



Appendix A: Our current practice in setting AIP fees

An appendix to SRSP: The revised Framework for
Spectrum Pricing

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Appendix A

Our current practice in setting AIP fees

Outline of this appendix

1.1 This appendix outlines the steps we have followed to date in setting AIP fees. During our workshops several stakeholders commented that our current practice in setting AIP fees was not widely understood. This appendix explains our current methodology and describes how we have set fees in the past.

Stages involved in the calculation of AIP and cost-based fees

1.2 To date, we have mainly carried out fee reviews by licence class. Our pricing proposals normally apply to all licences within the licence class under consideration. A licence class will normally span several frequency bands and will include those licences that provide users with the right to access one or more of the bands allocated to the licence class (e.g. from 26 to 466MHz in the Business Radio classes, or from 1.35 to 57GHz in Point to Point Fixed Links).

1.3 In the rest of this appendix, when we speak of pricing of specific bands, we mean setting fees for licences giving users in the licence class in question access to the bands allocated to it¹. Figure 1 outlines the key steps involved in the calculation of licence fees for specific bands. Our general approach involves two stages:

- Stage one - determine whether or not an AIP fee is likely to promote optimal use, taking into account the circumstances of the band and of current and potential alternative uses;
- Stage two - where AIP is appropriate, set AIP fees for licences giving access to those bands.

1.4 Stage one comprises the following two steps:

- Step 1. Identify the existing and potential alternative uses of the bands within the relevant timeframe;
- Step 2. Determine whether there is excess demand for that spectrum from one, or both of those uses.

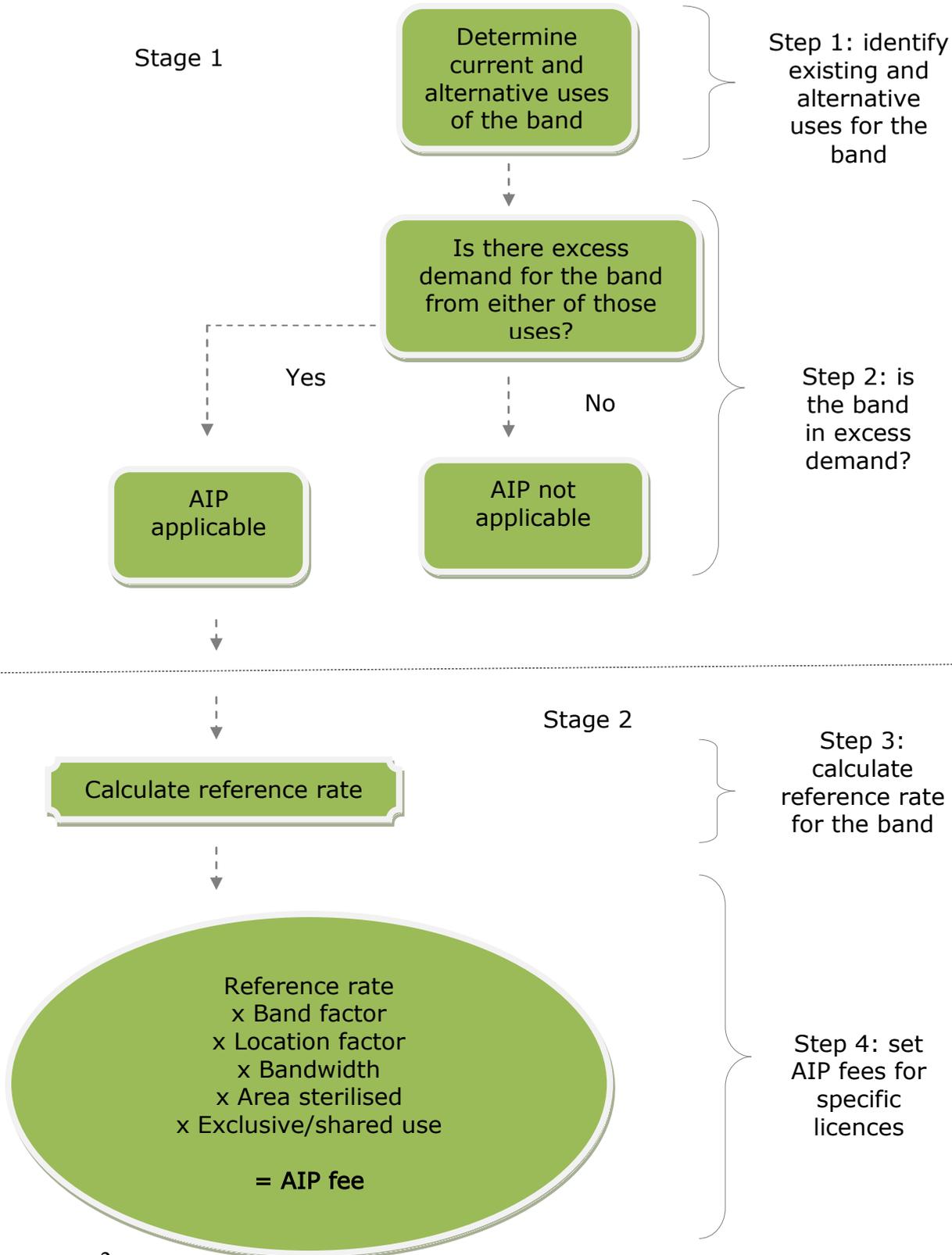
1.5 Stage two involves two further steps which are taken only if we consider AIP is applicable.

- Step 3. Calculate the reference rate to reflect the opportunity cost of spectrum in the bands;
- Step 4. Set AIP fees for individual licences based on the specific nature of licensed use.

¹ To illustrate, when to speak of our pricing of Business Radio bands we mean the pricing of licences giving users access to the 'highly popular', 'medium popular' and 'less popular' bands used by the Area Defined and Technically Assigned Business Radio classes.

1.6 In Sections 3 and 4 of the consultation document we outline how we propose to continue with this approach, including how we propose to make the assessments in Stage one, and makes proposals for adopting refinements to our methodology for general application to any future fees review.

