



Government of Canada  
Department of Communications

Gouvernement du Canada  
Ministère des Communications

20  
1969-1989

**RADIO FREQUENCY SPECTRUM  
MANAGEMENT PROGRAM EVALUATION**

**ECONOMIC NATURE OF THE SPECTRUM:  
A REVIEW OF THE LITERATURE**

---

# **Background Study**

---

HE  
8679  
C2  
L49  
1989

**MARCH 1989**

**PROGRAM EVALUATION DIVISION**



**United Way**

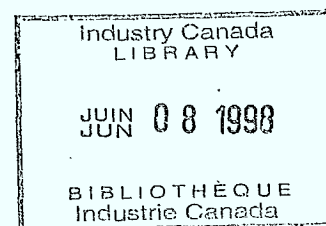


Government of Canada  
Department of Communications

Gouvernement du Canada  
Ministère des Communications

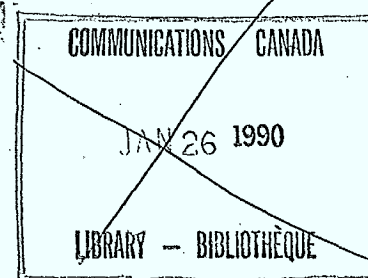
HE  
8679  
C2  
L49  
1989

1969-1989



*① Lewis, Pamela*

②/  
**RADIO FREQUENCY SPECTRUM  
MANAGEMENT PROGRAM EVALUATION**  
**ECONOMIC NATURE OF THE SPECTRUM:  
A REVIEW OF THE LITERATURE**



# Background Study

MARCH 1989



United Way

PROGRAM EVALUATION DIVISION

HE  
8679  
C2  
L49  
1989

DD 9012960  
DL 9290539

This is one of several Background Studies that form part of the evaluation of the Radio Frequency Spectrum Management Program.

The study was conducted by Pamela Lewis for the Program Evaluation Division of Communications Canada.

The views expressed herein are the views of the author and do not necessarily represent the views or policies of the Department of Communications.

La présente est une des études de fond portant sur l'évaluation du Programme de gestion du spectre des fréquences radios.

L'étude a été entreprise par Pamela Lewis pour le compte de la division de l'Évaluation des programmes de Communications Canada.

Les points de vue exprimés sont ceux de l'auteure et ne reflète pas nécessairement ceux du ministère des Communications ou les politiques du ministère.

## EXECUTIVE SUMMARY

As one of several background studies to be completed for an evaluation of the Spectrum Management Program of the Department of Communications, this study involved (1) a theoretical examination of the rationale for the current system of spectrum management in light of alternative management systems proposed in the literature, and (2) a theoretical evaluation of these alternatives in terms of their relevance for spectrum management in Canada. It has been prepared for the Program Evaluation Division who, together with those employed at the managerial level within the Spectrum Management Program, will form the key audience for the study. It is predominantly based on a review of the literature but has also been contributed to by spectrum managers at district, regional and headquarters levels of the Department of Communications.

Major observations found in the body of this study are summarized as follows:

- ❑ The radio frequency spectrum is universally managed by governments, outside the market. The rationale for central control over the allocation, assignment and use of the spectrum resource is based both on its unique physical properties and its characteristics as an economic object. In particular, the international character of the resource combined with its interference attributes which can cause negative externalities have provided impetus to the current regulatory approach to spectrum management.
- ❑ Having all rights to the spectrum resource centralized in the licencing authority is advantageous insofar as (a) spectrum managers can require users to change their transmitting activities if deemed necessary to increase spectral efficiency; and (b) non-economic objectives of society can easily be pursued by allocating spectrum on a priority basis to those services producing public goods on a non-profit basis, although they could as easily be sustained in an indirect fashion.
- ❑ Criticisms of the existing system of spectrum management are based on observations that maximum value for the spectrum resource may not be attained and allocation and assignment techniques may not lead to the most *economically* efficient use of the spectrum. These results, it is argued, are a direct consequence of treating spectrum as a free good. Incentives under such a system are held to result in over-consumption of the resource; rigidities in assignments in that less efficient uses are not replaced; lack of innovation in equipment which would allow for more intensive use of spectrum; under-utilization of substitutes for the resource; and assignments to lower valued uses than would be made in a market environment. At the same time, conceptualization of the resource as a free good precludes deriving economic rent from the resource for the benefit of society which can result in windfall gains for users.
- ❑ The extreme solution to many of the problems identified with the current system would be to establish property rights in spectrum and thenceforth rely on market forces for

allocation and assignment purposes. Whether or not a free market would be superior would depend on costs associated with redefining and enforcing property rights and the extent to which a market would result in socially desirable goals. Advocates of central control generally argue there are too many compelling reasons for government intervention to even consider the pure market alternative while advocates of the approach accede it may be too costly.

