An Implementation of Spectrum Usage Rights for Liberalization of the Radio Spectrum

Joe M. Butler and William T. Webb

Abstract: **This paper presents one possible approach for liberalization of the radio spectrum based around spectrum usage rights (SURs) which are technology and usage neutral. This is challenging technically because of the complexity of defining rights which are flexible and technology-neutral while retaining sufficient safeguards against interference. The work presented here is part of an ongoing process of defining and testing SURs. Ofcom is currently considering SURs, though is not committed to implementing them at this stage, and will issue further discussion documents on this area in due course.**

Index Terms: **Radio spectrum management.**

I. INTRODUCTION

Ofcom proposes to liberalize use of the radio spectrum in the UK. It is proposed that this liberalization be introduced in two phases. Initially, Ofcom will assess whether a proposed change in spectrum use is acceptable, but eventually it is expected that change in spectrum use will be negotiated in the market within a suitable technical and procedural framework.

Ofcom has already introduced spectrum trading in the UK for some bands of the spectrum. It is planned to extend trading to almost all suitable license classes by the end of 2007. Spectrum trading, however, is only one part of the mechanism which will enable the market to determine the usage of the radio spectrum. A mechanism is also required to allow the change of use of the radio spectrum, currently determined by a license. It is this element that is discussed here.

This paper presents one possible candidate implementation for liberalization of the radio spectrum in the UK based around spectrum usage rights (SURs) which are technology and usage neutral. The work is part of an ongoing process of defining and testing SURs. Ofcom is currently considering SURs, though is not committed to implementing them at this stage, and will issue discussion documents to stakeholders in due course. Some of the work covered here has been undertaken by a team of consultants whose contribution we gratefully acknowledge.

In Section II, we give the context of the SUR approach. In Section III, we go on to describe one potential approach to implementation of SURs. Section IV gives a brief comparison of the approach with some other nations who have taken steps to liberalize radio spectrum. Finally, we give our conclusions in Section V.

Manuscript received November 7, 2005.

The authors are with the Technology and Spectrum Operations Group, Ofcom, UK, *email:* {joe.butler, william.webb}@ofcom.org.uk.

II. CONTEXT

A. Background to the Current Management Mechanisms

Spectrum has been managed in the UK for around 100 years. The general approach adopted world-wide during this period has been for the spectrum manager to decide on both the use of a particular band and which users are allowed to transmit in the band. This approach was appropriate when much of the spectrum was used by the government for purposes such as defence, public safety, aeronautical and maritime communications, and broadcasting. While there were relatively few uses and users, the spectrum manager could also reasonably have as good an understanding of the best use of spectrum as the market itself and hence could sensibly control all aspects of spectrum usage.

However, in recent years, as demand has started to exceed supply in some areas, this "command & control" approach to spectrum management has become problematic. Where spectrum is scarce the use of "beauty contests" meant that government had to choose between competing would-be service providers. In the US, such command & control decisions were increasingly subject to legal challenge leading initially to the use of lotteries to overcome this problem and then eventually to the use of auctions. In the UK, as in other European countries, there were few contenders for the original cellular licenses in 1982, allowing a beauty contest approach to be simply applied. However, by the time the 3G licenses were auctioned in 2000, there was an international field of 13 applicants. A fair and transparent beauty contest would have been virtually impossible in these circumstances.

In parallel with these developments, economists have long argued that market mechanisms should be applied to radio spectrum. Seminal papers in this area start with Coase in 1959 [1]. The combination of a growing body of theory pointing to the role of market mechanisms, particularly auctions, and the increasing demand for the radio spectrum, led to the widespread use of auctions around the world during the 1990s. Auctions are now used as the preferred competitive means for assigning spectrum in many countries. Auctions solved the most pressing problems for many of the regulators—they allowed spectrum to be assigned where demand significantly exceeded supply in a way that is demonstrably transparent and far less prone to legal challenge than the alternatives. However, auctions without liberalization cannot let the market decide on the most appropriate use for spectrum.

