Administered Incentive Pricing for Aeronautical VHF Communications

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1 Introduction

1.1 General

This document has been prepared by Helios Technology Ltd (Helios) for Ofcom.

It presents the results of our investigations into the applicability of Ofcom's Business Radio pricing structure[1] for aeronautical VHF communications services.

The objectives which have driven this work have been to:

- Understand the International (ICAO) VHF planning parameters and processes;
- Understand how aeronautical VHF frequencies are deployed in the UK;
- Having regard to Ofcom's existing Business Radio pricing framework, identify whether a more granular structure for pricing of aeronautical VHF communication licences could be arrived at.

1.2 Structure of this Document

This document has been structured as follows:

- Section 2 details the existing Business Radio licence fee structure including details of the parameters which are used in order to determine the applicable fee. It further considers how this has been proposed to apply to maritime VHF communication services. Finally it details the existing VHF aeronautical licence fee structure.
- Section 3 examines how the existing Business Radio licence fee structure may be used as a basis to provide a structure for the pricing of aeronautical VHF communication services.
- Section 4 outlines the study's conclusions and addresses the issues of the impact of UK spectrum use on neighbouring countries and considers how single-frequency multi-site ('CLIMAX') services may be priced.

[1] http://www.ofcom.org.uk/licensing/applications08/changes/Fees/

2 Existing Business Radio licensing fees

2.1 Introduction

All Business Radio licence fees are based on the use of a national MHz rate, which varies by the popularity of the band:

- £396,000 per annum (which equates to £9,900 per 2 × 12.5 kHz channel) applies to Highly popular bands;
- £330,000 per annum (which equates to £8250 per 2 x 12.5 kHz channel) applies to Medium popular bands;
- £132,000 per annum (which equates to £3,300 per 2 × 12.5 kHz channel) applied to Less popular bands.

To calculate the applicable fee, the appropriate rate is adapted by a number of modifiers. This section briefly reviews these modifiers in order that comparisons between the decisions made for Business Radio users and the way in which aeronautical licences may be priced can be made.

2.2 Principles

In establishing a pricing regime for Business Radio users, Ofcom took into account the following factors:

- the degree of popularity of a particular frequency band;
- the amount of spectrum bandwidth used;
- whether a location is highly populated;
- the extent of coverage of a radio system;
- whether the spectrum is shared with other users.

Two licence types are available:

- Technically Assigned licences in which the parameters of the transmitter(s) determine the applicable licence fee;
- Area Defined licences in which the user pays a fee based on the overall operational coverage area of the radio service being provided.

These are briefly discussed below in order that their potential applicability to aeronautical VHF use may be assessed.

2.2.1 Frequency band popularity

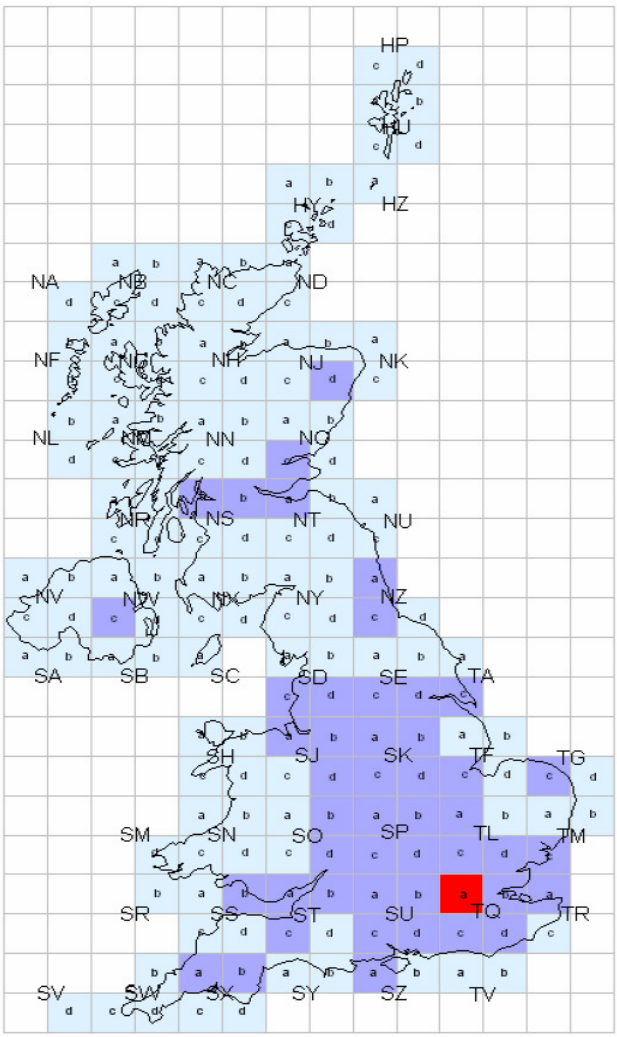
For Business Radio users, Ofcom has categorised each licensable band as either Highly popular, Medium popular or Less popular. This categorisation is based on the physical parameters of the band, such as propagation, building penetration and antenna size. Bands with good physical parameters and where there is a choice of manufacturer and mass market production of equipment are categorised as being more popular, meaning that equipment costs are at their lowest, and the opportunity costs of the spectrum frequencies are likely to be relatively high.

2.2.2 Bandwidth used

Ofcom bases its Business Radio fee calculations on the use of a figure of £9,900 per 2 × 12.5 kHz channel for a Highly popular band and £8,250 for a medium popular band; the actual bandwidth consumed by a user is charged *pro rata*.

2.2.3 Population density

In setting fees for Business Radio users, Ofcom has adopted a system in which the UK landmass is divided into 50 km squares. The population within each of those squares has been assessed and a map produced to indicate which fall into low, medium or high population density categories. This map is reproduced below.



These areas are defined as follows:

- High population density (shown in red) areas with a population in excess of 3 million;
- Medium population density (shown in dark blue) with a population between 300,000 and 3 million;
- Low population density (shown in light blue) representing areas with a population of less than 300,000.

Population density is used as a proxy for the density of assignments within the area concerned, and hence for relative levels of frequency congestion in that

geographic area, and thus the difficulty in finding frequencies for new applicants. The underlying assumption is that where there is most demand for frequencies, the opportunity costs associated with spectrum use in that location are higher.

2.2.4 Coverage

Three coverage categories are used as a proxy for the operational area for technically assigned licences. The following table reproduces the criteria used to determine the coverage category together with the estimated operational radius.

Coverage Category	Base station ERP[2] (P) in Watts, and Antenna height above ground level (A_h) in metres	Operational radius (R) in km for mobile to mobile systems
1	$P \leq 5$ and $A_h \leq 10$	$0 < R \leq 3$
2	$P \leq 5$ and $10 < A_h \leq 30$	$3 < R \leq 15$
	$P > 5$ and $A_h \leq 10$	
3	$P > 5$ and $A_h > 10$	$15 < R \leq 30$
	$P \leq 5$ and $A_h > 30$	

Table 1: Technically Assigned Licence Coverage Definitions

As an alternative, for services whose operational radius extends beyond 30 km, Area Defined licences are also available. These can cover the various nations of the United Kingdom (ie England, Scotland, Wales and Northern Ireland) or can be defined in terms of the same 50 km squares used to identify the various population densities. There are 171 squares which between them describe the whole UK landmass.