- Elimination of the pure market alternative as a solution has resulted in the exploration of a wide range of options which would give greater scope for the operation of market forces while retaining central control over the resource. Three major approaches emerge as promising techniques by which to incorporate economic factors into spectrum management including shadow pricing, application of user charges and assignment by auctions with a lease arrangement. Overall, these techniques appear to offer the best of all worlds insofar as market incentives can be introduced at the same time as administrative discretion is maintained. The caveat, of course, is that there is no empirical evidence to support the claims made by those advocating implementation of hybrid approaches.

Based on the analysis provided, it is noted that the government may choose one of three options. It may choose the status quo; it may adopt the pure market alternative; or it may move more towards hybrid approaches which combine elements of an administrative approach with a free market approach. In view of the fact that deficiencies associated with current management practices are expected to intensify as demand for the resource increases, keeping the current system does not appear to be rational. On the other hand, neither of the two remaining options have been tested and therefore cannot be properly evaluated.

## SOMMAIRE POUR LA DIRECTION

La présente étude, qui fait partie d'une série d'études préliminaires effectuées en prévision de l'évaluation du Programme de gestion du spectre du ministère des Communications, a comporté (1) un examen théorique du bien-fondé du système actuel de gestion du spectre en comparaison des autres systèmes proposés dans les documents traitant du sujet, et (2) une évaluation théorique des avantages de ces systèmes de rechange pour la gestion du spectre au Canada. Elle a été rédigée à l'intention de la Division de l'évaluation des programmes qui, avec les gestionnaires du Programme de gestion du spectre, constitue le public cible de l'étude. Elle est fondée principalement sur le dépouillement des documents traitant de la question, mais elle a bénéficié de la contribution des gestionnaires du spectre des bureaux de district, des bureaux régionaux et de l'administration centrale du ministère des Communications.

Les principales observations qui se dégagent de cette étude sont résumées dans les paragraphes qui suivent :

- Le spectre des fréquences radioélectriques est administré à l'échelle du globe par les gouvernements, en marge du marché. La régie centralisée de l'allocation, de l'assignation et de l'utilisation des fréquences du spectre est fondée aussi bien sur les propriétés physiques propres à cette ressource en que sur ses caractéristiques en tant qu'objet économique. En particulier, c'est le caractère international de cette ressource, joint aux risques de brouillage qui lui sont inhérents et sont susceptibles d'occasionner des embarras avec les pays étrangers, qui a imprimé l'élan de la formule actuelle de gestion du spectre par voie de réglementation.
- Il est avantageux que toute autorisation à utiliser les fréquences du spectre soit régie de façon centralisée par les responsables de la délivrance des licences, étant donné que (a) les gestionnaires du spectre peuvent obliger les usagers à modifier leurs activités de transmission s'ils le jugent nécessaire pour accroître l'efficacité spectrale; et (b) que la poursuite des objectifs autres qu'économiques de la société peut être facilitée par l'attribution prioritaire de fréquences aux services qui contribuent au bien public à titre non lucratif, bien que ces derniers pourraient être subventionnés de façon indirecte.
- Les critiques formulées à propos du système actuel de gestion du spectre sont fondées sur des observations selon lesquelles il se peut que l'on n'obtienne pas la valeur maximale qu'on est en droit d'attendre du spectre et que les techniques d'attribution et d'assignation n'aboutissent pas à l'utilisation la plus rentable du spectre. On prétend que ce manque d'efficacité est directement attribuable au fait que le spectre est traité comme un bien gratuit. De l'avis des intéressés, un régime de la sorte incite à une consommation excessive de la ressource, donne lieu à un cadre rigide d'assignations qui empêche de remplacer les utilisations moins efficaces; paralyse, dans le domaine de l'équipement, l'innovation qui permettrait une utilisation plus efficace du spectre,



n'incite pas à recourir à des moyens de substitution, et consent des assignations à des fins de moindre valeur qu'un régime tributaire des forces du marché. Par ailleurs, le fait de percevoir la ressource comme un bien gratuit prive la société des gains économiques que pourrait procurer la location de la ressource, d'où pourrait découler une véritable manne pour les usagers.

