempt and allowing access to any user satisfying certain conditions (relating to, for example, the power of equipment utilized). A list of bands which are currently licence-exempt is given in Table 7.

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**Table 7: Unlicensed spectrum in the United Kingdom**

<b>Generic frequency band</b>	<b>Application</b>
9 kHz to 30 MHz	Short range inductive applications
27 MHz	Telemetry, telecommand and model control
40 MHz	Telemetry, telecommand and model control
49 MHz	General purpose low power devices
173 MHz	Alarms, telemetry, telecommand and medical applications
405 MHz	Ultra low power medical implants devices
418 MHz	General purpose telemetry and telecommand applications <sup>1</sup>
458 MHz	Alarms, telemetry, telecommand and medical applications
864 MHz	Cordless audio applications
868 MHz	Alarms, telemetry and telecommand applications
2400 MHz	General purpose short range applications, including CCTV and RFID. Also used for WLANs, including Bluetooth Applications
5.8 GHz	HiperLANs, general purpose short range applications, including road traffic and transport telematics
10.5 GHz	Movement detection
24 GHz	Movement detection
63 GHz	Second phase road traffic and transport telematics
76 GHz	Vehicle radar systems

Source: Ofcom

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<sup>1</sup> This band is to be withdrawn by December 2007.

Unlicensed spectrum has caught the imagination in the United Kingdom, as elsewhere, as a result of the development of Wireless Fidelity, or “Wi-Fi” hotspots, offering Internet access to nomadic users over a small radius. Following a consultation, the UK Government permitted operators to provide commercial services using unlicensed spectrum. This has allowed, for example, the supply of paid Wi-Fi services in areas such as coffee shops.

In its *Strategy for the Future use of the Radio Spectrum in the UK* (2002), the RA noted that:

“Licence-exemption can offer significant advantages for users, particularly the cost savings and convenience resulting from the possibility of using radio equipment without the need to apply for a Wireless Telegraphy Act Licence and a specific spectrum assignment. This offers obvious advantages in relation to mass-produced items for domestic use, such as remote controls or garage-door openers, for which individual licensing would not be feasible, and for private users or small businesses who wish to use radio equipment in a domestic or office setting. The Agency has made a number of bands available on a licence-exempt basis and these are set out in Exemption Regulations which are reviewed periodically.

[...]

Licence exempt bands are not centrally coordinated and interference between devices on the same frequency is limited to some extent by the power limitations imposed in the Interface Requirements. The self-evident limitation of uncoordinated licence-exempt bands is that there can be no guarantee of any Degree of spectrum quality for users in any given area, who must expect that on occasions there will be instances of co-channel interference. Moreover, the Agency is aware that short range low power devices for mass market applications invariably have limited receiver performance in terms of poor selectivity. This renders them liable in particular to interference from generally higher power devices operating in adjacent licensed bands.

As the number of short range wireless applications increases, it is possible that, in some areas of dense use, the noise floor will increase and new techniques may be required to ameliorate the effects of interference. Such techniques are available in the form of technologies to improve channel access generally through dynamic frequency selection and power control. Nevertheless, the Agency is aware that under extreme conditions there will be limitations through possible congestion and intends to work with industry to ensure that these are understood by potential users, particularly in regard to the unprotected nature of deregulated spectrum.

Another potential difficulty, from a spectrum management point of view, is that the process of deregulating a band is very difficult to reverse, as there will be no record of the equipment used in the band and no way of requiring its use to be discontinued other than the slow process of withdrawing the relevant UK Interface Requirement and waiting for the items in use to reach the end of their life.”

In the *Spectrum Trading Consultation*, Ofcom notes that:

“Where Ofcom is satisfied that particular radio equipment is not likely to involve any undue interference with wireless telegraphy, Ofcom will be required to exempt the use of that radio equipment from the general obligation to obtain a WT Act licence. As part of this process, the RA is currently considering the possibility of deregulation in certain licence classes. For example, it may be possible in future to exempt on-board maritime spectrum use from individual licensing. In future, as technologies such as software-defined radio advance and become more widespread, Ofcom may make much greater use of licence exemption as a spectrum management tool, rather than issuing tradable licences.”