2.2.5 Frequency band popularity

For Business Radio users, Ofcom has identified, for each licensable band, whether it falls into a Highly popular, Medium popular or Less popular category. This is based on the physical parameters of the band such as propagation, building penetration and antenna size. The most popular bands are those with good physical parameters and where there is a choice of manufacturer and mass market production of equipment, meaning that equipment costs are at their lowest.

2.2.6 Bandwidth used

Ofcom bases its Business Radio fee calculations on the use of a figure of £9,900 per 2 × 12.5 kHz channel; Changes in bandwidth from this figure are charged for *pro rata*.

2.2.7 Sharing of spectrum

A 50% reduction in the calculated rate is applied[3] for frequencies which are shared (as opposed to those which have exclusive use). In the majority of cases, frequencies will be classed as shared. Ofcom's statement says on this issue:

[2] Effective Radiated Power

[3] A minimum fee of £75 per annum applies to all licences.

'*The majority of existing assignments will fall into the Shared category apart from those licensees which have users with safety critical activities…*'

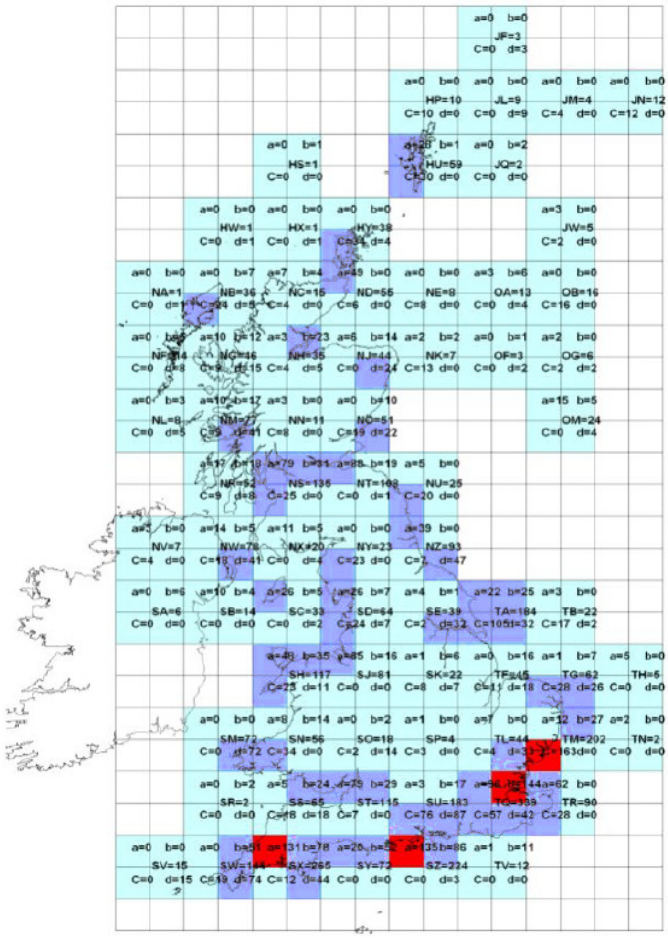
The exception to this being for Common Base Stations (CBS) and analogue Public Access Mobile Radio (PAMR), where frequencies are classed as exclusive.

2.3 Application to maritime VHF communications

In considering the licence fee structure for maritime VHF channels, Ofcom has based its initial proposals on the Business Radio fee structure.

In applying the structure described above, the following changes have been proposed:

- **Frequency Band Popularity:** Ofcom has proposed to class internationally harmonised maritime channels as 'highly popular' with UK-allocated channels as 'medium popular'.
- **Bandwidth Used:** The same categories as for Business Radio have been proposed.
- **Population Density:** Ofcom has proposed to replace the concept of population density with the concept of measuring assignment density. Areas with more than 125 assignments per 50 × 50 km square are proposed to be considered 'high density'; those with between 20 and 125 assignments are proposed to be considered 'medium density'; and those with less than 20 assignments are proposed to be considered 'low density'. This change yields a different map from the one for standard business usage namely one which reflects the number of maritime assignments. This produces an alternative 'density' map as shown below. Note that as the area concerned includes some squares which are out at sea (where there are offshore fixed maritime VHF transmitters), and hence are not part of the UK landmass, there are 288 50 x 50 km squares in the maritime map.



- **Coverage:** The same three coverage categories as for Business Radio have been proposed, based on the same technical parameters.
- **Sharing of Spectrum:** Ofcom has proposed that only UK marina channels (channels M, M2 and 80) should be classed as shared.

2.4 Existing aeronautical VHF fee structure

The table below details the fees payable by VHF aeronautical users under the existing Ofcom pricing structure for each of the different licence types based on The Wireless Telegraphy (Licence Charges) Regulations 2005.

Licence Type	Annual Fee
Aeronautical Ground Station (Air Traffic / Ground Movement Control)	£150
Aeronautical Ground Station (Air/Ground Communications Services)	£100
Aeronautical Ground Station (Airfield Flight Information Service)	£100
Aeronautical Ground Station (Operations Control)	£250
Aeronautical Ground Station (General Aviation)	£25
Aeronautical Ground Station (Fire)	£25
Aeronautical Ground Station (Offshore Platform)	£250

Table 2: Current Aeronautical Licence Fees

3 Application to aeronautical VHF communications

3.1 Introduction

Ofcom's Business Radio licensing scheme provides a framework for applying administered incentive pricing to certain radio users. To arrive at a proposal specifically for maritime VHF use (as described in section 2.3), each of the various parameters which form inputs to the Business Radio scheme has been assessed by Ofcom in the context of maritime VHF use.

This section examines those same parameters but in the context of aeronautical VHF communications services to explore whether the broad structure of the Business Radio scheme can also be adapted for these users.

3.2 Coverage

Aeronautical VHF communication services operate in the frequency range 117.975 to 137 MHz. The planning processed used to assign frequencies in Europe is documented in two key texts:

- **The ICAO European Frequency Management Manual[4]:** this provides the planning criteria and procedures to be used when planning VHF (and other) aeronautical services.
- **The COM2 Table:** this documents all frequency assignments in Europe and the North Atlantic detailing the frequency, use type, location and certain other operational parameters.

The ICAO Frequency Management Manual provides a table of the separation distances[5] which should apply between the edge of the service or operational areas of different types of VHF aeronautical use. Whilst this table is essential for planning purposes, it does not provide a simple method for calculating the area sterilised by each of the various VHF aeronautical services as it does not provide separation or protection distances for equivalent services such that the figures for any given service would need to be assumed rather than being directly calculable.

Outside of Europe, however, ICAO does define like-service geographical separation criteria used when planning VHF air-ground communication stations. The table below provides details of the criteria used in planning.