- La façon la plus radicale de régler bon nombre des problèmes inhérents au système actuel serait d'établir des droits de propriété à l'égard des fréquences et de se fier au jeu des forces du marché pour leur attribution et leur assignation. La supériorité du marché libre serait fonction des coûts afférents à la redéfinition et au respect des droits de propriété, et de la mesure dans laquelle les forces du marché permettraient d'atteindre les objectifs socialement souhaitables. Les tenants du contrôle centralisé allèguent de façon générale qu'il y a trop de raisons militant en faveur de l'intervention du gouvernement pour songer même à s'en remettre aux seules forces du marché, alors que les tenants de la formule admettent qu'elle peut être trop coûteuse.
- L'élimination du seul jeu des forces du marché comme solution a eu pour conséquence d'amorcer l'étude de toute une gamme d'options susceptibles d'élargir le champ d'intervention des forces du marché sans éliminer le contrôle centralisé de la ressource. Il se dégage trois grandes formules qui semblent être des techniques prometteuses susceptibles de faire intervenir les facteurs économiques dans la gestion du spectre, c'est-à-dire l'établissement d'un prix fictif, l'application de frais d'utilisation et l'assignation par voie d'enchère, jumelée à un bail de location. Dans l'ensemble, ces techniques semblent être celles qui offrent les meilleurs résultats, étant donné qu'elles laissent libre cours aux avantages offerts par le libre marché tout en sauvegardant la discrétion administrative. Bien entendu, la seule réserve est qu'aucune preuve empirique n'appuie les prétentions des personnes qui favorisent la mise en oeuvre de formules hybrides.

À partir de l'analyse effectuée, les auteurs expliquent que le gouvernement peut choisir l'une des trois solutions suivantes : il peut maintenir le statu quo, choisir de se fier uniquement aux forces du marché ou se tourner vers des formules mixtes qui marient les éléments d'une formule administrative à ceux du libre marché. Étant donné que les points faibles des pratiques actuelles de gestion vont vraisemblablement s'accroître au fur et à mesure de l'augmentation de la demande, il ne semble pas logique de conserver le système actuel. Par contre, aucune des deux autres solutions n'ayant été mise à l'essai, on ne peut les évaluer à proprement parler.



## TABLE OF CONTENTS

EXECUTIVE SUMMARY .....	i
SOMMAIRE POUR LA DIRECTION .....	iii
TABLE OF CONTENTS .....	v
I. INTRODUCTION .....	1
II. SPECTRUM CHARACTERISTICS .....	3
A. An Invisible Natural Resource .....	3
B. Physical Characteristics of the Radio Frequency Spectrum .....	3
1. The Radio Frequency Spectrum Defined .....	3
2. Interference Attributes .....	4
3. International Character .....	4
C. Economic Characteristics of the Radio Frequency Spectrum .....	5
1. Public Goods .....	5
2. Externalities .....	7
3. Common Pools .....	7
III. THE CURRENT SPECTRUM MANAGEMENT SYSTEM .....	9
A. Functions .....	9
1. Policy Development .....	9
2. Planning and Engineering .....	10
3. Authorization .....	10
4. Control .....	10
5. International Representation .....	11
B. Principles and Practices Underlying Spectrum Allocation .....	11
IV. CONSIDERATIONS TO EVALUATE THE CURRENT SYSTEM .....	13
A. Advantages of the Current Management System .....	13
B. Disadvantages of Spectrum Management by Regulation .....	14
1. Distorted Demand .....	14
2. Rigidities .....	15
3. Opportunity Costs Not Considered .....	15
4. Economic Rent Not Derived .....	16
5. Government Administration .....	16
V. THE PURE MARKET ALTERNATIVE .....	19
A. Establishment of Property Rights to the Spectrum .....	19
B. Advantages of the Pure Market Alternative .....	20