Figure 1: Stages and steps in the calculation of spectrum fees



Step 1. Identifying existing and alternative uses for each band

- 1.8 We assess the demand for spectrum used by a licence class by identifying the range of potential uses of that spectrum. In general, current observable spectrum demand will come from the existing uses in the form of congestion. For example, the level of demand from the existing use may be indicated by whether or not it is difficult to meet new requests for assignments in those bands (or at certain locations) from the current users.
- 1.9 However, there may also be demand from other sectors of industry. This demand from alternative uses may not be apparent to existing users if this use is not permitted. However, operators of alternative uses may face shortages of spectrum that could be alleviated if the bands in question were made available to them:
- in some cases, existing uses could co-exist in bands with these alternative uses. For instance, alternative uses could be accommodated by Ofcom making licences for both types of use available in the band, or by a new user buying an existing licence in a trade and then seeking any necessary changes to the licence conditions to enable the new use;
 - in other cases, the alternative use might be incompatible with the existing use.
- 1.10 When identifying possible alternative uses for a specific band, we need to assess whether this alternative use could realistically use that spectrum within the relevant timeframe.
- 1.11 In our informal pre-consultation, stakeholders asked us to clarify what we took into account when determining whether a use was feasible and what the relevant timeframe is that we apply when considering whether demand from an alternative use for spectrum is realistic. Section 3 of our consultation document sets out our analysis and proposals for deciding both of these issues.

Step 2. Assessing excess demand from existing and alternative uses

- 1.12 When considering whether or not to apply AIP we consider two key questions;
- **Question 1** Does demand for the current use exceed supply, now or in the future, over the relevant timeframe?
 - **Question 2** Is it feasible in the relevant timeframe to use this spectrum to meet excess demand for the alternative uses identified in Step 1?
- 1.13 Section 3 of the consultation document explains that we use congestion in the existing use and demand from alternative uses in other bands as an indicator of excess demand. We outline below the different approaches to assessing congestion and demand from alternative uses that we have taken in fee proposals to date.

The relevant dimensions of congestion

- 1.14 The degree of congestion experienced in individual bands and locations will be determined by the existing capacity (the available supply) and the demand for that spectrum.

- 1.15 Both demand and supply have a frequency and a geographical dimension². Broadly, individual licences in a licence class will provide users with a right to transmit on a specific set of frequencies, and either:
- a) over a given coverage area, which may be:
 - directly specified in the licence, as with national cellular, area defined business radio, area defined international maritime VHF or fixed wireless access licences (**'explicit area licences'**); or
 - implicitly defined by the technical specifications of the licence (i.e. specified power and antenna height), as with technically assigned business radio or technically assigned international maritime simplex VHF licences (**'implicit area licences'**); or
 - b) between two points or locations, as in fixed terrestrial point-to-point links or satellite earth stations (**'point to point licences'**).
- 1.16 As regards the available supply, each frequency band and location will typically have a finite capacity to accommodate transmissions of a given type at any point in time. The limit to the number of assignments and services that can be accommodated in any given band and area will be largely determined by the need to keep interference to an acceptable level.
- 1.17 The demand for spectrum may vary greatly between frequency bands and locations. Due to their propagation characteristics, some bands will be more popular than other bands in the same area. Equally, a band may be in high demand at certain geographical locations but not in others:
- for implicit and explicit area licences, demand will be area-specific. For instance, in business radio demand for the High Band, UHF1 and UHF2 bands is very high and making new assignments is difficult in the Central London area, but those bands are less congested in other parts of the UK;
 - for point to point licences, demand will occur at specific sites or along defined routes. For example, for some point to point fixed link bands usage is high at certain busy sites along roads, or on hills, or simply where there are already masts to which antennae can be fitted.
- 1.18 In general, when evidence indicates that congestion varies significantly between frequency bands or locations, we have sought to assess it band-by-band and location-by-location, and set fees informed by this assessment, if it is practical and proportionate to do so. We were unable to do this on a geographic basis when we last set fees for fixed link licences, for reasons set out below.

How we measure congestion in existing uses

- 1.19 To assess congestion in individual bands and locations, we still use many of the criteria originally developed by the RA in consultation with stakeholders. It is necessary to use different criteria depending on the type of licensed use.

² A third dimension, time, may be relevant in some cases. For programme making and special events (PMSE), existing capacity may be lower than demand only infrequently at large events (e.g. the British Formula One Grand Prix) in specific locations and at certain times. Alternatively, demand may regularly outstrip supply during the course of normal day to day usage.

Measuring congestion in bands and locations used by implicit area licences

- 1.20 Implicit area licences (e.g. technically assigned business radio licences) typically provide coverage over a small geographical area from an assigned base. The difficulty we experience in making new assignments of this type varies by band and geography. In some bands and areas, we rarely need to reject requests for new assignments outright, although we are often unable to meet users' preferences with respect to their first choice of frequency band and users have to accept an assignment in an alternative band.
- 1.21 To measure congestion we follow a similar grid-based approach developed by the RA in relation to Private Mobile Services³. In respect of shared users, the RA measured channel loading (i.e. traffic levels) during busy hours in certain shared PBR channels operating in 10km x 10km squares. Each channel was then classified as heavily congested, congested or non-congested based on its blocking probability (i.e. the proportion of unsuccessful calls experienced). On that basis, the RA considered the VHF High Band, UHF Band 1 and UHF Band 2 heavily congested in some squares, while other bands (Band 1, Low Band, VHF Mid Band and Band III) were classified as non-congested throughout the UK. For national and regional exclusive channels, the RA based the classification of bands on that used for shared channels in the same band.
- 1.22 We refined this approach for Technically Assigned business radio licences in 2007 by creating three rather than two congestion categories for both shared and exclusive channels⁴. We now categorise each band as Highly Popular, Medium Popular or Less Popular based on the number of assignments throughout the UK (relative to the existing capacity).
- 1.23 From our assignment system (Unify) we are able to produce maps of the UK that, for the purposes of fees setting, we have on occasion used to assess the density of assignments in each band and to identify whether individual bands are more or less congested. We no longer measure the channel loading of shared channels, but rather assess their level of congestion based on the assignment of channels as described above.
- 1.24 As regards geographical congestion for these licences, we divide the UK into a 50km x 50km grid and classify each square according to three categories of High Population, Medium Population or Low Population. In assessing congestion from business radio use, we use population density in each square as a proxy for congestion in that square. Case Study 1 below explains in greater detail our approach in Technically Assigned business radio licences.

Measuring congestion in bands and locations used by explicit area licences

- 1.25 Licences with explicit geographic rights (e.g. cellular and area defined business radio licences) are typically for users who operate over large geographical areas, like the whole of the UK, GB or an individual nation within the UK. They normally have well defined geographical boundaries.

³ That is, shared and exclusive PBR licences, now incorporated under the technically assigned business radio licence class. The approach is explained in Radiocommunications Agency. *Spectrum Pricing. Implementing the Second Stage. A Consultation Document* (1998), pages 23-25.

