Applying Fees for Government Spectrum Use

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1 Introduction

In the United States, the Federal Communications Commission (FCC) and the National Telecommunications and Information Administration (NTIA) regulate the wireless spectrum. The FCC is responsible for commercial and non-federal use of the spectrum, whereas the NTIA is in charge of federal use. According to the United States Department of Commerce’s “Office of Spectrum Management, federal entities have exclusive use of 18.1% of the prime “beachfront” frequencies, while non-federal users own individual spectrum licenses for 30.4%. The remaining 51.5% of this spectrum is shared, with the federal government the primary user and the private sector secondary” [1].

Current spectrum scarcity in the US is a widely acknowledged fact, yet almost 90% of the spectrum remains woefully underutilized [2]. Approximately 40-80% of the unused broadcast spectrum is in rural areas. It is imperative to note that the wireless spectrum is a limited resource and the growth of technology depends on its availability. Hence, underutilization of spectrum is undesirable and measures have to be taken to maximize efficient utilization. Spectrum markets in the United States are not currently open. This contributes to the present situation, because it does not incentivize efficient allocation and use of spectrum, especially for government use. Therefore, new spectrum management policies, involving economic and regulatory techniques, are required. Our research examines a more efficient method of managing government use of spectrum in the United States. The ensuing results could foster US technological competiveness and leadership on a global scale.

2 The Objective

This paper attempts to answer a fundamental question: Would applying a fee for spectrum use by government agencies promote efficient use of spectrum? We hypothesize that by forcing government agencies to pay fees for their spectrum use would result in more efficient spectrum utilization and free up unused frequencies. This would not only resolve the existing spectrum crunch, but also drive technological innovation in the market to cope with future demand.

Measuring spectrum efficiency is not by any means a trivial exercise, and requires a multi-dimensional analysis covering both technical and subjective considerations. An
analysis based on a sole parameter may lead to erroneous results and misinterpretation. The goal of any spectrum management policy should be to maximize the societal benefit and utility of wireless spectrum resources, and not merely to achieve technical efficiency [3].

Spectrum is "The radio frequency spectrum (range) of hertzian waves used as a transmission medium for cellular radio, radio paging, satellite communication, over-the-air broadcasting and other services" [4]. The radio spectrum typically used for wireless communications refers to a frequency range from 3 kHz to 300 GHz. Frequencies below 3GHz are considered prime ("beachfront") property because users of these frequencies can operate with low-power transmitters and smaller antennas, which are less expensive. [5].

Spectrum, as an essential resource underpinning one of the fastest developing and dynamic sectors of the economy, wireless communications, needs to be conserved and optimally used. ‘Optimal use’ of spectrum "maximizes the value that citizens and consumers derive from it, including broader social benefits, and taking into account the specific consumer and citizen interests, including the interests of particular groups within society" [6].

3 The Scope and Assumptions

The scope of this paper is limited to spectrum management practices in the United States, pertaining specifically to government entities. The intended audiences of this paper are the telecommunications regulatory authorities and government agencies.

In order to implement fees for spectrum utilization that would result in efficiency gains, this paper assumes that NTIA would be responsible for the entire process. This would include determining and administering fees as well as collecting payment from other government entities. The second assumption is that the fees collected by NTIA would be used to set up a new financial resource called the Spectrum Innovation Fund (SIF) managed by NTIA or the Department of Commerce [2]. This fund would in turn provide financial support for research and development activities seeking spectrum-saving technological advancements. We also assume that NTIA and the cabinet-level Office of Management and Budget (OMB) possess enough legislative authority to mandate other government agencies to conform to the set rules and regulations and to pay fees for spectrum use. Otherwise, appropriate legislative measures would need to be proposed and adopted to bring the concerned government agencies under this jurisdiction.

There are different mechanisms by which spectrum may be managed and enforcing a fee for usage is one. In December 2010, the UK’s telecom regulator, The Office of Communications (Ofcom), issued a policy statement significantly revising its framework for spectrum management, and focusing on future demand. Ofcom had previously implemented a spectrum administrative incentive pricing (AIP) mechanism with positive results. Other countries, including Australia and Hong Kong have adopted pricing mechanisms for spectrum use, which are discussed in detail later.

Taking a cue from these, the US should also develop and adopt a better spectrum management strategy, in order to keep pace with ever-increasing demand. Given that government entities exclusively occupy 18.1% of “beachfront” spectrum, and share a
whopping 51.5% as primary user, it is necessary to ensure that this spectrum is properly utilized. This inspired us to look into a fee implementation strategy for government users.