As an illustration of this approach, In October 2003, the RA published a consultation document on *Use of the 2010 to 2025 MHz Band for the Provision of 3G Telecommunications Services*. This is of interest since for the first time it sought views on whether the band should be employed for licence-exempt self-providing applications or whether it should be licensed.

## **8 Conclusion**

This paper has given an overview of the major changes in spectrum management under way in the United Kingdom. If all plans are realized, by 2007 almost all high-value spectrum will be subject to price and market instruments, and most of it will be tradable. The UK experience is thus likely to provide the first valuable information on the operation of economic incentives in frequency management in Europe.

## Annex: Spectrum pricing implementation

Sector	Smith/NERA recommendation on incentive pricing	Basis for prices	Date of introduction of incentive pricing (or other measures taken e.g. simplification)	Phased Introduction period position proposed for July	Full implementation date	Fixed Sum (Administrative)	Fee rate (£/MHz/Km <sup>2</sup> )	Annual accrued fees received for 2000 - 2001
<b>Aeronautical</b>	Administrative pricing limited to TFTS, channel 36. Needed to recognize international dimension for the pricing of ground station.	Set relative to alternative use.	Simplification of Ground Station licence classes (July 2000). Radar deferred for further study. No demand for TFTS.	N/A	N/A	Range £20 to £250	N/A	£0.3 M
<b>Aircraft</b>	All aircraft share the same spectrum worldwide.	Cost recovery only, flat fees.	Simplification of licence classes (July 2000).	N/A	N/A	Range £15 to £350 by aircraft size and usage.	N/A	£0.6M
<b>Amateur/citizens' band</b>	Administrative pricing not appropriate.	Cost recovery only, flat fees.	Simplification of licence class (July 2000).	N/A	N/A	£15 for most users.	N/A	£1.2M
<b>Broadcasting (Audio and TV only)</b>	Administrative pricing seen as worthwhile, subject to resolution of policy issues.	Cost recovery only, flat fees at pre-1998 levels.	N/A	N/A	N/A	N/A	N/A	£4.9M
<b>Fixed links</b>	Administrative pricing seen as worthwhile. Set relative to cost of alternate services.	Standard (fixed) Tariff Unit. Scaled to reflect efficiency and congestion.	From 1998 (for point to point) other products from 1999.	Year 3 of 4	July 2002	N/A	Up to £1.05 ≡ £925 fixed link reference fee <sup>φ</sup>	£18.3M

<sup>φ</sup> Licence fee = Fixed Links Reference Fee x Frequency Band Factor x Adjusted Bandwidth Factor. This is equivalent to using the STU of GBP 1.05

<b>Sector</b>	<b>Smith/NERA recommendation on incentive pricing</b>	<b>Basis for prices</b>	<b>Date of introduction of incentive pricing (or simplification of sector)</b>	<b>Phased Introduction period position proposed for July 2001</b>	<b>Full implementation date</b>	<b>Fixed Sum (Administrative)</b>	<b>Fee Rate (£/MHz/Km<sup>2</sup>)</b>	<b>Annual accrued fees received for 2000 - 2001</b>
<b>Maritime</b>	Administrative pricing seen as only worthwhile for Maritime Business Radio. Need to recognize international dimension for pricing maritime use.	Benchmarked from other mobile prices.	Rationalization July 2000.	N/A	N/A	Range £75 to £1000 per channel of base station.	N/A	£0.3M
<b>Ships</b>	Administrative pricing seen as worthwhile. All ships share the same spectrum worldwide.	Cost recovery only, flat fees.	Rationalization from July 2001.	N/A	N/A	£15 to £20 from July 2001.	N/A	£1.3M
<b>Private business radio</b>	Administrative pricing seen as worthwhile.	Standard (mobile) Tariff Unit or scaled proportion according to congestion or pricing incentives.	From July 1998.	Several classes each year	July 2000.	N/A	Up to £1.65	£8.1M
<b>Programme making and special events</b>	Administrative pricing seen as worthwhile. Recommend that account be taken of the mobile & fixed STU.	Incentive pricing introduced from July 2001.	From July 2001.	Year 1 of 4	July 2004.	Range £2 to £2,400 depending on channel and/or region.	N/A	£1.1M