<http://www.ofcom.org.uk/static/archive/ra/rahome.htm>

⁴ *Modifications to Spectrum Pricing Statement* (2007), pages 11-12 and 15.
<http://www.ofcom.org.uk/consult/condocs/pricing06/statement/statement.pdf>

- 1.26 In respect of congestion in the 900 and 1800MHz cellular bands, we follow the criteria developed by the RA and stakeholders⁵. The RA's approach was to consider 900 and 1800 MHz uniformly congested in the UK, because they were allocated to a small number of operators on the basis of demonstrable need to meet their traffic demands, and were in high demand from these and other operators. We continued with this approach in our pricing proposals in 2005, where we proposed no changes in fees.
- 1.27 For Area Defined business radio licences, requests for these licences are particularly difficult to meet in some cases due to their wide geographical coverage. We capture variations in frequency congestion by using the same band classification (Highly Popular, Medium Popular and Less Popular) as technically assigned business radio licences. As regards geographical congestion, we consider each band to be uniformly congested throughout the UK and do not distinguish between high, medium and low population areas. Fees for the defined areas of England, Wales, Scotland and Northern Ireland simply apportion the UK channel rate on a pro-rata population basis. The exception are fees for licences covering 50km x 50km grid squares, which are categorised as high, medium and low population as above for technically assigned licences. This is explained in Case Study 1.

Case Study 1: How we currently reflect congestion in existing use

Technically Assigned and Area Defined Business Radio licences⁶

To reflect geographical variations in congestion in technically assigned licences (and for area defined licences that partition their licences through trading into smaller geographical areas), we divide the UK into a grid of 50km x 50km squares which are then grouped by population density, as follows:

- Category A - High population density - representing a population of greater than 3 million (London);
- Category B - Medium population density - representing a population of between 300,000 and 3 million (e.g. Leeds);
- Category C - Low population density – representing a population less than 300,000 (e.g. rural areas).

We use population as a proxy for geographical congestion in the belief that demand is greater in areas of high population density and most business radio licences are held by organisations serving the general population (taxis, utilities, public transport operators, etc.). Population is also an easily observed and objective measure.

We reflect variations in congestion by frequency by pooling individual bands into groups of bands experiencing similar levels of congestion. We updated the RA's band classification based on the number of assignments in each band throughout the UK. We further determined that bands that are less popular due to propagation characteristics, the large antenna size required and lower availability of suitable equipment deserved a separate classification. Hence, we added a new category of Less Popular bands as follows:

- Highly Popular bands (High Band, UHF1 and UHF2), in high demand and heavily congested;

⁵ Ibid, page 19.

⁶ *Modifications to Spectrum Pricing Statement* (2007).
<http://www.ofcom.org.uk/consult/condocs/pricing06/statement/statement.pdf>

- Medium Popular bands (Mid Band and Band III), also in demand and congested (at the current level of AIP), though less so than highly popular bands;
- Less Popular bands (Paging, Band I and Low Band), which are in less demand because of their propagation characteristics.

In a recent consultation, we reviewed the status and fee levels for Band I⁷. Given regulatory restrictions on its use and the comparatively poor quality of the spectrum at these frequencies (in particular the levels of interference it suffers due to bi-lateral co-ordination agreement with our neighbouring countries), we reviewed the fees and proposed that they should instead be set at a level to contribute to our administrative costs.

Measuring congestion in bands and locations used by point to point licences

- 1.28 Point-to-point licences (e.g. fixed point to point licences) permit users to transmit between two fixed points. Unlike implicit or explicit area licences, congestion here occurs at specific sites or along defined routes, and a grid-based approach may not be appropriate. As a result, measuring congestion in specific bands and sites/routes used by these licences has been challenging.
- 1.29 Originally, the RA followed a grid-based approach that considered individual bands and squares as congested if assignments were difficult to make or required modification (such as the installation of higher performance antenna or reduced link availability). The 'difficulty' thresholds were determined by statistical methods. The RA produced maps showing congested squares in each of the three bands it considered congested (4, 7.5 and 13/14GHz). Individual links operating in those bands and beginning or ending in a congested square attracted a higher fee than equal links operating in a) congested bands and uncongested squares, or b) uncongested bands⁸.
- 1.30 In 2003, the RA proposed to move away from a coarse geographic approach based on grid squares to one based on precise nodes or sites to recognise the site or route-specific nature of demand for fixed links⁹. Specific sites would be considered congested if more than a certain percentage of the available spectrum had been assigned. A geographical 'congestion modifier' would then increase the fee in congested sites at either or both ends of the link¹⁰.
- 1.31 However, establishing consensus on the appropriate percentage proved difficult. On a fixed links site, it is not unusual for most links to point in the same azimuth directions along the main trunk routes, with few or no links pointing in other directions. Hence, while a site might be highly congested in certain azimuth directions, assignments in other directions might be easily accommodated. In addition, the industry considered that the resulting fees might adversely affect incentives for site-sharing. In view of these considerations, Ofcom did not take the RA's proposals further forward.

⁷ *Review of Radio Licence Fees in Band I* (2009). <http://www.ofcom.org.uk/consult/condocs/bandi/statement/br.pdf>

⁸ Specifically, a reference rate of £925 per 2x28MHz was applied to all links. Where links used spectrally efficient equipment, a band factor of 1 was applied to congested bands (4, 7.5, 13, 14GHz and 15GHz Bands), while non-congested bands between 18 and 28 GHz had a factor of 0.95 and the 38GHz bands one of 0.75. For links operating in congested bands and uncongested areas, or those operating in uncongested bands, the reference fee of £925 was reduced over a three year period.

⁹ Radiocommunications Authority. *Spectrum Pricing, Year Six. A Consultation Document* (March 2003), paragraph 2.12. <http://www.ofcom.org.uk/static/archive/ra/rahome.htm>

¹⁰ Specifically, the modifier was set at 1, 0.7 or 0.5 depending on whether both, one or neither link end was congested. A link end was defined as congested when at least half of the available slots had been assigned. The number of available slots at a node was defined as twice the total number of 28 MHz channels in that band. When a link end was congested, any other link end within a circle of radius 500 m from the congested link end would be treated as congested for charging purposes.

- 1.32 As a result, we currently make no attempt to measure congestion in bands or sites used by fixed links for the purpose of developing relative fee rates:
- As regards congestion by frequency band, the fixed link algorithm includes a 'band factor' that reduces the AIP fee in higher bands (from 1 at 1.35GHz to 0.17 at 57GHz).;
 - As regards geographical congestion, the algorithm does not contain a location factor to reflect geographical variations in congestion.

How we assess demand from alternative uses

- 1.33 Demand from alternative uses is difficult to gauge since, by definition, these are uses which do not currently operate in the band. In practice, when assessing demand from alternative uses for a specific band used by a licence class:
- we determine whether the bands used by the alternative uses are broadly substitutable with the band we are assessing and are congested; and
 - if so, we assess whether the band under examination could be used to mitigate congestion in those other bands via AIP.
- 1.34 If the answer is yes, we apply an AIP fee to the band or location, even if we find no congestion in its existing use. For example, the use of reduced bandwidths by the current users or their moving to less congested bands could make spectrum available for alternative uses.