[4] ICAO EUR Doc 011 (Europe and North Atlantic)

[5] Section 4.2.7 of EUR Doc 011

Service	Symbol	Operational Coverage Range	Operational Coverage Height	Minimum Separation Distance	Adjacent Channel Separation
Aerodrome control	TWR	25 nm (46 km)	1200 m (4000 ft)	175 nm (324 km)	50 nm (93 km)
Aerodrome flight information service	AFIS	25 nm (46 km)	1200 m (4000 ft)	175 nm (324 km)	50 nm (93 km)
Surface Movement Control	SMC	Limits of the aerodrome	Surface	50 nm (93 km)	25 nm (46 km)
Approach control – Upper	APP-U	150 nm (278 km)	13700 m (45000 ft)	820 nm (1519 km)	180 nm (333 km)
Approach control - Intermediate	APP-I	75 nm (139 km)	7600 m (25000 ft)	550 nm (1019 km)	95 nm (176 km)
Approach control - Lower	APP-L	50 nm (93 km)	3650 m (12000 ft)	370 nm (685 km)	60 nm (111 km)
Area control service - Upper or Flight information service - Upper	ACC-U FIS-U	Defined service area	13700 m (45000 ft)	520 nm (963 km) between limits of service areas	180 nm (333 km) between limits of service areas
Area control service - Lower	ACC-L	Defined service area	7600 m (25000 ft)	390 nm (722 km) between limits of service areas	95 nm (176 km) between limits of service areas
SST[6] high level operations VHF extended range Flight information service – extended range	ACC-ER FIS-ER	Defined service area	20000 m (66000 ft)	1300 nm (2407 km)	350 nm (648 km)
VOLMET	VOLMET	260 nm (482 km)	13700 m (45000 ft)	520 nm (963 km)	180 nm (333 km)
ATIS	ATIS	150 nm (278 km)	13700 m (45000 ft)	820 nm (1519 km)	180 nm (333 km)

Table 3: ICAO VHF Communication Planning Criteria

[6] Super-Sonic Transport

The extent to which any particular service using VHF frequencies sterilises use for other services can be most closely compared through the minimum separation distance. This is the distance that must exist between two equivalent services if interference is to be sufficiently low that operation is not adversely affected. Half of this distance, for any given usage type, therefore represents the extent to which that usage type sterilises use for other aeronautical users.

In all cases the operational service area extends beyond the typical maximum operational area of a Business Radio technically defined licence. As such, it would be more appropriate to base aeronautical fees on an Area Defined licence product basis determined by the number of 50 x 50km squares that are sterilised (or by national boundaries should these prove appropriate).

Aeronautical use of a particular channel has two impacts on other users:

- It sterilises the particular channel (of frequency) in question;
- It sterilises both (upper and lower) adjacent channels, albeit over a much smaller area.

Table 4 below details the co-channel and adjacent sterilisation radius based on the use of half the minimum separation distance together with the number of 50 by 50 km squares represented by the circle swept out by this radius (see Table 5 for physical representations of these shapes). It should be noted that for many of these services, the number of squares sterilised exceeds the number of squares (171) required to physically represent the UK landmass. This represents the extent to which UK usage sterilises areas outside the UK.

Service	Co-Channel Sterilisation Radius	Equivalent number of 50 x 50 km squares	Adjacent Channel Sterilisation Radius	Equivalent number of 50 x 50 km squares	Total number of squares sterilised[7]
Aerodrome control	166 km	37	46.5 km	4	45
Aerodrome flight information service	166 km	37	46.5 km	4	45
Surface Movement Control	46.5 km	4	23 km	1	6
Approach control – Upper	759.5 km	753	166.5 km	37	827
Approach control - Intermediate	509.5 km	333	88 km	13	359
Approach control - Lower	342.5 km	157	55.5 km	5	167
Area control service - Lower	*Defined service area[8] (assumed 509.5 km)*	333	*Defined service area (assumed 88 km)*	13	359
Area control service - Upper or Flight information service - Upper	*Defined service area (assumed 759.5 km)*	753	*Defined service area (assumed 166.5 km)*	37	827
SST high level operations VHF extended range Flight information service – extended range	1203.5 km	Coverage significantly exceeds the whole of the UK (would be over 1900 squares)	324 km	137	Over 2200
VOLMET	481.5 km	317	166.5 km	37	391
ATIS	759.5 km	753	166.5 km	37	827

Table 4: Sterilisation Areas by Service Type

[7] Equivalent to the number of co-channel squares sterilised plus twice the number of adjacent channel squares sterilised

[8] The service area for these services is individually tailored to meet their operational requirements. For simplification purposes, approximations based on the minimum re-use separation have been taken.

3.3 Density of assignments

As per Business Radio and maritime radio pricing fees, it is worth considering the density of aeronautical assignments in order to ascertain whether usage density and hence relative congestion of the VHF band varies significantly across the UK in a way that it would be appropriate to reflect by different price levels.

The map below shows the number of UK and European[9] aeronautical VHF communications assignments registered per 50 × 50 km square. This is based on the data provided by the ICAO COM2 Table, which details international aeronautical frequency usage (frequency, location and use type) for the whole of Europe.

Note that some frequencies are not used at the specific location to which they are registered. This is particularly the case for those with a defined service area, where the registration is often recorded at the location at which the frequency is controlled (eg the Prestwick air traffic control centre), but where the actual transmitters may be at different locations across the country. As such this map, as well as those which follow in this report, contain some known (though relatively small) inaccuracies.

Further, within the COM2 Table, there are a number of VHF frequencies which are allotted to the UK on a national basis by ICAO which are then re-assigned nationally by the CAA. These frequencies fall into two categories:

- National Aerodromes: These frequencies are used for various (typically short-range) services as well as providing the necessary frequencies for national usages such as to support gliding and ballooning.
- Operational Control: These frequencies are assigned to companies who provide operational support to air transport (such as airlines and handling agents).

For the UK, these frequencies are registered in the COM2 Table as being physically located in London, although in reality they are used at several different points across the UK. As the data from the COM2 Table has been used to create this map, there therefore appears to be particularly high apparent density of usage in London, whereas in reality this usage would be more evenly spread across the UK. Further, in terms of actual licences, whilst these usages are only shown once in the COM2 Table, they will represent multiple licences across the UK such that the number of assignments shown in the COM2 Table will be less than the number of actual licences in issue.

Should Ofcom seek to implement pricing structures based on the use of density maps, a thorough re-examination of the assignment data (both for UK and other European) should be conducted to ensure that the resulting maps reflect the actual location of assignments.

[9] Assignments from Belgium, France, Denmark, Germany, Iceland, Luxembourg, The Netherlands, Norway and Sweden have been included. Note that due to the way in which this data has been analysed, in some cases assignments over 1000 km from the UK have not been taken into account – this will slightly underestimate the level of congestion.

In defining levels of density for other users, the breakpoints between high, medium and low density have been adapted to the particular use and user, bearing in mind the operational circumstances of those services (eg maritime). It is necessary to define similar breakpoints for aeronautical VHF use. To this end, the following density categories have been adopted:

- High density (shown as red on the following maps) indicates those squares where there are more than 720 channels or frequencies sterilised. As there are only approximately 720 (25 kHz) channels available in the VHF band[10], this represents areas where there are theoretically no spare frequencies available.
- Medium density (shown as dark blue on the following maps) indicates those squares where there are between 360 and 720 frequencies sterilised. This represents areas where over half of the available frequencies are unavailable.
- Low density (shown as light blue on the following maps) indicates those squares where there are less than 360 frequencies (ie less than half) sterilised.