The National Broadband Plan (2010) underscores the importance of improving efficiency in spectrum utilization. In addition, President Obama recently announced initiatives to increase the spectrum available for commercial users in view of deeper broadband penetration throughout the US. These plans aim at the future technological growth of the country and this can be brought about only with adequate spectrum available for future use - which in turn calls for efficient measures in spectrum allocation and utilization [7]. Larry Summers, Director of the National Economic Council recently stated that “wireless network traffic has grown by 250% per year in recent years, and that based on estimated data, the next five years will see traffic increase to between 20 and 45 times the 2009 level” [7].

4 The Relevance to Prior Work in the Field

Our research focuses on studying the different spectrum management approaches adopted by other countries. We also examine reports released by agencies like the NTIA, and the FCC, pertaining to feasibility studies of the implementation of a fee system for government use of spectrum in the United States. We also referred to whitepapers authored by non-profit policy institutes like New America Foundation and consultancy companies like Shared Spectrum Company. Opinions obtained from interviews with staff of government entities and members of the Incentives Subcommittee of the Commerce Spectrum Management Advisory Committee (CSMAC) helped us to understand the potential advantages and probable obstacles to implementing the intended fee system.

From our studies, we noted that countries like the UK, Australia, and Hong Kong have adopted fees models for spectrum usage, in addition to license fees and capital obtained from spectrum auctions. These fees models have yielded results, and the UK model has been evaluated after the adoption of these fees. This raises the question of whether the United States could adopt similar fees model, especially for government use of spectrum. Such fees models could aid in providing incentives for efficient spectrum utilization and earn revenue to support technological innovation and to cover the cost of spectrum management.

Models successfully adopted by other countries cannot be implemented in the US straight away. As the saying goes, “one size does not fit all” and modifications need to be made to the model according to the geographic, legislative, regulatory, and economic characteristics of the US. This makes our research relevant as it attempts to determine if adopting fees for spectrum use is a reliable method of increasing efficiency in the US specifically, considering both existing spectrum scarcity and predicted future demand.

We critically analyze and study each model, and ascertain the essential factors that would feature in a hypothetical model adoptable for the US. We also consider possible objections and obstacles to such a fee system, and try to establish that these are outweighed by the possible advantages. In our conclusion, we try to provide an informed view of whether spectrum pricing would aid in improving spectrum efficiency.

The following examples of spectrum use fee models have been adopted by countries around the world:
4.1 UK AIP Model

According to the Wireless Telegraphy (WT) Act of 2006, Ofcom manages the wireless spectrum with the goal of ensuring the availability of spectrum to meet the demands of future wireless technology. Ofcom aims for an efficient, economically beneficial, spectrum management approach to allocate the spectrum to users who value it the most. Therefore, Ofcom has adopted two methods of spectrum pricing [8].

Cost recovery: When pricing on a cost recovery basis, Ofcom charges an ‘administration fee’ for the spectrum allocation to cover its administrative and management costs.

Administrative Incentive Pricing: The license fee assessed under the AIP model is based on estimated opportunity cost. This fee is calculated as follows:

\[
License \text{ Fee} = STU \times Bandwidth \times Area \times Modifier
\]  

In equation (1), “STU is spectrum tariff unit, an average tariff per MHz of spectrum used, and Modifier is the modifier to the fee based on specific technical or commercial considerations.” [8]

AIP is an example of an incentive method of spectrum allocation other than auctions and trading. All of these methods are market mechanisms for spectrum management designed to promote optimal use of spectrum. Since these mechanisms are complementary, AIP is not an isolated factor and so the impact of AIP is difficult to measure in isolation. However, Ofcom’s strategic review of spectrum pricing (SRSP) evaluated the AIP approach against the following criteria [8]: Did it enhance spectrum allocation in order to have more optimal use, by improving trading or unused spectrum releases, and thus meet increasing demand? Did it result in optimal distribution of spectrum allocations? For example, was spectrum allocated wherever there was demand for it?

According to the SRSP, the following indications of optimal use of spectrum could be regarded as positive results of the AIP strategy in the UK:

Radio Astronomy: The total 384.5 MHz spectrum bandwidth used by radio astronomy has been released, since the value of the spectrum was raised from £350k to £1.4m after AIP implementation, see Table 2 Appendix A. This is considered the strongest impact of AIP in the UK.