Step 3 calculating reference rates

- 1.35 In this section we discuss our current approach to calculating reference rates in Step 3 of our methodology. The reference rate is our best estimate of the market value or opportunity cost of a block of spectrum of a given size (e.g. 2x12.5kHz) in the bands and locations used by the licence class. It is the main parameter used to derive the AIP fee for individual licences.

The role of reference rates in setting AIP fees

- 1.36 If in steps 1 and 2 of our AIP methodology we have determined that AIP is likely to promote optimal use in some or all bands used by a licence class, we must then calculate the appropriate reference rate.
- 1.37 If it is appropriate to apply AIP to many bands (and locations) within the licence class under consideration, we must decide how many rates to estimate. If we derive a single reference rate for several bands (and locations) that are likely to have different market values, in Step 4 we must adjust that rate via a band factor (and a location factor) to capture value differences between bands (and locations) subject to the same rate.
- 1.38 At present, fees have been set using different combinations of rates and band factors depending on the licence class:
- We may calculate a single rate for each licence class and then average rates for different classes to produce a single rate for those, which is applied across bands licensed to those classes. This approach was taken by the RA in setting a

'spectrum tariff unit' which was applied to cellular mobile and two business radio classes. The rate is then adjusted in Step 4 by a band factor and a location factor, where relevant, specific to those licence classes, to capture value differences between bands and locations (see Case Study 2);

- In other cases there is a single rate for all AIP bands (and locations) used by the licence class in question – for instance, all AIP bands (between 1.35GHz and 57GHz) used by fixed links attract a single rate, which is then adjusted in Step 4 via a band factor (see Case Study 2).
- Finally, in other cases there is a specific rate for each individual AIP band used by a licence class. This obviates the need for a band factor – for instance, in our second consultation on the detailed design of the award of spectrum to a band manager with obligations to PMSE, we proposed one rate per band¹¹.

1.39 In the rest of this section we explain how we estimate a single reference rate for an individual band or for a number of bands used by a licence class, which can then be averaged with rates for other licence classes if required.

Case Study 2: reference rates and band factors for selected radio applications

Use	Reference rate	Unit
Business Radio and Cellular 2G	£1.65	per MHz per km ²
Fixed Links (1.35GHz-57GHz)	£88	per 2x1 MHz for each bi-directional link

The 'mobile' reference rate of £1.65 per MHz per km² was first set by the RA and is common to business radio, cellular 2G and other 'mobile' classes¹². The rate equals £9,900 for a 2 x 12.5 kHz national channel in business radio or £158,400 per 2 x 200kHz channel in 2G cellular use¹³.

In business radio (which operates from 26 MHz to 466MHz), the £9,900 rate is adjusted with a band factor of 1, 0.83 or 0.33 (area defined licences) or 1 and 0.83 (technically assigned licences) based on the degree of congestion of different bands, as determined in Step 2.

The reference rate of £88 per 2x1 MHz bi-directional link was calculated in our Spectrum Pricing Consultation¹⁴. It is applied to fixed links operating between 1.35GHz and 57GHz. The rate is adjusted via a band factor with six possible values (1, 0.74, 0.43, 0.30, 0.26 and 0.17) to recognise variations in the value of those bands.

¹¹ *Digital Dividend Review: Band Manager Award Consultation on Detailed Award Design* (2008), paragraph 8.33.

<http://www.ofcom.org.uk/consult/condocs/bandmgr/condoc.pdf>

¹² *Spectrum Pricing. A Statement on Proposals for Setting Wireless Telegraphy Act Licence Fees* (2005), paragraph 3.19.

http://www.ofcom.org.uk/consult/condocs/spec_pricing/statement/statement.pdf

¹³ Area of UK = 240,000 km². Therefore, rate for 2 x 12.5 kHz national channel in business radio = £1.65 x 240,000 x 2 x 0.0125 = £9,900. The rate for a 2x200 kHz national cellular channel = £1.65 x 240,000 x 2 x 0.2 = £158,400

¹⁴ Spectrum Pricing Statement, paragraph 3.46.

Our current approach to calculating reference rates

1.40 If, in Step 2 of our AIP methodology, we have found that the band in question is congested in both its existing and in alternative uses, we calculate two values to arrive at the reference rate:

- 'Value in own use' (or 'own use opportunity cost') – the value that an average user in the current use of the band (or bands) attaches to a small additional block of spectrum in the band, which measures the value of that spectrum in its existing use;
- 'Value in alternative uses' (or 'alternative use opportunity cost') – the value of that spectrum in other potential uses of the band (or bands) which are realistic within the relevant timeframe.

1.41 We currently estimate the reference rate according to the following steps:

1. we calculate the value in the existing and alternative uses identified in step 1;
2. if there is a higher value feasible alternative use, we set the reference rate between the two values, but towards the bottom end of the range;
3. if there is no feasible higher value alternative use, we set the rate at the value in existing use.

1.42 We explain below how we calculate both values.

Calculating the value in own use

1.43 We currently use the 'least cost alternative' (LCA) method to calculate the value in own use. We describe it in this section, together with an alternative approach based on discounted profits (DP).

The LCA method

1.44 Following the method developed by Smith NERA (1996) and later refined by Indepen, Aegis and Warwick Business School ('Indepen'), we have used LCA to set reference rates in our pricing of all licence classes subject to AIP to date¹⁵.

1.45 The LCA method considers the response of a reasonably efficient representative provider of a service to the loss of a small block of spectrum in the band(s) in question. The minimum additional cost (or cost saving) that the user would incur in order to maintain output at the same level provides a measure of the value of spectrum to the user, since it reflects the amount that it would have to spend to maintain its current service without it.

¹⁵ Smith NERA. *Study Into the Use of Spectrum, Report for the Radiocommunications Agency* (1996)

<http://www.ofcom.org.uk/static/archive/ra/topics/spectrum-price/documents/smith/smith1.htm>

Indepen, Aegis Systems and Warwick Business School. *An Economic Study to Review Spectrum Pricing* (2004).

http://www.ofcom.org.uk/research/radiocomms/reports/independent_review/spectrum_pricing.pdf

We accepted the Indepen approach in our Spectrum Pricing Consultation (2005). *Spectrum Pricing. A Statement on Proposals for Setting Wireless Telegraphy Act Licence Fees* (2005), paragraph 2.15.

http://www.ofcom.org.uk/consult/condocs/spec_pricing/statement/statement.pdf

- 1.46 The LCA method relies on input substitution to sustain the same output from the use of spectrum. When it is possible to vary the proportions in which spectrum and other resources (e.g. equipment) are used, a user will have a choice between different methods of providing the same level of service. For instance, one method of delivering the same level of service may use more spectrum and less equipment (e.g. base stations), while another method may use less spectrum and more equipment. Hence, the same output may be obtained with a smaller amount of spectrum if other inputs are increased in a compensatory manner.