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<b>Sector</b>	<b>Smith/NERA recommendation on incentive pricing</b>	<b>Basis for prices</b>	<b>Date of introduction of incentive pricing (or simplification of sector)</b>	<b>Phased Introduction period position proposed for July 2001</b>	<b>Full implementation date</b>	<b>Fixed sum (Administrative)</b>	<b>Fee Rate (£/MHz/Km2)</b>	<b>Annual accrued fees received for 2000 - 2001</b>
<b>Public telecom networks</b>	Administrative pricing seen as worthwhile. Set relative to cost of alternate services.	Standard (Mobile) Tariff Unit.	From July 1998.	Year 4 of 4 for public telephony	July 2001	N/A	Up to £1.65	£40.0 M
				2 of 4 for RFA	July 2003	N/A	Up to £1.65	£0.8M
				3 of 4 other PMO	July 2002	N/A	Up to £1.65	£2.9M
				3 of 4 for CBS	July 2002	N/A	Up to £1.65	£0.7M
<b>Satellite uplinks (inc. PES, TES &amp; VSATS)</b>	Administrative pricing seen as worthwhile, incentive pricing should be applied to all licensing products.	Benchmarked from Standard (fixed) Tariff Unit.	July 2001.	Year 1 of 2	July 2001 (TES) Oct 2001 (PES)	N/A	Up to £1.05 (using benchmarking)	£2.9M
<b>Scanning Telemetry</b>	Administrative pricing seen as worthwhile. Benchmarking to PBR.	Cost recovery, plus introduction national channel which is incentive priced.	July 2001 National incentive priced channel.	Year 1 of 2	July 2002.	£40 per station or £7,920 national channel.	Up to £1.65	£0.4M

## Spectrum Management - Case Study on the United Kingdom

Sector	Smith/NERA recommendation on incentive pricing	Basis for prices	Date of introduction of incentive pricing (or simplification of sector)	Phased Introduction period position proposed for July 2001	Full implementation date	Fixed Sum (Administrative)	Fee Rate (£/MHz/Km2)	Annual accrued fees received for 2000 - 2001
<b>PUBLIC USE</b>								
<b>Defence</b>	Administrative pricing seen as worthwhile.	Set relative to fixed links, mobile radio fees depending on the band.	1999	Year 3 of 3	2001	N/A	As for appropriate PMO or Fixed links	£22.7M
<b>Home Office</b>	Not covered. RA have taken same approach as Defence.	As Defence.	2000	Year 2 of 4	2004	N/A	(As previous.)	£1.0 M
<b>Radio Astronomy, space research, meteorology</b>	Administrative pricing seen as worthwhile, although there are some policy issues.	Needs further consideration.	N/A	N/A	N/A	N/A	N/A	£0.3 M

Note: STU = Standard Tarif Unit. £ = GBP.

Source: RA- Spectrum Strategy 2002 Annex D.

**UK Spectrum-Related Enactments and Official Documents since 1998**

Auction of Radio Spectrum for the Third Generation of Mobile Telephone, NAO, 2001.

Communications Act 2003.

Government Response to the Review of Radio Spectrum Management, 2003.

Implementing Spectrum Trading; Consultation Document, RA, 2002.

Review of Radio Spectrum Management, 2002.

Spectrum Trading Consultation, Ofcom, 2003.

Strategies for the Future Use of the Radio Spectrum in the UK, RA, 2002.

Summary Report on the 28 GHz Auction, RA, 2001.

Use of the 2010 to 2025 MHz Band for the Provision of 3G Telecommunications Services: Consultation Document, RA, 2003.

Wireless Telegraphy Act 1998.