Any potential problems with the current approach of the regulator deciding the best use for the spectrum are far less visible. The tendency of central command approaches is to be slower than approaches such as trading and liberalization in enabling new applications. The lack of emergence of an application is difficult to observe. However, there are a number of pointers to po-

tential problems. Some European harmonised allocations have not resulted in successful use of the spectrum. Examples include the terrestrial flight telephone system (TFTS), the European radio messaging system (ERMES) and to some degree the digital PMR terrestrial trunked radio (TETRA) which has not fully met expectations. In environments where innovation can be applied more quickly, such as the US, new applications such as WiFi, WiMax, and ultra-wideband (UWB) have emerged many years before the UK. Finally, convergence in areas such as broadcasting and telecommunications could render problematic the allocation of some spectrum to broadcasting and other spectrum to telecommunications in the case where, say, a telecommunications operator provided a form of broadcasting over their system.

As these problems have been growing, so the body of theory and experience in techniques such as trading and administrative incentive pricing (AIP) have been improving to the extent that the most practitioners would now agree that market mechanisms should be used to determine the best use of the spectrum, although there is still some disagreement over the details.

B. Trading and Liberalization of Radio Spectrum

As set out above, a key change that Ofcom proposes to make is to increasingly allow market forces to prevail wherever this is judged to be in the best interests of the citizen-consumer. The key mechanisms which will be used to achieve this are

- trading of spectrum between users so that they can buy, sell, aggregate, and disaggregate spectrum holdings and
- liberalization of spectrum use, so that increasingly users can change the technology or type of use that they make of the spectrum they hold.

Ofcom implemented trading in some license classes at the end of 2004. This is now being progressively extended to enable trading of almost all suitable license classes by the end of 2007.

Spectrum liberalization is a more complex issue than trading. Spectrum users have been packed in tightly by spectrum managers over the years, with many users sharing spectrum. Inappropriate liberalization could cause intolerable interference or inefficient use of the spectrum. Therefore, some restrictions on the use of spectrum are essential. There are two mechanisms by which Ofcom will implement liberalization.

- The first relies upon license variation to implement changes requested by users. Ofcom will consider all such requests in the light of its statutory duties and other factors, in particular we will consider whether the request can be granted without resulting in unacceptable interference to other users.
- The second mechanism involves Ofcom varying existing licenses to make them less usage and technology specific. This would allow licensees to make certain types of change to their use of spectrum without needing the prior consent of Ofcom.

The first mechanism is now in place. The second mechanism is intended to allow the market to make change of use decisions, leading to a market led liberalized radio spectrum, and is intended to supersede the first mechanism. One possible approach to implementation of the second mechanism is discussed below.

III. AN IMPLEMENTATION OF TECHNOLOGY AND USAGE NEUTRAL SPECTRUM USAGE RIGHTS

Implementation of a framework which allows a liberalized usage of the radio spectrum is complex and many details need to be considered, for example process and licensing issues, legal issues and economic issues. Therefore, in this section we outline our top level philosophy to liberalization, before going on to explain a candidate mechanism which aims to achieve this.

A. Philosophy

As discussed above, a change of use by a license holder may change the interference experienced by neighbors in both geography and spectrum terms. Our current thinking, which we will consult on further, is that

- a license holder should not be adversely impacted by the actions of their neighbor unless
  - they agree or
  - their neighbor has not taken up all their existing rights.
- The market is better able to determine optimal outcomes such as boundary conditions, than the regulator.
- We should strive for a mechanism that places a minimal burden on all parties.

B. How SUR could Work in Outline

Those who own a license for a large area could have their license restated in technology neutral terms covering in-band and out-of-band power levels, geographical boundaries and a measure of the distribution of interference that they cause to neighbors.

Those who own a license for a particular transmitter would effectively become tenants to a spectrum management organisation (SMO) who owns the whole area. The SMO would have responsibility for setting the terms for these "equipment" licenses.