Case Study 3: input substitution in fixed links

A fixed link user can typically trade off its use of spectrum with other inputs, such as using more spectrally efficient technology, a leased line or higher frequency spectrum. In general, more efficient higher order modulation schemes enable the same data rate to be achieved using less bandwidth. Alternatively, the user may switch to a less popular frequency band by investing in equipment suitable for that band, or may deploy a leased line to replace the loss of a marginal block of spectrum.

- 1.47 In essence, the LCA method measures the value of a block of spectrum in terms of the market prices of other inputs that can be substituted for it while maintaining output constant. The identification of the range of alternative ways in which a representative user could maintain output following a reduction in spectrum availability is therefore key. These ways could include:
- investing in more network infrastructure (e.g. additional base stations);
 - using high modulation requiring narrower bandwidth equipment;
 - switching to an alternative service (e.g. a public service like PAMR rather than private communications like PMR);
 - switching to an alternative technology (e.g. fibre or leased line rather than a fixed radio link);
 - switching to a less popular band.
- 1.48 To estimate the value of a (marginal) block of spectrum, each of the alternatives is costed. The difference between the cost of providing the service at current levels, and that of the least cost alternative, is the value in existing use.

Key assumptions of the LCA method

- 1.49 To apply the LCA method, we need to assume that the user is denied access to a marginal block of spectrum. The size of this block is usually chosen to reflect the minimum amount of spectrum that is of practical benefit to the user (e.g. a 2x12.5kHz channel in business radio).
- 1.50 Another assumption concerns the ‘average’ user, taken as representative of users in the band(s). In some cases, users will not differ much in their size or spectrum use. In other cases they may vary widely and the selection of the average user has to be made carefully – there will be many user types and different estimates of the value of spectrum to each. Case Study 4 sets out how we have arrived at a single measure in

some cases by taking a weighted average based on the bandwidth used by each user type.

- 1.51 Finally, the LCA approach involves comparing two future cost streams (with and without the marginal block of spectrum). Assumptions regarding equipment costs, equipment lifetime, maturity of the network and the point at which the user is assumed to switch to the least cost alternative are needed. One-off costs such as investment in equipment need to be converted into equivalent annual values to produce an annual reference rate. This entails assuming a market-based weighted average cost of capital (WACC) and a discount period.

Case Study 4: Indepen's estimates of the value in own use for fixed links¹⁶

Indepen (2004) provided illustrative values in own use for several applications. We discuss here the value calculations for fixed links as an example of how the methodology has been applied in the past.

Indepen considered the following alternatives to the use of fixed link radio equipment:

- Use more spectrum efficient technology within the same frequency band;
- Move to a less popular, higher frequency band;
- Use of a non-radio alternative, such as leased line or fibre

The first option was the least cost alternative for a typical link user. Given the variety of transmitted data rates and technologies, Indepen considered 6 user types using different link technology, ranging from that transmitting at 2 Mbits/s using QPSK technology to that transmitting at 155Mbits/s with 16QAM. For each link type, it estimated the additional cost of using a more efficient technology (assumed to require 75% of the bandwidth used by the less efficient system), calculated the value per 2x1 MHz equal to the additional cost per MHz of spectrum saved, and translated that cost into an annual value per 2x1MHz using a discount rate reflecting a market WACC of 10% over 15 years:

User type	More efficient alternative	Spectrum use (MHz)		Equipment cost		Value per 2x1 MHz (£)	Annualised value (£) per 2x1 MHz link
		Old	New	Old	New		
2 Mbits/s QPSK	16QAM	3.5	2.625	5,000	8,000	3,429	410
4 Mbits/s QPSK	16QAM	3.5	2.625	5,750	9,200	3,943	471
8 Mbits/s QPSK	16QAM	7	5.25	6,500	10,400	2,229	266
17 Mbits/s QPSK	16QAM	14	10.5	8,150	13,040	1,397	167
34 Mbits/s QPSK	16QAM	28	21	10,000	16,000	857	102
155 Mbits/s 16QAM	128QAM	56	42	25,600	28,800	229	27

The value in own use was then estimated as the weighted average of the annual cost per 2x1 MHz for those link types, where the weights reflected the total bandwidth used by each type of link according to the RA database.

User Type	Spectrum use (MHz)	# of links licensed by the RA	Total bandwidth (b)	Value per 2x1 MHz (£ per annum)	Total value (£) (a)
2 Mbits/s QPSK	3.5	1,086	3,801	410	1,557,606
4 Mbits/s QPSK	3.5	4,789	16,762	471	7,898,968

¹⁶ Indepen, Annexes 3-8.

8 Mbits/s QPSK	7	10,454	73,178	266	19,491,872
17 Mbits/s QPSK	14	2,207	30,898	167	5,159,619
34 Mbits/s QPSK	28	8,125	227,500	102	23,306,715
155 Mbits/s QAM	56	1,812	101,472	27	2,772,137
Total			453,611		60,186,917
(a / b) = £132			(b)		(a)

This produced an estimate of the value in own use of £132 per 2x1MHz per individual link, which was the reference rate for spectrum used by fixed links. However, the figure was sensitive to assumptions regarding equipment costs and the number and types of link used – Indepen used the more popular link data rates but covered only 27,000 links out of a total installed base of almost 40,000¹⁷.

We adjusted Indepen’s estimate by including all utilised link data rates and bandwidth possibilities, together with revised equipment costs. The result yielded a reference rate of £99 per 2x1MHz per link, which was later adjusted to the current £88 per 2x1 MHz link to be consistent with other amendments to the fixed link algorithm¹⁸.

The Discounted Profit method (DP)

- 1.52 In a 2005 report for Ofcom, Indepen and Aegis recommended the Discounted Profit method as an alternative to LCA for the pricing of broadcasting spectrum¹⁹. The DP method may be used when it is not realistic to assume that output would be kept constant in response to the loss (or an award) of a block of spectrum, as the LCA assumes.
- 1.53 In outline, the DP method calculates what an average user would be willing to pay at an auction for a licence giving access to a block of spectrum in the band(s) in question. It requires estimating the incremental effect that holding the licence (or, conversely, of being denied access to that spectrum) will have on the user’s cash flows. The value to that user equals the present value of the future cash flows expected from the licence.
- 1.54 The DP method entails:
- estimating future cash inflows and outflows expected from the licence, and
 - applying an appropriate market-based discount rate to those cash flows.
- 1.55 In addition to cash inflows resulting from holding the licence, projections would include (efficiently incurred) cash outflows which can be directly attributed or reasonably allocated to the licensed service, including a ‘normal’ return on capital.
- 1.56 The resulting cash flows would be discounted by the user’s weighted average cost of capital (WACC) to arrive at their net present value, from which the market values of other assets would be deducted.

