The Duffer's Guide to Spectrum Pricing

What is Spectrum Pricing, and how does it affect Radio Amateurs?

The radio spectrum is a valuable resource: a 2005/6 study [1] said that the use of the radio spectrum in the UK contributed £37 billion to the economy and created 240,000 jobs. Demand for spectrum is ever increasing but supply is fixed, leading to problems of congestion (where spectrum can not handle more users) and scarcity (where no spectrum can be found for new uses). Traditional 'technical' techniques for managing spectrum struggle to solve the problems of congestion and scarcity in that they:

- require complex and lengthy compatibility studies between new systems, slowing down decision making;
- can lead to decisions over the use of radio spectrum which do not take into account the value of the particular use or application;
- may not encourage existing users to be efficient in the way that they use spectrum;
- can stifle the introduction of new technologies and techniques.

To try and overcome some of these limitations, in the mid 1990s, the Radiocommunications Agency (now part of Ofcom) decided to explore new spectrum management techniques which relied on economic instead of technical methods. One of the main outputs of their thinking was the concept of 'spectrum pricing'. Put simply, spectrum pricing is a method whereby the price which users pay for access to the radio spectrum is set at a level which encourages efficient behaviour. Contrary to popular belief, this does not necessarily mean that prices increase. Whilst it's true that increasing the price of spectrum may force users to think hard about their usage, lowering prices may encourage efficient behaviour too.

Take the example where one band of frequencies is underused whereas another is congested. There are two ways in which users could be encouraged to migrate to the underused band: firstly the price of licences in the congested band could be increased, or the price of licences in the underused band could be lowered, or both!

One of the subtleties which the Radiocommunications Agency battled with was: 'how much do prices need to change to encourage efficient behaviour'. A report was commissioned [2] which considered how prices might be arrived at. The principle developed was to consider what a user might do if they were denied access to a particular piece of spectrum and to cost the alternatives available to them. If the licence were then priced at the lowest cost alternative, users would, in theory, have the choice of continuing to use their existing spectrum and technology or migrating to the alternative, both of which should be equal in cost. If the price is raised above this threshold, then users should 'see the light' and migrate to the alternative to make savings.

Consider a bus company, with a fleet of 500 buses covering a medium sized city with 5 VHF base stations and 500 radios. What options do they have if they are forced to give up their VHF frequencies?

- They might migrate to UHF, if UHF bands are lower priced. This would require the replacement of all 500 radios (and antennas) and the 5 base stations, but as UHF coverage may not be as good as VHF, they might also need to install additional base stations.
- They could move to a publicly provided service (eg PAMR or CBS) and share facilities with other users such as the local council. This would require the replacement of the radios and the payment of a monthly service fee.
- If coverage were available in the right places, they might be able to replace the radios with mobile phones. This would require the payment of monthly subscription fees and call charges.

The cost of each of these three options would be calculated and the lowest of these would then represent the value of the spectrum to the bus company. If the price is raised above this threshold, then they should be motivated to migrate to an alternative to make savings. However there may be non financial reasons which stop such a move, such as security (of the service and of the handsets) and lack of equivalent functionality (eg being able to speak to all 500 buses simultaneously). It is feasible that such a calculation may indicate that a move to, say, mobile phones yields a spectrum value which is negative, that is to say that the cost of moving over to such a service is actually less than continuing with the existing VHF system. In this case, the logic dictates that the bus company should already be considering migrating to mobile phones without any change in spectrum fees. In most cases, however, the value calculated is positive.

Despite recent re-estimates [3], the value of spectrum (in the UK) has remained relatively constant. For 'mobile' spectrum which is not just that used by mobile phones but includes our friend the bus company, the current annual rate is £396,000 per national MHz. This rate is factored by the area covered and the amount of spectrum used. A single, national, 25 kHz channel is therefore valued at £9,900 per year and smaller coverage areas attract lower fees.