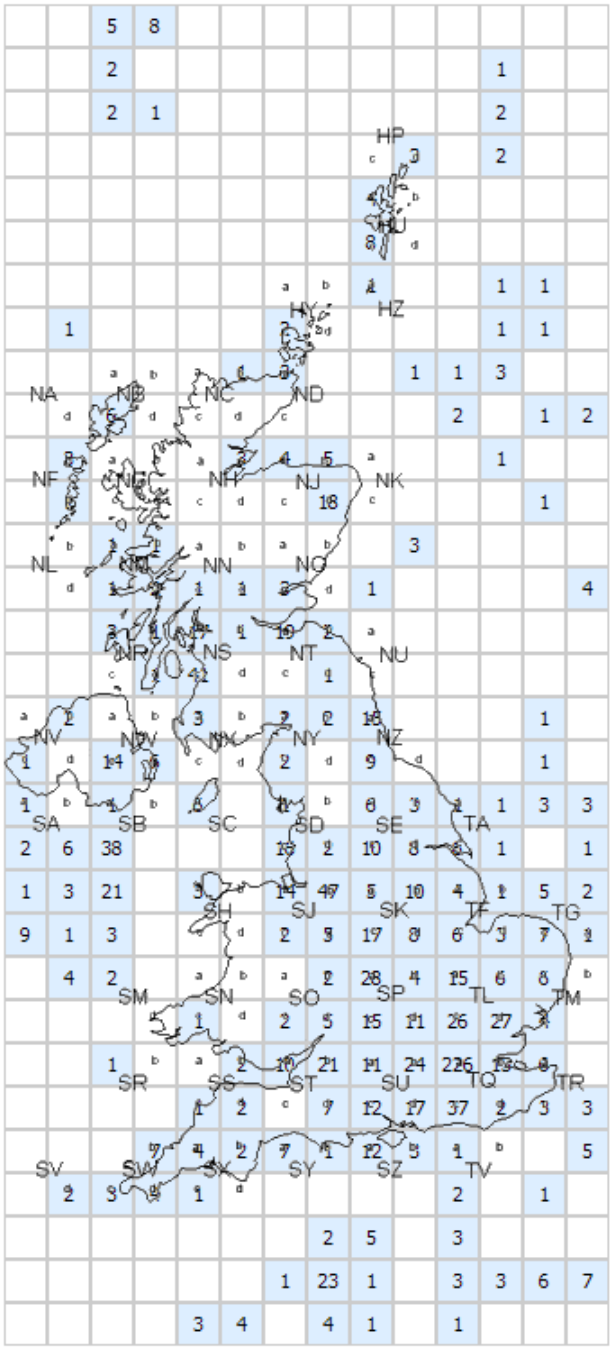
[10] The use of 8.33 kHz channels marginally increases the overall number of available channels.

Plotting the location of existing assignments reveals the map shown on the right. Note that there are UK (and other) assignments shown on this map which are outside the UK landmass on, for example, oil rigs.

White squares show areas where there are no VHF aeronautical assignments (these would normally be coloured light blue in Ofcom's maps but have been left white for illustrative purposes).

However, these results do not show the full picture. For each assignment, the area over which the frequency may not be re-used, if interference is to be prevented, extends beyond the 50 km square in which it is located. For some assignments, the area sterilised extends over several hundreds of kilometres as illustrated in Table 4 above.

In order to get a truer picture of the extent to which existing use denies access to the spectrum to other (aeronautical) users on a geographic basis we need to consider the co-channel and adjacent channel area sterilised by each assignment.



To do this, we have used the radii indicated in Table 4 to define patterns of 50km by 50km squares sterilised by each assignment type. These are shown Table 5 below.

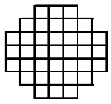
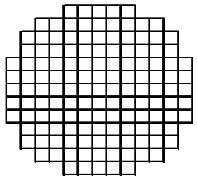
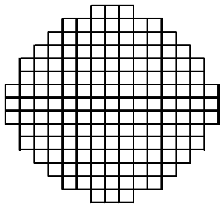
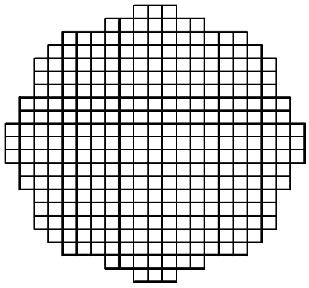
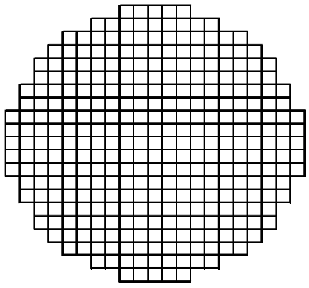
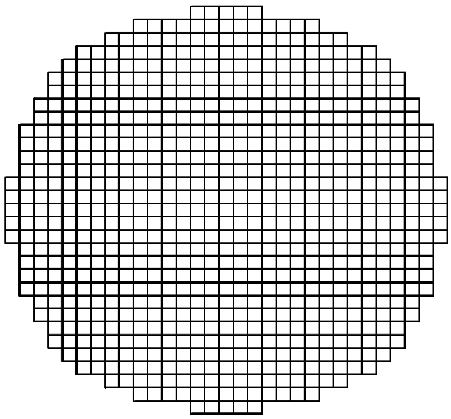
Radius Sterilised	Pattern of 50 km Squares Sterilised
46.5 km	
55.5 km	
88 km	
166 km	
324 km	
342.5 km	
481.5 km	
509.5 km	
759.5 km	

Table 5: Shapes of 50 x 50 km Sterilisation Squares

The coverage area of some frequencies is specifically tailored to include only those areas where air traffic management services are provided and as such may be smaller or of a different shape to those generic shapes indicated above. Protection (sterilisation) for such frequencies is usually defined by these actual areas of service provision. These areas will be defined by operational sectors which in turn tend to be defined by the density of traffic and by air traffic routes. Such routes include those used by international traffic which are outside the control of the UK insofar as the routes taken by international flights across the UK are defined at an international level. This is the case for some of the ACC frequencies, but will not impact the majority of UK assignments. It is also worth noting that the ICAO COM2 Table gives specific protection criteria for each assignment and that in some cases this may differ from the generic protection provided to the service in question as described in Table 3. These factors will mean that the ensuing analysis will, in general, marginally overestimate the extent of congestion, however the extent to which this overestimation occurs is small.

The COM2 table entries for the UK do not tie directly into the ICAO planning definitions listed above. As such, the following translations between COM2 references and ICAO values have been assumed:

COM2 reference	Meaning	Service Assumed
APP	Approach	Approach control - Lower
ATIS	ATIS	ATIS
AFIS	AFIS	AFIS
VOLM	VOLMET	VOLMET
ACC	Area Control	Area control service – Upper
FIS	Flight Information Service	FIS - Upper
All Others		As for Surface Movement Control

Table 6: Translation between COM2 and ICAO references

In considering the extent of congestion, we have used the shapes set out above to sterilise the UK for each of the service types identified. Doing this alone would indicate the extent to which the UK was sterilised for a ground-based user who required just one square in which to operate a service, however even short-range aeronautical uses (such as surface movement control) require 4 neighbouring squares to be clear. Our analysis therefore counts, for each square, the number of frequencies which are sterilised in that specific square, plus those which are sterilised in the appropriate number of neighbouring squares. The extent to which neighbouring squares are counted depends on the service in question. For example, for surface movement control, only directly adjacent squares are counted whereas when considering frequencies available for ATIS use, the specific square in question plus those in use within a 759km radius have been counted. Adjacent channel sterilisation has also been taken into account and follows the same principle however the sterilisation radii are smaller.