If someone wishes to change the use they would need to assess whether it will materially change the interference distribution caused to neighbors. If it did not then they would be able to go ahead and make the change. If it did, then they would need to negotiate the change with their neighbors.

C. Implementation

C.1 Area and Equipment Licenses

Ofcom currently has broadly two categories of license, referred to here as equipment and area licenses, and defined below.

- *Equipment license*: The license is likely to be for a specific, localised system of a given class of usage, with a single or limited number of transmitters. The license is likely to contain a high level of detail, for example the location of the transmitter. An example might be a private business radio license. There are likely to be many licenses nationwide.
- *Area license*: The licensee is likely to have access to spectrum over large areas (frequency and/or geography). The license parameters are specified at a higher level. There is only likely to be a single license, covering a large area containing multiple equipments. An example of where an area license would be valuable would be a mobile network operator that requires the flexibility to deploy base stations based

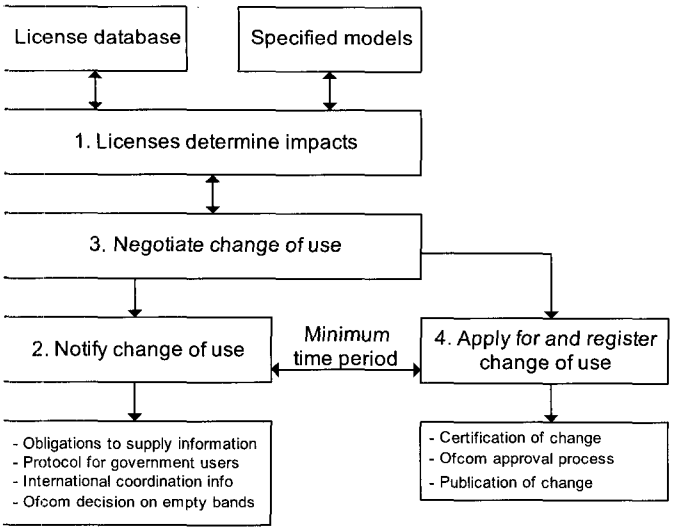

Fig. 1. Elements of the change of use process.

upon demand quickly and flexibly without extensive regulatory overhead.

The approach suggested here is to provide technology and usage neutrality at the area license level. The area licensee would then take on the responsibility for overseeing the equipments covered within the band for example the base stations of a mobile operator.

License parameters (discussed later) would need to be suitable to allow flexibility of usage within the constraints of maintaining interference to neighbors. If the usage change requires alteration of license parameter values, then this would be negotiated with neighbors.

The area licensee would effectively become an SMO, responsible for managing the users of the band within the terms of the area license. Individual 'equipment' level users of the band could then change use at the area licensee's discretion; this may be either within the terms of the area license, in which case the area licensee would need take no action, or outside the license terms, which would require the area licensee to negotiate with neighbors.

C.2 Framework for a Change of Use

We have considered options for a process for changing the use of radio spectrum against the following criteria.

- *Timeliness*—transactions can be completed in a timely manner so that incentives to innovate are preserved and new services can be deployed quickly.
- *Low cost*—the administrative costs for all parties involved in making a change of use are kept low for reasons of productive efficiency and to preserve incentives to innovate.
- *Clarity*—the steps in the process should be transparent and unambiguous so as to keep administrative and other costs down.
- *Provide appropriate incentives for taking action*—those who cause costs should bear them.

A four step process is suggested here which is outlined below and in Fig. 1, and discussed in further detail in the subsequent subsections.

1) Determining the impact of a proposed change of use on other users.
2) Notifying Ofcom of a proposed change of use.
3) Negotiating the change of use with other users.
4) Applying for and registering license variations.