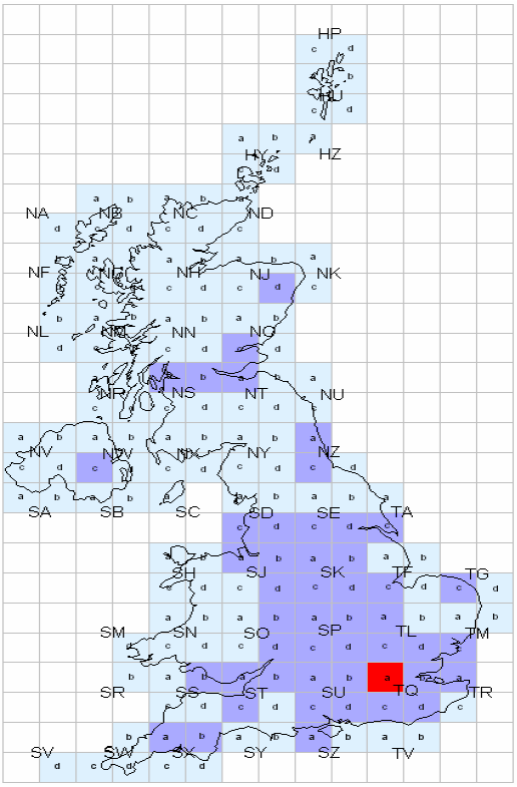
More recently, a second method has been considered. In this instance, the 'lost' opportunity cost of the spectrum is calculated. This is the value of the spectrum to someone (else) who is denied access to it. So if the bus company were using spectrum and in doing so were denying access to the local airport who could make more valuable use of it, the loss to a local airport could be calculated and this value applied to the spectrum. In this way, the full value of the spectrum is still being realised, not through its use, but through its charges, and no opportunity has been lost. Calculating the value of someone not having access to spectrum is, however, rather complex and fraught with problems. What is the value of not giving spectrum to an FM broadcaster for example? Without the spectrum they would have no business at all, so is it fair to charge someone else the turnover of the station? Generalisations have to be made and typically such calculations are done on the basis of the effect on a business of being denied access to some unit of spectrum rather than all of it.

In the FM broadcasting example, the cost of losing, say, 1 MHz of the FM band might be estimated. This would require some re-planning and re-tuning of transmitters and would most likely result in a reduction of coverage for some services due to increased interference as stations are packed more tightly together. The cost of changing publicity material (caused by a change of frequency) and the potential loss in advertising revenue due to the smaller audience could be estimated and these then taken as the value of 1 MHz of FM broadcasting spectrum.

Variations to the calculated price

The price calculated is typically varied depending on two other factors:

- **The popularity of the band in question**. Some bands are more expensive than others due either to their propagation characteristics (frequencies which propagate further or penetrate buildings better are seen to have a higher value) or the availability of equipment (bands for which equipment is readily available are more popular and thus have a higher price).
- **The degree of congestion at the location of usage**. For example, for business radio use, the UK is broken down into 50 by 50 km squares and each is assigned a high, medium or low level of congestion: the lower the level of congestion, the lower the price. In this case congestion (as shown in the figure below where red, medium blue and light blue represent areas of high, medium and low congestion respectively) is based on the population density in that square.



Source: Ofcom

For a 25 kHz channel, the price of a 50 by 50 km square varies as shown in the table below. There is also a sliding scale for areas smaller than this based on the antenna height and transmitter power. Note also that there is a £75 per year minimum fee which applies in situations where the calculated fee is less than this.

	Highly Popular Band	Medium Popular Band	Less Popular Band
High Population category	£1185 per year	£990 per year	£395 per year
Medium Population category	£150 per year	£125 per year	£75 per year
Low Population category	£75 per year	£75 per year	£75 per year

The following table details which bands fall into the different popularity categories:

Popularity	Frequencies
High	VHF High Band (165 – 173 MHz) UHF1 (425 – 450 MHz) UHF2 (453 – 466 MHz)
Medium	VHF Mid Band (138 – 165 MHz) VHF Band III (177 – 208)
Less	Paging (26 – 50 MHz) VHF Band I (55 – 68 MHz) VHF Low Band (68 – 88 MHz)

Frequencies above 1 GHz are charged at lower rates and there is a sliding scale depending on the band (the higher the frequency, the lower the price).

What is the value of Amateur spectrum?