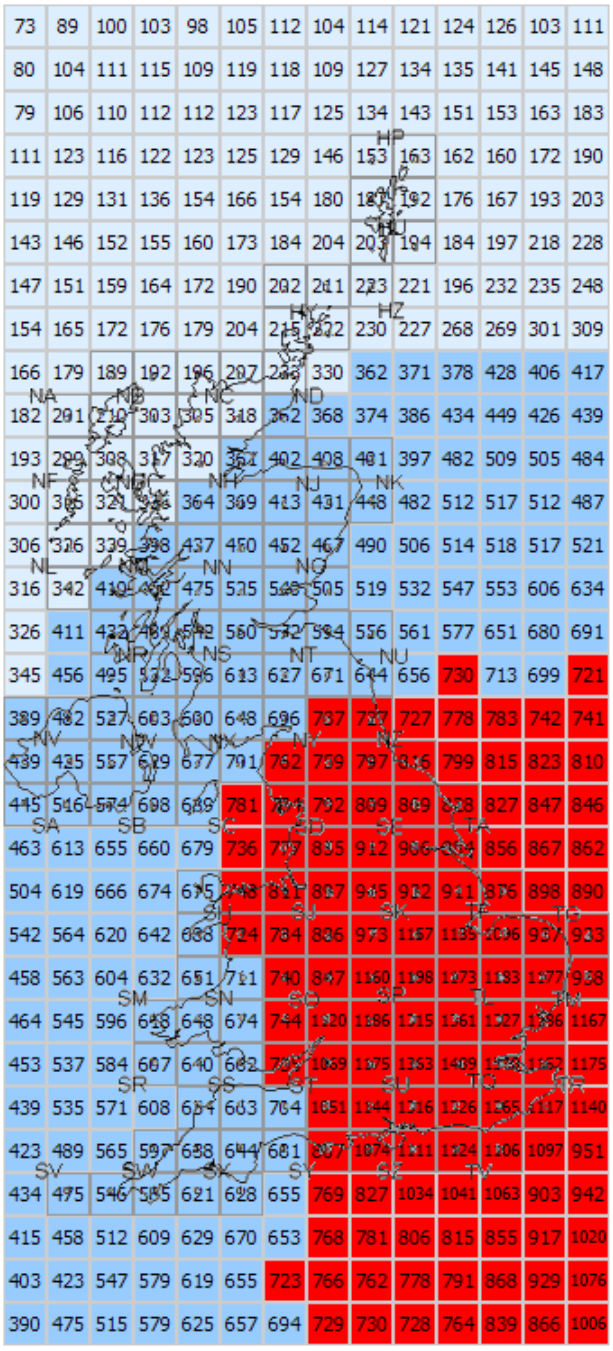
In order to examine whether there are variances in congestion across the UK we have taken two hypothetical scenarios:

- **Area Sterilised for a Ground-Based use**. In this case, for each assignment we have estimated sterilised areas based on the generic patterns defined in Table 5 above and assumed that we are trying to find a frequency for a ground based (ie surface movement control) use, thus requiring a further clearance of

approximately 50km from the nearest sterilised square. This approach shows the extent to which the country is sterilised from being used even by another ground-based service (such as surface movement control) and as such provides a lower bound to congestion.

- **Area Sterilised for a (high altitude) Airborne use.** In this case, for each assignment we have sterilised the areas defined in Table 5 above and assumed that we are trying to find a frequency for an ATIS operating up to 45,000 feet (that being the largest area sterilised of those services under consideration – see Table 4), thus requiring a clearance of over 750km from the nearest sterilised square. This provides a close approximation to the extent to which sterilisation would cause congestion to an airborne user flying at the maximum operational height and provides an upper bound to congestion in a given geographic area arising from the existing pattern of assignments.

For the ground based case, the resulting assignment density map is shown on the right. This shows the number of assignments per square which are unavailable for use for a ground-based alternative user (e.g. surface movement control).



This is equivalent to considering the number of frequencies which would not be able to be used from a ground station in any given square as the use of that frequency is sterilised by an operational service at any point from the ground to the highest operational altitude in that square and all immediately neighbouring ones.

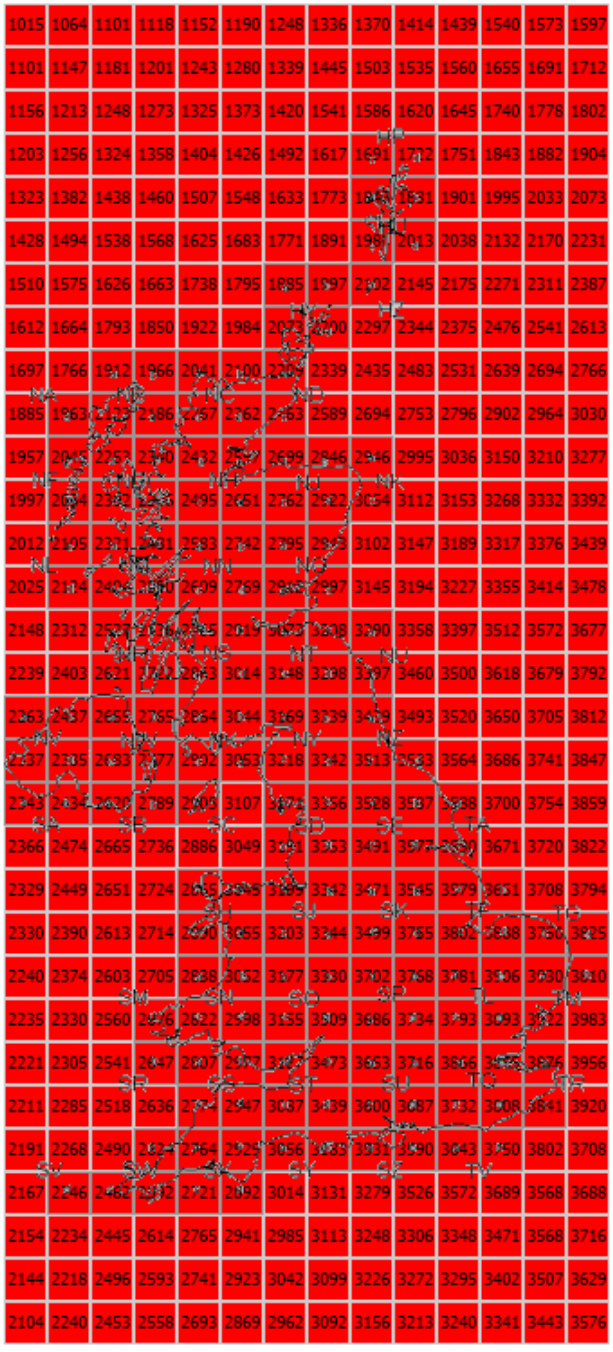
The density of assignments indicated using this method is significantly higher than for the previous assessment (which simply counted the number of assignments in each square), to the extent that most of England and some of Wales falls into the high density category with most of the rest of the UK (with the exception of Northern Scotland, the Scottish Isles and Shetland) falling into the medium density category.