¹⁷ *Spectrum Pricing; A Consultation on Proposals for Setting Wireless Telegraphy Act Licence Fees* (2004), page 74.

¹⁸ *Spectrum Pricing; A Statement on Proposals for Setting Wireless Telegraphy Act Licence Fees* (2005), page 23.

¹⁹ Indepen and Aegis; *Study into the Potential Application of Administered Incentive Pricing to Spectrum Used for Terrestrial TV & Radio Broadcasting* (2005), section 6.

Comparing the LCA and DP methods

- 1.57 The LCA method is relatively simple and practical to implement. The assumption that users can replace spectrum with other resources in a way that keeps output constant removes the need to estimate revenue implications of a change in spectrum use, including uncertain revenue forecasts and hypothetical demand scenarios.
- 1.58 In addition, the LCA method requires a limited amount of cost information that is usually publicly available. For instance, as explained in Case Study x it is often sufficient to consider the cost of the additional equipment required to substitute for the loss of spectrum.
- 1.59 In general, the LCA method may be used if technology allows input substitution. In those cases, it may be appropriate to ignore revenue implications by assuming that output can be kept constant, for instance:
- for spectrum used in support of internal business processes (such as private business radio or fixed links), where the loss of spectrum would have cost implications but may not result in changed output;
 - spectrum used to provide a public service (such as cellular), if it is possible for users to substitute spectrum with other resources and realistic to assume that output can be kept constant.
- 1.60 For a small number of applications, however, there may be indivisibilities in the amount of spectrum required by users – it may only be realistic to consider large, non-marginal blocks of spectrum. Users may then respond to the loss of one block by changing output substantially, which would have both cost and revenue implications. They may do so either because keeping output constant would be loss-making or because alternative responses would be clearly more profitable. Assuming constant output and ignoring revenue implications in that case may be unrealistic.
- 1.61 Where that is the case, the DP method may be used in preference to LCA. It reflects the methodology actually employed by users when estimating the value they attach to a block of spectrum (e.g. for an auction) and, in that respect, is the more realistic of the two methods. However, the DP method:
- requires considering a wider set of cost changes than the LCA method, normally involving detailed cost allocations and apportionments;
 - must take revenues into account, often requiring the use of uncertain revenue forecasts;
 - requires additional assumptions regarding forecast revenue growth, terminal and infrastructure cost changes and the profit-maximising level of output given the loss of marginal spectrum.
- 1.62 Both methods have similar drawbacks, based on the fundamental problem of estimating costs (and revenues) on behalf of operators who would, in an efficient market, determine these in response to their own circumstances and information. Any cost-based methodology will always be second best compared with spectrum values determined by an efficient market. They can be very sensitive to the assumptions used, such as those concerning equipment lifetime, equipment costs, nature of the average user or the discount rate. Cost-based estimates will typically

yield a range of possible values and we will have to exercise a degree of judgement when choosing the appropriate level of fees to apply given the range of values produced by the chosen method.

1.63 The pros and cons of each method are summarised in the following Table.

Table 1: advantages and disadvantages of the LCA and DP methods

	Advantages	Disadvantages
Cost-based estimates – LCA method	<ul style="list-style-type: none"> Information requirements are not demanding Easy to implement 	<ul style="list-style-type: none"> Not applicable if output cannot be assumed constant/ if revenue implications cannot be ignored Sensitive to assumptions, will produce a range of values Requires judgement to choose from range of values estimated
Cost-based estimates – DP method	<ul style="list-style-type: none"> Method used by users to estimate values in an auction Is applicable if output cannot be assumed constant/ if revenue implications cannot be ignored 	<ul style="list-style-type: none"> Same as LCA (except first point) Requires more cost information and uncertain revenue forecasts than LCA

Calculating the value in alternative uses

1.64 In theory, the LCA method could be used to estimate the value of a band in alternative uses based on the cost savings that an average provider of an alternative service would benefit from if given access to a block of spectrum in the band. Alternatively, the DP method could be used to estimate that value by reference to what an average provider of an alternative service would be willing to pay at an auction in order to have access to the band in question.

1.65 In practice, we normally use our existing value estimates for similar bands used by those alternative services as the value in alternative use for the band in question, with any adjustments required.

Step 4: Setting AIP fees based on the reference rate

1.66 Having calculated a reference rate, we translate it into AIP fees for individual licences based on the licensee’s actual use of spectrum. We explain in this section the variables we use in that process.

The general AIP algorithm and fee tables

1.67 To translate the reference rate into AIP fees for specific licences it is necessary to adjust it in two respects:

- a) To reflect the actual amount of spectrum denied to others by the individual licensee, in terms of bandwidth, area denied and whether the channel is used exclusively or shared by time;
 - b) To capture variations in the value of that spectrum, relative to the value of the band and location on which the reference rate is based.
- 1.68 Following the approach initially recommended by Smith NERA and adopted by the RA and the UK Government²⁰, we measure the amount of spectrum denied by reference to:
- i) **Bandwidth.** To reflect the actual bandwidth required by the licensee, in kHz, MHz or other relevant measure;
 - ii) **Area denied to others or ‘sterilised’.** This measures the geographical occupancy of the licensee, typically in km² for explicit or implicit area licences;
 - iii) **Exclusive or shared use.** To reflect that users will have either exclusive occupancy or will share a channel (by time) with other users.
- 1.69 To capture variations in the value of that spectrum by frequency and geography, we use two ‘factors’ or ‘modifiers’:
- iv) **Frequency band factor.** This factor intends to reflect differences in the value of bands subject to the same reference rate – in particular, the band in which the licensee operates relative to that in which the average user is assumed to provide its services (the ‘reference band’²¹).
 - v) **Location factor.** Similarly, this factor intends to capture the value of the spectrum where the licensee operates, relative to the location assumed for the average user (the ‘reference location’).
- 1.70 While the reference rate calculated in Step 3 will be common to many licences, these other variables depend on the individual transmission system being licensed. These variables are reflected in our general AIP algorithm, from which all individual algorithms and AIP fee tables (e.g. the business radio fee tables or the fixed links and satellite algorithms) are based, with more or less modification. We explain each variable in turn.

Figure 2: Our general AIP algorithm:

AIP fee = reference rate x bandwidth x area sterilised x sharing x band factor x location factor

Variables in the general AIP algorithm and fee tables

Bandwidth

- 1.71 The reference rate may be expressed in £ per MHz or kHz (e.g. 2x12.5kHz channel in business radio) or more generally in £ per MHz per km². All other things being

²⁰ Radiocommunications Agency. *Implementing Spectrum Pricing* (1997), Section 4. Also *Report on Modifiers to be Used in Determining Administrative Pricing Fee Charges for Mobile Services* (1997), page 3.