Determining the impact of the change on other users: If a licensee is contemplating a change of use, then they would need to assess the scale of impact on other users in order to determine whether it is worthwhile embarking on the change of use process. It is suggested that the interference impact assessment should be the licensee's responsibility, as it is the licensee who causes and benefits from the change of use and so they should bear the related costs of making the change, including the cost of the interference impact assessment. The interference assessment would be made using relevant ITU/CEPT propagation models where they exist and otherwise using either agreed models or models derived under an industry code of practice.

Ofcom, as the national regulator, could make available a license database (register) which would contain the majority of the relevant information for current licensed users, enabling the change of use impact assessment. In some circumstances not all information may be available, for example if detailed information is unavailable for security reasons. In this case the licensee could contact potentially affected parties directly for relevant information.

Notifying an application for a change of use: The licensee would notify its intention to apply for license variations to achieve a change of use to Ofcom, as the national regulator. The purposes of this step are to

- trigger the release of information that is not in the public domain, as discussed above and
- to put all users on notice that a change of use may occur.

The licensee would need to provide Ofcom with information on the change in license parameters it is seeking. This information would be published by Ofcom to all other relevant users who may not otherwise become aware of the change of use application. Ofcom would not play any role dealing with resultant comments, but rather all communications about the change of use would be directed at the applicant. This step would trigger

1) obligations on potentially affected licensees to provide the party seeking the change of use with certain information about current spectrum use that is not given on the register but is necessary to assess the impact of a change of use, e.g., receiver characteristics.
2) Obligations on the party initiating the change of use to provide all potentially affected parties with certain information about the proposed change within a specified time period.
3) Provision by Ofcom, as the national regulator, of information concerning international co-ordination constraints within a specified time period.

Negotiating the change of use: Here the licensee wishing to change their license terms to achieve a change of use would enter negotiations with the affected parties. An example result of this process may be financial compensation paid to the affected parties for reduced quality of service due to increased interference levels as a result of the change of use.

An issue to be considered here is hold-out by a commercial licensee, i.e., a situation in which a licensee either refuses

to accept payment in return for allowing the proposed change of use, or prolongs negotiations excessively (e.g., over many months/years).

Hold-out might also be motivated by the desire to block competitive entry (rather than just being a means of extracting a high payment). We suggest here that such issues would be dealt with under existing UK competition law.

Applying for and registering license variations: If negotiations conclude satisfactorily, then the change of use licensee would apply for license variations. At this stage, Ofcom would formally approve or reject the proposed change of use, and modify the license as appropriate. We suggest that Ofcom would not have a role in approving the technical aspects of the license variations. Its responsibility would be for ensuring regulatory compliance, for example ensuring compliance with issues such as

- interests of national security,
- community obligations and international agreements.

C.3 License Parameters and Triggering a Change of Use

As we have described, we believe that the best mechanism for implementing change of use is through technology and usage neutral spectrum usage rights. These will allow users to understand their ability to change their technology or usage without needing prior approval from Ofcom or expensive interference studies.

A key challenge in defining such rights is to allow maximum flexibility to change technology or usage while at the same time preventing increased interference suffered by others. Successful implementation of such rights might for example give a mobile national operator the freedom to change their spectrum usage from 2G to 3G or WiMax, subject to other regulatory considerations.

However, some changes of use will inevitably lead to significant changes for example to the interference levels suffered, or to public safety criteria. In these cases, the license parameters should be sensitive enough such that the change of use triggers a requirement for the license parameter values to be changed, and the framework outlined in Section III-C.2 above to be initiated.

A wide range of possible parameter sets could be used to define SURs. The following criteria have been used to evaluate the suitability of proposed license parameters.

- *Transparent*: It should be easily apparent what the license holder is permitted to do and what protection from interference they can expect.
- *Technologically and usage neutral*: The parameters selected should be those necessary to ensure efficient management of the radio spectrum including interference issues without requiring identification of particular services.
- *Complete and consistent*: There should as far as possible be little or no ambiguity and the data set should not contain inconsistencies.
- *Measurable*: To ensure that compliance with license terms can be verified.