UHF release in Scotland: The emergency services in Scotland released the UHF band after AIP deployment, Table 2 Appendix A.

CBS licenses: As shown in Figure 2 Appendix A, the allocation of CBS licenses decreased after applying AIP to the CBS spectrum band. This reduction in demand could also happen with other factors, such as alternative technologies becoming more affordable. For example, taxi drivers started using GSM services instead of CBS systems.

Decommissioning inefficient spectrum band: The 4 GHz point-to-point band became inefficient compared to the available alternative spectrum bands after adopting AIP.

More efficient investment in the un-tradeable spectrums: Even though GSM technology later became the industry standard, the change from the analog to digital GSM technology in 1998 could be considered an indication of spectrum use optimization.
4.2 Australian Model

Australia is a prime example of a country that has implemented pricing for spectrum access with the goal of achieving more efficient utilization. The Australian Communication and Media Authority (ACMA) is in charge of planning and managing Australia’s radio spectrum. For spectrum bands in high demand, Australia adopts auctions as the allocation mechanism. However, most of the spectrum remains under the ‘apparatus license system.’ The apparatus licensing system was established in 1995 and incorporates a fee formula-based approach. This system imposes an annual transmitter or receiver license fee. The ACMA has employed a set of guiding principles to ensure that the fees obtained contribute to efficient spectrum allocation, and to promote and maintain a consistent fee scheme. The ACMA is involved in an on-going project to assess the relative value of parts of the spectrum, including seeking to identify parts of the spectrum where the opportunity cost is higher than the current fees [9].

The apparatus licensing system is based on a formula that takes into account four parameters – spectrum location, geographic location, bandwidth and power, and is calculated as follows [9]:

\[
Fee = K \times (S_i, G_i) \times B \times A_i \times Adj
\]  

(2)

In this formula, \(K\) is a scaling constant that is updated yearly by the Consumer Price Index (CPI) allowing adjustment of the overall level of fees, \((S_i, G_i)\) is a weight term related to the spectrum location \(S\) and the geographic location of the license (Australia wide, high, medium, low and remote density) \(G\), \(B\) is the bandwidth of the license (in kilohertz), \(A_i\) is a factor used to reduce fees for services that only deny spectrum to other users over a small geographic area (1 for local or 0.1 for sub-local), and \(Adj\) is an adjustment factor used to reflect a premium value for spectrum in higher demand (mobile) or a discounted value for frequency reuse. This allows flexibility in adjusting the values.

4.3 Hong Kong Model

The application of Hong Kong’s spectrum utilization fee (SUF) is another example of a model where fees are intended to reflect the opportunity cost of spectrum in order to promote more efficient use of resources. The opportunity cost of spectrum is derived from different factors, and these factors are appraised against multiple criteria. These criteria are incentives for static and dynamic use of spectrum, objectivity - where we define the value of spectrum judgmentally as opposed to calculations, simplicity and transparency. The valuation given to the spectrum depends on numerous assumptions made in order to estimate revenues and costs. First, the revenue and cost changes need to

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1 The opportunity cost of spectrum is the value of the opportunity forgone by the current spectrum use (i.e. it is the value to the next best alternative user of the spectrum) at the point where supply and demand for spectrum are in balance.
be considered if there are relevant changes in spectrum holdings. Second, cost changes are enough to value the spectrum if there are feasible small changes in the spectrum Table 3 Appendix A. The SUF formula values the radio spectrum based on $, a reference value in HK$/annum/MHz, bandwidth in MHz, a frequency band factor, the type of license, and $E$ which is six if the frequency is allocated on an exclusive basis, otherwise one [9]:

$$SU F = S \times BW \times F_{Freq\, band} \times L_{License} \times \ E$$

(3)

5 The Analysis

The purpose of this paper is to answer the question of whether or not a spectrum usage fee results in efficient use of spectrum amongst government users. First, we should determine a relevant definition of ‘efficient use of spectrum’ from both the economic and technical perspectives. Economically, efficient use of spectrum is when the spectrum is allocated to the user (i.e. agency) who values it the most, maximizing societal benefits [6]. Technically, spectrum efficiency is when a service or an application uses as little spectrum as possible without adversely affecting the desired consumer service. Theoretically, the efficiency of the spectrum fee could be measured using different criteria, for example by studying usage before and after applying a spectrum fee to government use. However, efficiency is difficult to measure in reality since there are different factors that affect demand for, and the use of, spectrum. The impact of the spectrum fee on the spectrum use is complementary to other spectrum allocation mechanisms, such as auctions or spectrum licenses. Furthermore, accurate measurements of government spectrum use that show spectrum demand efficiency are not currently available for United States, based on our research and interviews with experts from government entities.