Spectrum Management: into the 21st Century, DTI White Paper (1996). Section 7: Administrative Pricing.

²¹ See Indepen, page 52.

equal, users who occupy larger bandwidths deny more spectrum to other users and should pay a correspondingly higher fee, in order to provide users with incentives to utilize the minimum bandwidth necessary²².

- 1.72 Typically, a duplex channel (where 2 channels are used for communications) will attract twice the fee as a simplex channel (where a single channel is used for communications in both directions or there is one way communication only, e.g. paging), but there are exceptions to this rule²³.

Area denied

- 1.73 The final AIP fee should also reflect the actual area denied to other users and uses. All other things being equal, if a licensee denies a greater area with its transmissions (for example by using a higher transmitter power) it should pay a correspondingly higher AIP fee. Reflecting this greater denial in AIP fees provides incentives for users to minimise their geographical occupancy to what is needed for their use (e.g. by reducing transmitter power or link availability requirements).

- 1.74 Licences subject to AIP have geographical limitations. We explained above that in some cases, licences provide users with a right to transmit over an implicitly or explicitly defined area. In other cases, licences permit transmission between fixed points or locations. However, radio transmissions extend further than their effective coverage area and may deny other users and uses beyond that area.

- 1.75 Hence, it is important to distinguish between:

- coverage area, or the area within which an acceptable and usable signal is received; and
- area sterilised, or the area within which another service using the same channel cannot be assigned without harmful interference.

- 1.76 Using area sterilised as the basis for AIP fees better reflects the actual amount of spectrum denied to others. The area sterilised by an individual licensee will typically depend on the service:

- Explicit area licences (e.g. cellular, area defined business radio or FWA licences) typically cover the whole of the UK, a nation or a specified region. The area sterilised is taken to be the whole of the United Kingdom, the nation or the region respectively;
- Implicit area licences (e.g. technically assigned business radio licences) typically cover small geographical areas. It would be possible to determine the area sterilised by an individual system using our modelling tools. This, however, would be opaque to users unless licensees had access to our systems to estimate their AIP fees; and accessing those systems would place a burden on users. Instead we have in the past classified area sterilised in three predefined categories (e.g. area with a radius of 3km or less, 3 to 15km and 15 to 30km) as determined by the transmitter's power and antenna height.

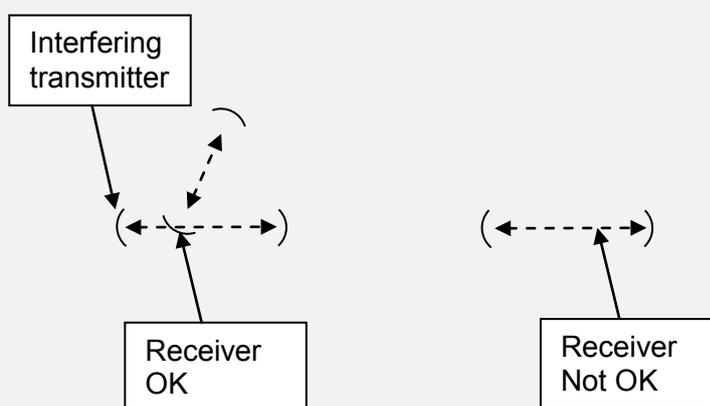
²² For certain applications, however, there is no linear relationship between bandwidth and the amount of spectrum denied to others. For instance, if three 8 x 3.5MHz links are installed in a specific grid they place more limitations on other assignments than a single 28MHz link.

²³ For example, if a business radio licensee requests a 1x12.5kHz simplex channel, the reference rate (which is based on a 2x12.5kHz channel) would be halved, subject to the minimum licence fee. Where the user requests a 2x25kHz channel, the rate would be doubled. There is an exception with fixed links, where the reference rate is applicable to bi-directional links, and unidirectional links attract 75 per cent of that rate.

- With point to point licences (e.g. fixed links and satellite earth stations), the concept of area sterilised does not work well, as discussed in Case Study 5. Our current pricing algorithms make no attempt to measure the area of interference directly. Instead, the reference rate is adjusted by a 'link availability' factor (i.e. the probability that the fixed link user can receive a signal) in the fixed link algorithm and by a 'peak transmitter power' factor in the case of satellite earth stations, to capture the fact that the area impacted will vary directly with those variables.

Case Study 5: Area denied or interfered with by an individual fixed link

In fixed links, highly directional antennas are used and (for a parabolic dish) variations in gain with off-axis angle will exceed 40 dB. For unobstructed interference geometry, a receiver may experience harmful interference from a transmitter located some distance away and tuned to an adjacent channel but not from a near-sited transmitter sharing the same channel. This situation is illustrated in the diagram below. Harmful interference into fixed links receivers is highly dependent on link geometry and it is not possible to simply define an 'area sterilised' within which co-channel working.



While the above makes it impracticable to establish 'no-go' areas for co-channel links, it is nevertheless good practice to encourage users to transmit only the power necessary to achieve the required quality of service.

Exclusive or shared use (by time)

- 1.77 Some users in a small number of licence types (e.g. implicit area licences like technically assigned business radio) only need a channel for a proportion of the time. It is then possible for them to share the same channel (by time) with other users in the same location, by drawing on general correlations between particular kinds of use and how much channel capacity they require.
- 1.78 All other things being equal, a licensee sharing a channel with other users (by time) denies less spectrum than one using an exclusive channel, and hence should pay a correspondingly lower AIP fee. Ideally, the fee should reflect the proportion of total traffic on the channel that originates from the licensee. Intermittent users of spectrum would then be charged on the basis of to the duration of their use. In practice, it is not practical to measure individual traffic levels in that way, so that a fee modifier of 0.5 is normally applied to assignments categorised as shared.

Frequency band factor

- 1.79 The final AIP fee should reflect the relative value of spectrum in the band where the licensee operates, so that users in more valuable bands face a higher fee than those operating in less valuable spectrum. If we have calculated in Step 3 a single reference rate applicable to several bands with different market values, the rate must be adjusted to reflect value differences between those bands. A band factor is used for this purpose.
- 1.80 A band factor will not be required if the licence class has been allocated to a single band or if we have calculated a separate reference rate for each band used by the licence class – for instance, in our second consultation on detailed award design for the band manager with PMSE obligations²⁴.
- 1.81 In many cases, however, a band factor will be needed. The licence class may span several bands with very different market values (e.g. in fixed links or the business radio classes). In such cases, the band factor will have the task of capturing value differences between bands (e.g. between 1.35GHz and 57GHz in fixed links).
- 1.82 At present, where band factors are applied (e.g. in fixed links, satellite earth stations and business radio, excluding light licences) they attempt to reflect the relative market value of each band. However, this does present difficulties in estimating the relative market value of different bands.
- 1.83 In outline, in our current methodology one of the bands subject to the same reference rate is the ‘reference band’ where the average user in the reference rate calculation is assumed to operate. The band factor then assigns:
- a numerical value to the reference band (sometimes, unity i.e. a factor of 1); and
 - larger (or smaller) values to bands which are assessed to be more or less valuable. Often the measure we use is congestion on the assumption that there is a direct relation between the degree of congestion in a band and its market value (in own use).