A candidate set of license parameters are shown in Table 1, and the key points discussed below.

Effective isotropically radiated power (EIRP): The EIRP parameter is required in the license for public safety reasons and to manage interference received due to receive filters being overloaded.

Table 1. Area license—example transmit parameters.

Parameter description	Limits
Frequency band held	E.g., 1,995 MHz–2,010 MHz
Geographical limits	E.g., UK national boundaries
Maximum EIRP from a transmitter	62 dBm
In-band interference: Aggregate in-band PFD at or beyond geographical boundary should not exceed X dBW/m^2 /[reference bandwidth] at any height up to H m above local terrain for more than P% of the time.	$X = -183.4$ dBW/m^2/4 kHz $H = 30$ m above ground level $P = 10$%
Out-of-band interference: Out-of-band PFD at any point up to a height H m above ground level should not exceed X dBW/m^2/MHz for more than Y% of the time at more than Z% of locations in any area A km^2.	$H = 30$ m above ground level $X = 123.8$ dBW/m^2/MHz $Y = 10$% $Z = 50$% $A = 3$ km^2
Indicative Interference Level: Interference level is not expected to exceed X dBW for more than Y% of the time at more than Z% of locations.	$X = -146$ dBW $Y = 10$% $Z = 50$%

This would be defined as the maximum in time, but mean over the bandwidth, for all carriers from the specified transmitter. Systems employing power control could specify a set of EIRPs with associated percentage of time to define a cumulative distribution function.

Geographical limits: Geographical limits will be specified either by well understood boundaries lines, such as national borders, or by a sequence of grid references with a straight line boundary between each reference. Maximum heights of transmitters would also be specified within the license for public safety reasons.

In-band power levels: A maximum in-band power limit is needed to allow designers of equipment intended for neighboring bands to assess the need for adjacent channel rejection. Maximum in-band power could be specified in terms of EIRP, as it is today, however, this makes it difficult for neighboring users to assess whether the level of interference they are receiving is excessive.

This license approach is based upon use of power flux density (PFD) masks on and outside of specified geographical limits. This would control the aggregate power crossing the geographic boundary by ensuring the licensee meets the following constraint:

The predicted mean aggregate power flux density should not exceed a value of X dBW/m^2/[reference bandwidth] at any height up to Y m above ground level at or beyond the border line.

Out-of-band power levels: This would control the aggregate power crossing the frequency boundary, using a similar constraint to that above:

The predicted mean aggregate power flux density should not exceed a value of X dBW/m^2/reference bandwidth at any height up to Y m above ground for more than Z% of locations within any area of size A within its service area.

Indicative noise floor: This parameter would give license holders an indication of the interference level that they can ex-

pect. Just as PFD masks are specified for in-band and out of band transmission interference, here we propose the same conditions are applied for specifying aggregate interference levels that may be expected to be received both in and out-of-the licensee's band.

This would provide both interfering and victim licensee with a common baseline. The percentage is not calculated over either's licensed area, but to a reference area (for example, 1 km^2). This format could be used to calculate a cumulative distribution function of PFD vs probability that PDF is exceeded, that could be used in interference analysis when assessing the impact of a change of use.

Where there is a case of interference the license holder would be encouraged in the first instance to discuss the problem with the interferer. If resolution could not be reached then the regulator would be required to step in and determine who is at fault.

IV. COMPARISON WITH OTHER NATIONS

A number of countries, most notably Australia, Canada, New Zealand, and the US, have already taken steps to liberalize the radio spectrum. We have drawn on the experience of these regimes with the management of interference issues in developing our proposals.

It is difficult to make useful broad comparisons between the national approaches because there are significant differences for example in the framework and processes involved. However, noting this caveat, we make some simplistic, high level observations here.