Note that although the map shows over 720 assignments in use in some squares we have previously noted that in reality there can never be significantly more than 720 frequencies in use at a given point. However, in this analysis no

account is taken of the actual frequency assigned, just of the location and service type of each assignment. Also, the ICAO planning criteria used to develop this map are occasionally relaxed where, for example, topographic features (hills and mountains) allow greater frequency re-use than might otherwise be indicated. Relaxation of adjacent channel restrictions is also possible in some cases.

Our second analysis assumes that there needs to be a clearance of 750km between the edge of any area sterilised by an existing use and its availability for a new service. This represents the extent to which the band would be sterilised for use for another upper airspace aeronautical use.

The resulting map is shown on the right. This is equivalent to considering the number of frequencies which would not be able to be used from an aircraft flying at maximum operational altitude in any given square as the use of that frequency would be sterilised by the assumed services operating at any point from the ground to the highest operational altitude in the square concerned and in any squares within 750km of it.



It is clear in this instance that there would be high levels of congestion right across the UK.

Given the large number of squares where there are 4 or more times the number of frequencies apparently in use compared to the number of channels available, using this particular method of assessing assignment density produces results which are not necessarily reflective of the actual situation in the air. This is largely due to the fact that, in reality, very few frequencies are used for services accessed by high altitude traffic, with the majority being for lower altitude services such as approach, tower and airfields, where the previous map is more likely to be representative of the pattern of congestion actually encountered for most uses. However it does serve to indicate the extent of the potential difficulty encountered in finding frequencies for high altitude services.

According to the CAA, finding new aeronautical VHF frequencies for services in the UK is difficult with few unused frequencies being available.

Based on this analysis, it is apparent that the level of congestion across the UK will be dependent upon the use to which the frequency is put at the location in question. Congestion for ground based services is less than for airborne services, and this also varies across the UK.

3.4 Frequency band popularity

As part of its initial consultation, Ofcom has proposed that the aeronautical VHF communications band should be classed as highly popular. This is on the basis that these aeronautical frequencies are highly popular in their current use.

The Business Radio band closest to the aeronautical VHF communications frequencies (118-137 MHz) is the band 137.9625 to 165.04375 MHz which is classified as Medium popular. Above this the band 165.04375 to 173.09375 MHz is classified as Highly popular. Below the aeronautical VHF band there is no closely comparable Business Radio band (there is a Less Popular band at 68.08125 to 87.49375 MHz)

While a simple comparison between aeronautical and Business Radio bands may be difficult to make, there may be an alternative approach under which the aeronautical frequencies are deemed to be Medium popular on the basis that these frequencies (118 to 137 MHz) are most similar to the adjacent Medium popular Business Radio band.

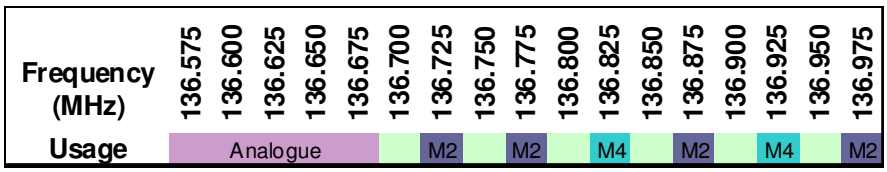
The following discussion assumes that, as per Ofcom's current proposals, the appropriate classification is Highly popular. In the event that the alternative conclusion is reached (that these aeronautical frequencies should be considered comparable with Medium popular Business Radio bands) the calculations would need to be adjusted *pro rata* (ie by a factor of £8,250/£9,900).

3.5 Bandwidth used

The majority of existing aeronautical VHF communications use analogue DSB-AM technology. Channel bandwidths are either 25 kHz or 8.33 kHz. The use of 8.33 kHz channel bandwidths is only deployed for frequencies which are used at altitudes exceeding 19,500 ft. This means that general aviation users are not required to re-equip with new 8.33 kHz radios at present.

Communication is usually single channel simplex working; paired frequencies are not deployed.

Although the majority of communications use analogue technology, new digital services known as VHF Data Links (VDL) are slowly being introduced into the VHF aeronautical band. There are two versions of VDL, Mode 2 and Mode 4, both of which operate in a 25 kHz channel. However in order to avoid interference a guard channel is required between digital frequencies. The diagram below[11] shows the current VDL frequency plan, with the guard channels clearly visible either side of the digital frequencies (M2 and M4 represent channels assigned for Mode 2 and Mode 4 respectively).



Whilst analogue usage sterilises the adjacent channels to a lesser extent than for co-channel usage, VDL usage sterilises 50 kHz of spectrum (the channel in use plus half of each of the adjacent channels) over the same area as for the co-channel situation. As such it would seem appropriate to charge the equivalent of the use of 50 kHz of spectrum for digital services, despite them nominally operating in a 25 kHz channel to take account of the need for these guard channels. Note that in this instance, there is no need to consider additional adjacent channel sterilisation.

We therefore propose that three possible channel bandwidths are used:

- 50 kHz (for digital services);
- 25 kHz; and
- 8.33 kHz.

3.6 Sharing of spectrum

Ofcom's initial proposals for the charging of aeronautical VHF channels proposed that a 50% sharing discount be applied to the full national rate in order to take account of frequency re-use in line with the Business Radio structure. This was an initial suggestion in lieu of further analysis of the situation.

Aeronautical assignments are regarded as safety-of-life services and as such are treated as exclusive. Indeed, given the level of protection offered to aeronautical services, any given frequency will be completely exclusive in the area in which it operates. As described above, there are a number of VHF frequencies which are allotted to the UK on a national basis which are then re-assigned nationally by the CAA and which may be re-used several times across the UK, however in each case usage is still protected and the service provided can include safety-of-life.

It would therefore follow that pricing of such assignments should not assume any sharing.

[11] Source: Eurocontrol VDL band implementation target plan (see: http://www.eurocontrol.int/vdl4/public/standard_page/frequency.html).

4 Conclusions

4.1 Pricing of aeronautical VHF communication services

The ICAO planning parameters together with UK and European use of VHF communication frequencies have been analysed in order to determine whether a more granular fee structure to that currently proposed by Ofcom can be arrived at. Our analysis has shown that the broad principles underpinning the existing Business Radio structure can be used as the basis to produce a more granular approach for pricing aeronautical VHF licences.

Based on the parameters used to derive Business Radio fees, our analysis has shown the following outcomes:

- **Frequency Band Popularity:** We have assumed, for the purpose of this exercise, that the VHF aeronautical band is comparable with 'Highly popular'. Business Radio bands, however we note that there may be arguments to support the classification of the VHF communications band as 'Medium popular'.
- **Bandwidth Used:** Three values, 50, 25 and 8.33 kHz are suggested as being appropriate given current aeronautical use.
- **Population/Assignment Density:** The degree to which the band is congested depends on the service type for which a frequency is assigned, with services at lower altitudes being subject to lower degrees of congestion than those for higher altitudes. To reflect these variations in the extent to which different services generate congestion, we suggest that Ofcom considers the use of different congestion 'maps' for the different service types.
- **Coverage:** A number of shapes, based on 50 x 50 km squares have been proposed to define the geographic area sterilised by different service types. In addition, the sterilisation of adjacent channels has been taken into account by the application of further 50 x 50 km shapes. The resultant sum of the co-channel and adjacent channel sterilisation shapes represents the total geographic sterilisation created by an assignment of any particular service at any given location in the UK.
- **Sharing of Spectrum:** No usage within the band should be classed as shared.