However, there are some studies of spectrum utilization and scarcity that could meaningfully contribute to understanding and evaluating the current spectrum market in USA. Therefore, three metrics are used in this analysis in order to evaluate the government use of the spectrum. First, spectrum use measures which show the spectrum utilization and occupancy in different locations in USA. Second, spectrum scarcity studies which are conducted by non-profit policy entity. Third, interviews results that are conducted with spectrum management experts’.

Shared Spectrum Company (SSC) measured spectrum utilization at seven different US locations, for frequency bands between 30 MHz and 3 GHz, and calculated the average spectrum utilization in these seven locations, outdoors and indoors as shown in Table 1. [10]

<table>
<thead>
<tr>
<th>Location</th>
<th>Dates</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Falls, Virginia</td>
<td>4/7/2005</td>
<td>Rural location</td>
</tr>
<tr>
<td>Vienna, Virginia (Location 1)</td>
<td>4/6/2004</td>
<td>Urban location</td>
</tr>
<tr>
<td>Vienna, Virginia (Location 2)</td>
<td>4/9/2004</td>
<td>Urban location</td>
</tr>
<tr>
<td>National Science Foundation NSF building roof, Arlington, Virginia</td>
<td>4/16/2004</td>
<td>Elevated, urban location</td>
</tr>
</tbody>
</table>

Table 1: SSC Measurement Locations
<table>
<thead>
<tr>
<th>Location</th>
<th>Dates</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Radio Astronomy Observatory, Green Bank, West Virginia</td>
<td>10/4/2004</td>
<td>Rural location</td>
</tr>
<tr>
<td>Chicago</td>
<td>11/16-11/18/2005</td>
<td>Elevated, urban</td>
</tr>
</tbody>
</table>

Figure 1 shows the maximum spectrum occupancy in all seven locations. The lowest utilization was at Green Bank, WV (1%). The highest utilization was in Chicago (17.4%) [10].

![Figure 1: Overall Spectrum Occupancy Measured at Seven Locations](image)

The latest reported SSC spectrum measurements [11], made in Vienna, Virginia, shows that different bands have lesser utilization of spectrum, including: “420-450 MHz (amateur/radiolocation), 745-810 MHz (public safety), 960-1020 MHz (aviation), 1240-1300 MHz (amateur), 1330-1400 MHz (military), 1400-1430 MHz (space/satellite), 1430-1520 MHz (telemetry), 1525-1710 MHz (mobile satellite/meteorological), 1710-1850 MHz (fixed/fixed mobile), and 1990-2110 MHz (MSS/TX auxiliary).”

Spectrum scarcity in the US is a widely acknowledged fact, yet Michael Calabrese notes that even in prime locations like downtown DC, near the White House, 60-80% of the prime frequencies are barely used [12]. The real issue is the scarcity of government authorization of spectrum access. Many prime parts of the spectrum have already been allocated exclusively to broadcasters, the military, and other services which now only require a fraction of their original allocations due to the proliferation of “spectrum saving” digital technologies. There is a need for new regulatory and economic incentive schemes to encourage more efficient utilization of the available spectrum [13].

The paper by Michael Calabrese [14], suggests that unutilized spectrum capacity can be put to better use through three steps – i) The NTIA and FCC should conduct an inventory of spectrum usage – both commercial and government users indicating how much of the spectrum is being utilized or under-utilized across various bands. This
exercise should include actual spectrum measurement data. ii) Based on the collected data, unlocking of unused spectrum capacity should begin immediately on a band-by-band basis. iii) NTIA and FCC should begin inquiring into technologies and incentives that can best facilitate better and more open sharing of spectrum resources in the future.

We conducted interviews with experts in spectrum management and asked questions about current spectrum use as well as arguments and counter arguments regarding the application of spectrum fees to government use of spectrum. Most of the experts agreed that spectrum use is currently inefficient, and that the entities need incentives to use it more efficiently. For example, most government bands are in full use only in emergency situations; otherwise they have low utilization. The military still uses ordinary commercial standards and its operational requirements are often not practically compatible with higher spectrum efficiency. Government agencies do not currently have any incentives to give up their spectrum allocations because they are a free resource. Therefore, a more economically and technically efficient approach should be applied to spectrum management for government users. The experts noted that applying a price or fee for the government use of spectrum would be a positive step towards better spectrum efficiency. However, this approach is only the beginning of a market-based spectrum management system, and a lot of spectrum management concerns and challenges should be considered.