Whilst juxtaposing existing Ofcom prices on amateur bands is not necessarily a valid way of calculating fees (for reasons which will become apparent later), the table below illustrates how various bands might be valued. The figures are based on Ofcom's most recent proposals relating to frequencies in similar bands [4]. Only frequencies up to 24 GHz have been included as above this, Ofcom is considering making vast swathes of spectrum unlicensed and hence no fee would apply.

Band	Price per national MHz	Total
50 – 52 MHz	£132,000	£264,000
70 – 70.5 MHz	£132,000	£66,000
144 – 146 MHz	£330,000	£660,000
430 – 440 MHz	£396,000	£3,960,000
1240 – 1325 MHz	£126,000	£10,710,000
2310 – 2450 MHz	£126,000	£17,640,000
3400 – 3475 MHz	£126,000	£9,450,000
5650 – 5850 MHz	£32,000	£6,400,000
10000 – 10125 and 10225 - 10500 MHz	£25,000	£10,000,000
24000 – 24250 MHz	£19,000	£4,750,000
TOTAL		**£63,900,000**

The population of UK radio amateurs is around 63,000 so in theory we should all be paying fees of over £1,000 per year. But clearly we are not! Why is this? There could be several reasons:

- we are not the primary or main user of most of the spectrum we use;
- there is little external pressure to use the bands we occupy;
- our usage patterns do not sit within a pricing regime.

Let's explore these reasons in more detail.

Sharing with the MoD

In much of the spectrum which radio amateurs use, we are the secondary user: we operate in the band but must not cause interference to primary users and must tolerate interference from them. It is not that we have no official status in the bands, just that our use is not the prime one. There are some exceptions to this: in the lower 1 MHz of the 6 metre band, the whole of 2 metres and the lower 50 MHz of the 24 GHz band amateur radio is the primary user but this represents only a very small portion of the overall spectrum we are allocated.

Where radio amateurs are not the primary user, it could be argued that we are also not the primary beneficiary of the value of the spectrum but are a marginal user who co-exist alongside the primary user at little to no cost to them. In most cases, the spectrum used by radio amateurs in the UK 'belongs' to the Government, either in the form of the defence forces or of various transport users. The table below shows who the main users or services are for the amateur bands from 50 MHz to 24 GHz ('main' referring to both primary users and other commercial users with whom the bands are shared).

Band	Main Users
50 – 52 MHz	Radio Amateurs 50 – 51 MHz Defence 51 – 52 MHz
70 – 70.5 MHz	Defence
144 – 146 MHz	Radio Amateurs
430 – 440 MHz	Defence Mobile (PMR) 431 – 432 MHz
1240 – 1325 MHz	Defence, Aeronautical Radar, GNSS
2310 – 2450 MHz	Fixed Links, PMSE[1], Low Power Devices, ISM[2]
3400 – 3475 MHz	Defence, Wireless Cameras
5650 – 5850 MHz	Defence, Wireless Cameras, Low Power Devices
10000 – 10125 and 10225 - 10500 MHz	Defence, PMSE
24000 – 24250 MHz	ISM Radio Amateurs, 24000 – 24050 MHz Low Power Devices 24050 – 24250 MHz

It can be seen that, in many cases, the main user of the spectrum which radio amateurs employ is defence. Defence use of radio spectrum is licensed in a very different way to that of civil spectrum: Ofcom is not the body responsible for its management, instead it is considered Crown property and is managed directly by the Ministry of Defence (MoD). Historically, the MoD has not been subject to spectrum pricing, however in 2005, an audit of Government spectrum holdings [5] recommended that Government use should be subject to pricing in order to encourage efficient use of the spectrum in the public sector as well as the private sector.

[1] Programme Making and Special Event (PMSE) includes uses such as wireless cameras and video links from outside broadcasts.

[2] Industrial, Scientific and Medical use, such as microwave ovens.

The total bill for Government spectrum use is estimated to be around £300 million per year, the vast majority of which falls to the MoD. Another outcome of the audit was to suggest that the MoD should identify bands in which it would be possible to permit commercial use and put in place mechanisms to share these bands with other users. To this end, the MoD went out to public consultation [6] on the management of defence spectrum. Following feedback from various interested parties, it then published plans for taking these initiatives forward [7].