4.2 Density based tariff gradients

For the purposes of Business Radio, the UK landmass is described by 171 50 x 50 km squares. The national value of a 25 kHz channel (in a Highly popular band) is £9900 per annum, which implies an average price per 50 x 50 km square of £57.89 per annum. In the existing Business Radio pricing structure, however, the price of a 50 x 50 km square is weighted to take account of relative assignment density, using the residential population encompassed within the squares concerned.

In the aeronautical case, the level of sterilisation density (spectrum congestion) in any UK 50 x 50 km square depends on assignments made elsewhere in the country and internationally and also varies depending on the service type, as described in section 3.3. Accordingly, the situation is more complex, such that any categorisation of High, Medium and Low density squares will need to be defined on a different basis to Business Radio and will attract different prices dependent on the service type in question.

In the case of high altitude services, where all of the 171 UK landmass squares fall into the High density category (if High density is defined as over 720 assignments apparently sterilising the use of a given square, as set out in section 3.3), and where the number of squares sterilised is greater than (or equal to) the 171 which describe the UK, the price per annual 25 kHz licence would be £9,900 regardless of the location of the assignment concerned.

For services used at lower altitudes, there will be a geographic differentiation in the extent of the congestion generated by the service concerned. Assignments in High density areas will generate relatively more congestion than implied by the national average and those in Low density areas will generate less.

Where all 171 squares fall into a single density category (eg 'High density'), the average annual congestion value of a 25 kHz assignment will be £9,900/171 or £57.89 per square. Where there is variation between categories amongst the 171 squares, the average cost per square per category can be derived using the equation:

$$\text{Cost/square} = \frac{\text{£9900} * \text{Total assignment sterilisation}}{\text{Total UK assignment sterilisation} * \text{Number of squares in that category}}$$

For this purpose, we can take the total assignment sterilisation to be the number of assignments which are sterilised in all squares of a given category for the service concerned, and total UK assignment sterilisation to be the number of assignments which are sterilised in all 171 UK squares for that same service.

As the granularity of the measurements of squares is only to the nearest 50km, it is possible to band together the various aeronautical services in Table 4, for the purposes of estimating the geographical variation in relative congestion levels, into the following five groups:

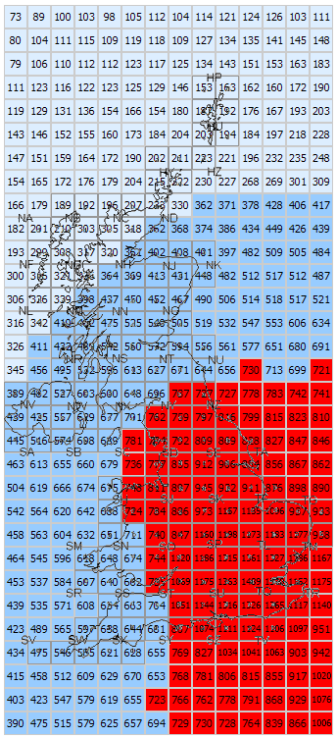
- Ground-Based services (e.g. surface movement control) which require clearance of approximately 50km;
- Aerodrome control and AFIS which require clearance of approximately 150km;
- Approach control (lower) which requires a clearance of approximately 350km;
- Approach control (intermediate), Area control (lower) and VOLMET which require a clearance of approximately 500km;
- Area control (upper) and ATIS which require a clearance of approximately 750km.

Table 7 below shows the required clearance as per the delineations above, together with the number of Low, Medium and High squares which result (in terms of less than 360, less than 720 and more than 720 existing assignments which notionally sterilise the square concerned), the assignment sterilisation in each of those types of square, and the equivalent fees.

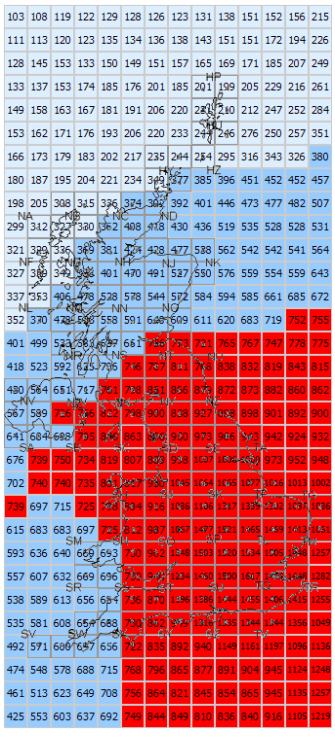
Required Clearance	Total Assignment Sterilisation		Number of Squares		Price per Square	
50km	Low:	7733	Low:	31	Low:	£21.63
	Medium:	41288	Medium:	75	Medium:	£47.74
	High:	65138	High:	65	High:	£86.90
150km	Low:	2721	Low:	9	Low:	£18.91
	Medium:	25310	Medium:	48	Medium:	£32.99
	High:	130221	High:	114	High:	£71.46
350km	Low:	0	Low:	0	Low:	-
	Medium:	5559	Medium:	8	Medium:	£25.89
	High:	260116	High:	163	High:	£59.46
500km	Low:	0	Low:	0	Low:	-
	Medium:	0	Medium:	0	Medium:	-
	High:	352439	High:	171	High:	£57.89
750km	Low:	0	Low:	0	Low:	-
	Medium:	0	Medium:	0	Medium:	-
	High:	504895	High:	171	High:	£57.89

Table 7: Tariff Gradients for Low, Medium and High density areas

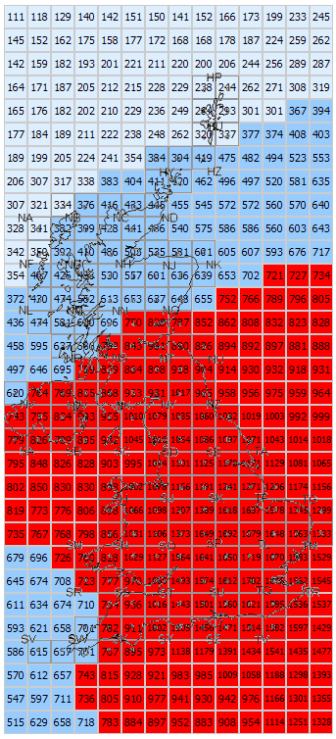
The density maps associated with these calculations are shown below:



50km clearance

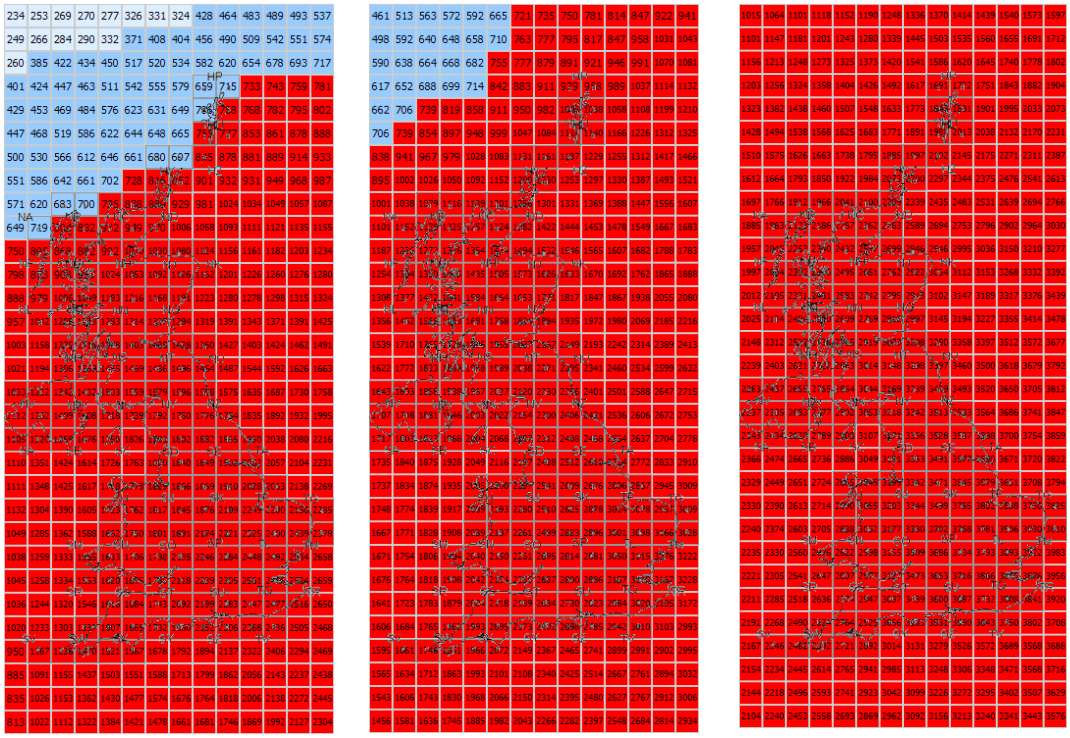


100km clearance[12]



150 km clearance

[12] Note that this map is not required for calculation. It is shown for interest only.



350 km clearance 500km clearance 750km clearance

As the proportion of higher density squares increases, the average price for these higher density squares tends towards the national average rate.

It therefore seems possible for Ofcom to consider the application of congestion based charging for different services. As was indicated in section 3.3, caution should be taken in using the information employed to create the maps in this report for such a purpose, due to the inaccuracies present in the data available in the COM2 Table. Should Ofcom decide to differentiate between congestion areas by service, either this should be based on the COM2 Table (as per these maps), or Ofcom should seek more accurate information from the countries concerned (including the UK).

4.3 Comparison with band value

In order to assess the extent to which the application of the prices under or over recovers the total value of the band, we have assumed the case in which all squares are nominally priced at £57.89 each (implying an even distribution of spectrum congestion for all services across the UK landmass). Applying this unit rate to the assumed number of grid squares impacted by each of the aeronautical VHF communications uses set out in Table 8 below, generates the following fees (for a 25 kHz channel):

Service	Total number of squares sterilised	Annual Fee
Aerodrome control	45	£2606
Aerodrome flight information service	45	£2606
Surface Movement Control	6	£347
Approach control – Upper	827	£9900
Approach control - Intermediate	359	£9900
Approach control - Lower	167	£9668
Area control service - Lower	359	£9900
Area control service - Upper or Flight information service - Upper	827	£9900
SST high level operations	Over 2200	£9900
VHF extended range		
Flight information service – extended range		
VOLMET	391	£9900
ATIS	827	£9900

Table 8: Calculated Fees by Service Type

In most cases, the fees calculated by counting sterilised 50 x 50 km grid squares would exceed the assumed value of a national channel (£9900). We recommend that, to maintain a conservative approach to fee setting (consistent with the approach described in Ofcom's July consultation) the figure of £9900 should be taken as a ceiling fee for any 25 kHz aeronautical channel.

It should be noted that, using the coverage areas identified, there will be many instances in which the coverage of a specific aeronautical assignment extends to squares which do not form part of the 171 which describe the UK landmass. Whilst it may seem inappropriate to charge for sterilisation caused outside the UK's landmass, the sterilisation of those squares has material consequences for other potential aeronautical VHF spectrum uses via UK-issued licences in these and other areas. This is because, in most cases, the sterilisation of a square outside the UK's landmass impacts the ability of others to transmit from within the UK due to the need for additional clearance between usage and any squares sterilised. It therefore seems appropriate that these areas should be included when setting fees.

The fee for an 8.33 kHz channel would be one third of those indicated above (subject to a minimum fee of £75). Fees in areas where there is a differentiation between Low, Medium and High density prices would also differ from the results presented in Table 8 above and may be lower or higher (subject to the minimum and maximum fees).

The fees for digital channels would be approximately double those indicated above, however the number of squares sterilised would be slightly smaller as the adjacent channel sterilisation as used for analogue services is not applicable. In the majority of cases this will yield an annual fee of £19800, with the following exceptions:

Service	Total number of squares sterilised	Annual Fee
Aerodrome control	37	£4284
Aerodrome flight information service	37	£4284
Surface Movement Control	4	£463
Approach control – Lower	157	£18177

Table 9: Calculated Fees for Digital Services

Note that Ofcom does not intend to charge for 'emergency' frequencies such as the international emergency frequency of 121.5 MHz.

More widely, Ofcom may not wish to set fees that in total come to more than the value of the band. For the frequencies from 117.975 to 137.000 MHz, at an average rate of £396,000 per national MHz, the value of the complete band is £7.534 million.

The table below shows the number of licences which fall into the various categories and thus the resulting total fees that would be collected on the basis described above (assuming the use of 25 kHz channels).

Type	Number	Fee per Station	Total Fee
ACC	224	£9900	£2,217,600
AFIS	36	£2606	£93,816
APP	139	£9668	£1,343,852
ATIS	48	£9900	£475,200
VOLM	11	£9900	£108,900
All Others (as SMC)	714	£347	£247,758
Total	**1172**		**£4,487,127**

Table 10: Total Fee Income

This analysis indicates that the overall fees charged to users might be 40% below the calculated total value of the band at £7.435 million (per annum). This might appear to suggest that the band is not as heavily congested as the preceding analysis implies, however we note that over 60% of the licences on issue (714 out of 1172) are for low altitude services where congestion is not as heavy. A rebalancing of fees for these services to reflect relative congestion as described above would go some way to redressing this apparent inconsistency. Further, some of the congestion identified in the UK is caused by services operating in neighbouring European countries. This extra-national sterilisation of UK territory is not taken account of by the fees raised from UK licensees such that it would be expected that the total value of the band may not be realised from UK usage alone.

4.4 'CLIMAX' operation

For some services, whose operational space extends over a very wide area, several geographically disperse transmitters are operated on the same

frequency[13] such that coverage is provided over an area larger than that which could be addressed from a single site. This technique is known as 'CLIMAX' operation and is used in the UK for control of upper air space sectors which extend beyond the coverage of a single transmitting station. Up to 4 transmitters may share the same 25 kHz channel. Such usage is always by the same organisation (eg NATS) and the licences held by a single party.

As all the transmitters in such a network share a single 25 kHz channel with coverage extending over the whole of the UK territory, it would seem appropriate to licence the group as a whole using Area Defined licensing. As such, the frequency in question would attract, say, a single £9900 annual fee, regardless of the number of co-frequency transmitters in operation.

[13] In practise, the individual transmitter frequencies are slightly offset from each other in order to prevent mutual interference, however all emissions from all sites are contained within a single 25 kHz channel.