Most government agencies are uncertain about their future needs and the future availability of funds, so they should consider spectrum as a resource, like land, water and electricity, and they should pay a price to use it. Similarly, international fees for government agencies such as the Department of Defense should be considered alongside other paid resources. Prices should reflect the market price, to drive government agencies to give up unused spectrum, improve their systems, or work towards more efficient spectrum utilization through sharing or trading.

Government and non-governmental agencies currently have totally different systems working in the same frequency bands, and their spectrum allocations are managed by two separate agencies, NTIA and the FCC. This situation makes sharing and trading systems between commercial entities and the government difficult and inflexible. The experts suggest having either a single agency, responsible for spectrum allocation for both sectors, or more cooperation between the NTIA and FCC, especially regarding classified government operations. Another solution could be to separate military spectrum management from civilian government services, and have a single body for civilian and non-governmental spectrum management while keeping the military spectrum under a separate entity.

Technical improvements should be encouraged in addition to spectrum fees. For example, trunking radio systems and mini-cells with short-range coverage that facilitates frequency reuse, and building one system for all State and Federal services such as 911 services. Better and more flexible policies and regulations should be developed to reuse the freed-up spectrum, through allocations, sharing and trading.
6 Conclusion

To address the looming spectrum crunch, the FCC has proposed making available 500MHz of spectrum for mobile broadband within the next decade, of which 300MHz between the 225MHz and 3.7GHz bands will be made available for use within the next five years. This is an essential move considering AT&T’s 5000% percent increase in mobile broadband traffic over the past three years and the significant growth seen by other carriers [15]. This information confirms the importance of efficient use of spectrum in order to meet future demands. In order to tackle this challenge, this report studies spectrum usage in different locations across the US, to determine the level of utilization by each party and government agency. This report also presents different fee models, tried and tested in the UK, Australia, and Hong Kong that work toward promoting efficiency in their spectrum use. The UK, for instance, has reported that applying fees played a major role in moving toward these goals. In addition to these fees models, the report addresses some concerns raised by experts, in published papers, and by government agencies in opposition to the application of fees in the United States.

One of the chief concerns is determining what spectrum price would be an incentive for government agencies to meet this goal. The spectrum price should not be too high or too low, in order to approach the market-clearing price and avoid implementation failure. This price cannot be ascertained without trial and error. Another concern regards how one could implement such a fee model in the United States, with the current regulatory barriers and in the absence of strong fund administration.

The current method of spectrum administration requires some modification in order to cope with our desired goals of maximizing economic efficiency and increasing spectrum capacity to meet future demand.
Appendix A

Table 2: UK Spectrum releases since 2004

<table>
<thead>
<tr>
<th>User</th>
<th>Total Bandwidth Released</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOD</td>
<td>110 MHz</td>
<td>2004</td>
</tr>
<tr>
<td>Commercial</td>
<td>70 MHz</td>
<td>2004</td>
</tr>
<tr>
<td>Radio Astronomy</td>
<td>384.5 MHz</td>
<td>2007</td>
</tr>
<tr>
<td>Police in Scotland</td>
<td>1 MHz</td>
<td>2007</td>
</tr>
</tbody>
</table>

Figure 2: CBS Assignments from 1986 through to 2008

Table 3: Suitability of options for different bands/services

<table>
<thead>
<tr>
<th>Options</th>
<th>Bands/services where most applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single service, change in costs</td>
<td>Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.</td>
</tr>
<tr>
<td>Multiple services, change in costs</td>
<td>Bands where there are few constraints on change of use or where change of use may be desirable. Bands where spectrum is used for private applications. But possible for bands used for public services where demand difficult to forecast and/or marginal changes in spectrum use are practical.</td>
</tr>
<tr>
<td>Single service, change in net revenues</td>
<td>Bands where change of use is highly unlikely because of international or regulatory constraints or where it is clear current use is highest value application. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.</td>
</tr>
<tr>
<td>--------------------------------------</td>
<td>----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Multiple service, change in net revenues</td>
<td>Bands with few constraints on change of use or where change of use may be desirable. Bands where spectrum is used by publicly provided services and changes in spectrum use are non-marginal.</td>
</tr>
</tbody>
</table>
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