The MoD's plan is to firstly conduct an audit of its own use to identify and clarify which frequencies it was actually using within the various bands it manages. From this it will identify where it could open up spectrum to commercial use. In order to permit such usage, it has to apply to Ofcom for 'Recognised Spectrum Access' (RSA). Under existing legislation, the MoD is not permitted to sell, lease or otherwise engage in commercial activities using its spectrum. RSA is a means by which the MoD's ownership of a particular piece of spectrum can be legally recognised under the Communications Act 2003 such that it can then go ahead and offer its spectrum to non-Government users.

The MoD's original timetable for the order in which it intends to go about releasing spectrum for commercially use is shown in the table below (note that this timetable has already slipped significantly). This includes some or all of the bands from 70 cm to 10 GHz except 2 metres and 23 cm.

Date	Bands
By September 2009	406.1 – 430 MHz 3400 – 3600 MHz 4400 – 5000 MHz 5300 – 5850 MHz
By March 2011	3100 – 3400 MHz 7900 – 8400 MHz 8500 – 9000 MHz 9500 – 10500 MHz 13400 – 13750 MHz 14620 – 15230 MHz
By March 2012	72.8 – 74.8 MHz 75.2 – 76.7 MHz 78 – 80 MHz 83.5 – 85 MHz 141.9 – 143 MHz 149 – 149.9 MHz 153.5 – 154 MHz 230 – 399.9 MHz 430 – 450 MHz 870 – 872 MHz 915 – 917 MHz 1375 – 1400 MHz 1427 – 1452 MHz 2310 – 2450 MHz 7250 – 7300 MHz

So what is the MoD's position with respect to the impact of its moves on radio amateurs? The consultation stated,

> "*In bands that radio amateurs share on a secondary basis, their freedom to operate could be affected by an increase in spectrum use by primary user, whether civil or military … However, the proposals in this document are not expected to have an effect before 2012 … In the longer term, the MoD hopes that its current good working relationship with the RSGB will continue into the future through any potential changes in spectrum usage*."

In being forced to pay for the use of their spectrum and having to release some of it, there is the chance that commercial users will pile into those bands currently shared with amateurs. Whilst amateurs do have certain rights to share the bands, the fact that we must not cause interference to primary users could make operation in some bands untenable.

Lack of pressure on bands

One of the original tenets of spectrum pricing was that it should only be applied where the frequencies in question were congested or there was excess demand. So the question of whether there is demand for amateur bands seems like a good one to ask.

The 2 metre and 70 centimetre bands sit amidst a wealth of heavily congested Government and commercial use and most commercial equipment built for VHF and UHF bands is capable of tuning to the amateur bands (a fact not overlooked by many amateurs!) As such, it seems clear that there would be demand for these bands if they were available commercially. A 1995 report by the European Radiocommunications Office (ERO) [12] suggested that the 70cm band could be shrunk to 432 – 438 MHz (in return for low power devices moving out of the ISM band centred on 433.92 MHz); there is already commercial use of the frequency range 431 – 432 MHz in London.

The 9cm band seems under particular pressure from the EU [10] and the ITU [11] for wireless broadband services. Frequencies from 3480 to 3500 MHz are already licensed to UK Broadband for this purpose. The lower part of the 13cm band (from 2310 – 2400 MHz) has been earmarked in some circles for broadband services and the MoD has recently signalled its intention to release part of this band for commercial uses, and, of course, we already co-exist with a variety of low power and ISM devices between 2400 and 2450 MHz.

For many other bands, however, the primary use is one which would largely preclude access by (and thus demand from) other users. The 23cm band, for example, lies in and around various aeronautical radars. If amateur operation were to cease, there would be no additional spectrum released. It is the agility and sensitivity of amateur equipment which allows us to generate any utility from this busy portion of spectrum in the first instance. If the radars were to cease operation then the situation would be very different, but this is unlikely.

For some bands therefore, there appears to be little pressure to force amateur operations to cease. In other bands though, it seems likely that our usage could be affected by new users keen to gain access to internationally designated and harmonised spectrum allocations.