Location factor

- 1.84 As with the band factor, it may also be necessary to adjust the reference rate to reflect the actual value of a block of spectrum in the area sterilised by the licensee, relative to the ‘reference location’ on which the reference rate was based.
- 1.85 Our current approach to location factors is as follows.
- c) For explicit area licences over the whole of the United Kingdom (e.g. cellular, FWA and some area defined business radio licences), the area sterilised is taken to be the whole of the UK so the national UK reference rate is applicable with no location factor needed. Where rights cover a nation or a region (e.g. other area defined business radio licences), we typically apportion the UK national rate by the population which resides in that Nation or region. For instance, in area defined business radio the fee for England is 83.6 % of the UK rate, so the implicit location factor is 0.83.

²⁴ *Digital Dividend Review: Band Manager Award Consultation on Detailed Award Design* (2008), paragraph 8.33. <http://www.ofcom.org.uk/consult/condocs/bandmgr/condoc.pdf>

- d) For implicit area licences (e.g. technically assigned business radio licences), we classify area sterilised in three predefined categories as explained above. To determine the value of that spectrum, we divide the UK into a grid of 50km x 50km squares which are then grouped by population density (areas of high, medium and low population). The location of the licensee's base station or the centre point of its operational area fixes the square in which the licensee operates.
- e) For licences providing the right to transmit between fixed points or locations (e.g. fixed links and satellite earth stations), as explained earlier in this document our current fee algorithms make no attempt to distinguish between different locations and hence to reflect their relative values via a location factor.

Other factors

- 1.86 In a few cases, we have applied other factors beyond bandwidth, area sterilised, the degree of exclusivity, band factor and location factor, where it has appeared to us that fees based on these alone may not promote optimal use. For example, in the fixed link fee algorithm we include a 'path length factor'. This is to encourage assignments in the highest available fixed link frequency band to ensure the lower frequencies are kept for the longer links, which are only achievable using the lower frequencies.
- 1.87 Case Study 6 discusses how our general AIP algorithm is reflected in the fees table for business radio and in the fixed links algorithm.

Case Study 6: Application of our general algorithm to business radio

The general algorithm in Business Radio licences

In our Statement on Modifications to Spectrum Pricing we set out a new pricing approach to business radio licences²⁵. Since then, in our pricing of those licences (excluding 'light' licences, which are subject to a cost-based charge), we take into account the five variables in our general fee algorithm, in addition to the reference rate. We explain each below.

Reference rate

The current reference rate for Technically Assigned and Area Defined business radio licences is £9,900 per 2 x 12.5 kHz channel and derives from the RA's STU of £1.65 per MHz per km².

Occupied bandwidth

The reference rate is defined in terms of the standard channel size of 2 x 12.5 kHz. The final fee in both the Technically Assigned and Area Defined classes reflects the occupied bandwidth subject to a minimum AIP fee of £75. For example a licensee deploying a simplex system using 6.25 kHz technology attracts a fee of 0.25 of the £9,900 rate.

Area sterilised

²⁵ See *Modifications to Spectrum Pricing. A Consultation on Proposals for Setting Wireless Telegraphy Act Licence Fees* (2006) and *Modifications to Spectrum Pricing Statement* (2007). Available at: <http://www.ofcom.org.uk/consult/condocs/pricing06/>

Technically Assigned licences cover local uses ranging from on-site to wide area systems from an assigned base. We define the typical area sterilised by an individual system (which we call coverage area) in three categories, depending on the transmitter's power and height:

- Category 1, refers to a relatively small coverage area, with an ERP of 5W or below and antenna height of 10m agl or less, or an operational area with a radius of 3km or less;
- Category 2, refers to a medium sized coverage area, with antenna heights up to 30m, or an operational area with a radius of up to 15km;
- Category 3, refers to a large sized coverage area, with high antennas and powers, or an operational area with a radius of up to 30km.

By contrast, Area Defined licences typically cover the whole of the UK or a specific nation within the UK. The fee calculation for the nations apportions the UK reference rate of £9,900 with reference to the percentage of the UK population which resides in that Nation. For example approximately 83.6 % of the UK population resides in England. Therefore the fee for England is 83.6 % of the UK channel rate ($0.836 \times £9,900 = £8,275$ per 2 x 12.5 kHz channel).

Shared assignment discount factor

For Technically Assigned licences a fee modifier of 0.5 is applied to assignments categorised as shared, subject to the minimum AIP fee for this licence class of £75. Users who require exclusive access to spectrum are charged at the full rate for their assignment, as do Area Defined licences, which typically provide exclusive access to spectrum.

Band factor

For both types of licence class, the starting point for Highly Popular bands (High Band, UHF1 and UHF 2) is the full reference rate of £9,900 per 2 x 12.5 kHz national channel (with a downward adjustment in technically assigned licences that do not use national channels). That spectrum is most in demand and is where congestion is greatest. Medium popular bands in which congestion is less (Mid Band and Band III) are charged at 83% of the full AIP rate. Less popular bands (Paging and Low Band) are charged at 33% of the full AIP rate in area defined licences or a flat rate of £75 for each assignment per 2 x 12.5 kHz channel per annum in technically assigned licences. Effectively, the values of the band factor are 1, 0.83 and 0.33 for area defined licences or 1 and 0.83 for technically assigned licences.

Location factor

To provide a simple and transparent categorisation of congested areas, we divide the UK into a grid (50 km squares) and categorise the population in each square into one of three categories:

- Category A - High population category - representing a population of greater than 3 million (London);
- Category B - Medium population category -representing a population of between 300,000 and 3 million (e.g. Leeds);
- Category C - Low population category –representing a population less than 300,000 (e.g. rural areas).

For Area Defined licences, licensees that take advantage of new flexibilities created by the division of the UK into 50 kilometre square coverage units (by trading or surrendering areas

that they do not require), are charged with reference to population category of each trading unit on the licence.

A combination of the five variables above produces the fee tables in our New Business Radio Licence Fee guide, available at:

<http://www.ofcom.org.uk/licensing/applications08/changes/Fees/nonexcelguide.pdf>