There is a significant difference between the Australian approach which specifies a wide range of parameters and allows for registration of terminals in order to reduce the risk of potential interference problems, and the US (and Canada who have a similar approach) where the technical framework is minimal and spectrum users are expected to resolve any interference problems that might arise. Both approaches allow a wide range of flexibility to be achieved, though in the US case the responsibility for settling interference disputes resides with users (except in the case of unlawful interference).

In New Zealand, a band manager approach has been adopted through spectrum management rights which offers wide flexibility in usage, although limited technical constraints and process and the requirement not to cause interference to existing users effectively imposes additional constraints.

The approach considered in this paper provides a significant degree of flexibility by providing for spectrum management rights similar to the practice in New Zealand. However, there is intense utilization of the spectrum in the UK, and in order to provide control over the interference environment the technical constraints proposed for the management rights have been specified to a greater degree and in this respect are closer to the regime in Australia. The technical constraints could be relaxed or tightened as required under the proposed approach through negotiation with neighboring spectrum users.

The approach here proposes registration of spectrum usage at both a wide area and system level, this information possibly being made available through a database. This could be of aid to the manager of a frequency band, as well as aiding the functioning of spectrum usage both at a technical and a market level. Registration is required both in Australia and New Zealand.

V. CONCLUSIONS

Ofcom's vision for spectrum where market forces can be applied can be summarized as

1) spectrum should be free of technology and usage constraints as far as possible. Policy constraints should only be used where they can be justified,
2) it should be simple and transparent for license holders to change the ownership and use of spectrum, and
3) rights of spectrum users should be clearly defined and users should feel comfortable that they will not be changed without good cause.

The key change that Ofcom intends to make is to increasingly allow market forces to prevail wherever this is judged to be in the best interests of the citizen-consumer. The key mechanisms that will be used to achieve this are

- *trading of spectrum* between users so that they can buy, sell, aggregate and disaggregate spectrum holdings, and
- *liberalization of spectrum* use, so that increasingly users can change the technology or type of use that they make of the spectrum they hold.

In this paper, we have discussed one possible candidate implementation of a framework based around technology and usage neutral spectrum rights aimed at allowing the liberalization of the radio spectrum use in a trading environment.

Our work in this area is ongoing. In our further work, we propose to test these and other candidate proposals with the objective of minimizing the uncertainty in making changes to the licensing framework to facilitate spectrum liberalization.

ACKNOWLEDGMENT

Work covered here has been undertaken by a team of consultants comprising Aegis Systems, Ltd., Indepen and Transfinite Systems, Ltd., whose contribution we gratefully acknowledge.

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Joseph M. Butler received his degree in physics from Southampton University, UK in 1992 and his Ph.D. in Electrical and Electronic Engineering from University College London, UK in 1996. He has worked in the areas of military radar systems, primarily in the area of active phased array radar systems, in signal and image processing and in computer vision, and in a number of companies including QinetiQ, Alenia Marconi Systems, and at NaturalMotion as head of R&D. Joe is currently research and development manager at Ofcom where he is responsible for managing a research programme which spans the areas of Ofcom's regulatory and technology interest.

William T. Webb joined Ofcom as head of research and development and senior technologist in 2003. Here, he manages a team of 10 engineers providing technical advice and managing research across all areas of Ofcom's regulatory remit. He also leads some of the major reviews conducted by Ofcom including the spectrum framework review and ultra-wideband consultation. Previously, William worked for a range of communications consultancies in the UK in the fields of hardware design, computer simulation, propagation modelling, spectrum management, and strategy development. William also spent three years providing strategic management across Motorola's entire communications portfolio, based in Chicago. William has published eight books, sixty papers, and four patents. He is a visiting professor at Surrey University and a fellow of the Royal Academy of Engineering. He is a vice president and fellow of the IEE. His biography is included in multiple "Who's Who" publications around the world. He sits on the judging panels of a number of awards including the Wall Street Journal "Annual Innovation Awards." William has a first class honours degree in electronics, a Ph.D. and an MBA.