International Framework

The principle of spectrum pricing is to encourage efficient user behaviour taking account of the value of the spectrum but there are cases (identified in the original spectrum pricing report) where there may be policy or other reasons why pricing is not appropriate. These include situations where:

- **There are opposing Government objectives** which counteract the objectives of spectrum efficiency. For example, if Government policy were that all rural communities should have access to wireless broadband, charging high prices for the spectrum required would be counter-productive.
- **There is no opportunity to recover the fees**. If spectrum pricing were imposed on, say, the use of spectrum by remote control toys, doorbells etc, there is no mechanism to charge those already using such devices (though an additional tax could be introduced for future sales).
- **There is no opportunity for users to become more efficient**. There are various measures of spectrum efficiency (eg throughput per Hz per square km) but even with a detailed knowledge of how these are calculated, proving efficiency is exceptionally difficult.
- **There are international treaties which constrict users to certain frequencies**. Take maritime services, for example: if each country used different frequencies or technologies for ship to shore communication, boats travelling from one place to the next would need multiple radios. This restricts the ability to introduce more efficient technology but that is not to say that it cannot be done: a programme of introducing more spectrally efficient radios onto aircraft [8] has done just this.

Do any of these apply to amateur radio? The amateur service is seen in many countries as a combination of experimentation; as communication fall-back in the case of national emergencies; and for self-training.

It is arguable that experimentation is both efficient and inefficient depending on the experiment being conducted. Digital techniques which use tiny amounts of spectrum (PSK31) demonstrate our ability to be highly efficient. By contrast, our use of bands such as 6 metres which remain almost completely empty except when enhanced propagation conditions occur could be argued to be highly inefficient.

Our ability to maintain communications in times of emergency and disaster is recognised at the ITU [9] and radio amateurs have played pivotal roles during events such as tsunamis, floods and storms. Even Ofcom recognises that emergency use of the spectrum should not be charged for, however to what extent could our use truly fall into this category? Does our ability to offer such a service at times of need qualify or are there alternate means to provide spectrum in emergencies that do not require us to have permanent access?

Perhaps the answer to this question falls within self-training. There would be no use in just making spectrum available to radio amateurs at times of emergency if we had not had an opportunity to learn how to use of it. The training aspect of amateur radio transcends just emergency situations however, and you will find many senior radio engineers and policymakers initially learnt their trade through becoming radio amateurs!

Finally, the frequencies we use are agreed at the ITU and thus our use is constricted by international treaties. This does not, however, stop national authorities from taking decisions on amateur spectrum use which differ from international agreements. The fact that amateur use of the 70cm band in the UK is secondary is, for example, at odds with the ITU allocation which affords us primary status. However the system favours us in other ways, such as the assignments at 40 and 60 MHz on which Ofcom have permitted amateur beacons as well as the whole of the 5 and 70 MHz bands which are not widely available elsewhere (even though they are slowly becoming so).

All of the above does not necessarily indicate that radio amateurs are should be exempt from spectrum pricing. Whilst some might see free licences as the first step towards denigrating the status of the amateur service, the fact that, at present, Ofcom have chosen not to introduce pricing for amateur use could, instead, be taken as a recognition of the wider social and societal benefits which accrue from our experimentation, emergency support and training.

The future

So what of the future? It seems almost inevitable that the inexorably growing demand for radio spectrum will place pressure on the amateur bands and that some will either shrink or disappear altogether. The 3.4 GHz band seems close to extinction with, perhaps, some (more) of the 10 GHz band following closely behind. 70cm is also not necessarily safe in its current form.

Perhaps the time has come for amateurs to take greater control over our spectrum. Maybe we should consider paying for the small, primary allocations we possess (2m in particular), to safeguard their future, and think about demonstrating the efficiency to which we put the spectrum. Our experience of operating alongside other users without causing them harmful interference is worth consideration. Could we, for example, co-exist in bands used by broadband wireless services and thus secure continued access to 3.4 and 10 GHz – we already share with them 2.4 GHz? Could we even teach commercial users a thing or two about sharing spectrum demonstrate the real added value which we bring to the wider spectrum community?

References

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