C.	Difficulties Associated with Property Rights .....	21
1.	Constraints .....	22
2.	Costs .....	22
VI.	HYBRID APPROACHES .....	25
A.	Shadow Pricing .....	25
B.	User Charges .....	26
C.	Auctions With Lease .....	27
VII.	POLICY OPTIONS AVAILABLE TO GOVERNMENT .....	29
A.	Policy Options .....	29
B.	Considerations .....	29
1.	Efficiency Considerations .....	30
2.	Equity Considerations .....	30
3.	Social Considerations .....	31
4.	Legal Considerations .....	32
5.	Financial Considerations .....	32
6.	Other Considerations .....	32
C.	Conclusions .....	33
VIII.	APPENDIX .....	35
A.	CSP International Report (1987) .....	35
B.	Illustrated Market Structures .....	35
1.	Current policy - regulated market .....	36
2.	Pure (competitive) market approach - competitive market .....	36
3.	Hybrid alternative - monopolistic competition .....	37
C.	Future of the Study .....	38
	BIBLIOGRAPHY .....	39

## I. INTRODUCTION

Throughout the Western industrialized world, resource allocation is mostly accomplished through market transactions utilizing the pricing mechanism. From the earliest years of radio development, however, tight control over the allocation, assignment<sup>[1]</sup> and use of the radio frequency spectrum has been exercised by administrative authorities at both the national and international levels. This approach to managing the spectrum resource was deemed necessary early on due to the unique interference characteristics of radio. With signals at relatively low energy levels interfering at diverse points many hundreds of miles away, and not confined to national borders, the international character of the resource was recognized as was the need for coordination of spectrum users within national boundaries.<sup>[2]</sup> Since that time, telecommunications systems utilizing the radio spectrum have become increasingly important in the pursuit of national economic, political and social goals of all societies. This fact, combined with a continuing concern and perceived need for central planning and control to minimize interference between radio stations, forms the basis of government intervention in this sector of the economy today.

That central planning and administrative control over the spectrum resource have emerged as primary organizing principles underlying spectrum management implies neither that this is an effective means of coordinating economic agents within this sector or that it is the only method of encouraging efficient utilization of the resource. This point is largely conceded in the literature. Similarly, it is widely acknowledged that greater scope for the operation of market forces is possible in terms of allocating the spectrum resource. Beyond this, however, little consensus has been reached respecting the relative advantages and disadvantages of the current approach to spectrum management compared to that of market alternatives. While such determinations will not be made with certainty until such time as empirical evidence

1. In relation to spectrum management, the terms "allocation" and "assignment" have very special meanings. Whereas allocation refers to the commitment of bands or blocks of frequencies to the use of specific radio services, assignment includes selecting and authorizing (licencing) the use of discrete frequencies by individual radio stations within a service.
2. The events which preceded government regulation in the United States illustrate this point. As described by Siepmann and quoted in Coase (1959): "The chaos that developed as more and more enthusiastic pioneers entered the field of radio was indescribable. Amateurs crossed signals with professional broadcasters. Many of the professionals broadcast on the same wave length and either came to a gentleman's agreement to divide the hours of broadcasting or blithely set about cutting one another's throats by broadcasting simultaneously. Listeners thus experienced the annoyance of trying to hear one program against the raucous background of another. Ship-to-shore communication in Morse code added its pulsing dots and dashes to the silly symphony of sound."

is brought to bear on the subject, a preliminary assessment of the issues is nevertheless possible. As such, the purpose of this background study is

- to examine the theory of the rationale for the current system of spectrum management in light of alternative management systems proposed in the literature, and
- to evaluate these theoretical alternatives in terms of their relevance for spectrum management in Canada.

To accomplish the twofold purpose of this study, it is necessary to understand how the radio frequency spectrum is currently managed. Therefore, after describing the essential characteristics of the resource, a thumbnail sketch of the spectrum management process in Canada and internationally will be provided. This will establish a context in which the rationale underlying Canada's approach to spectrum management can be critically reviewed and analyzed. Market alternatives ranging from a pure market system to incorporating economic criteria into the allocation and assignment processes will then be considered. In the absence of any empirical analysis of the alternatives it will not be possible to reach any final conclusions. However, through applying normative economic theory and reviewing scholarly literature on the subject, a preliminary assessment of consequences entailed in replacing the present method of spectrum management with one that gives greater scope for the operation of market forces is possible.

## II. SPECTRUM CHARACTERISTICS

### A. An Invisible Natural Resource

Coined as an "invisible natural resource", the radio frequency spectrum is a wireless medium through which various forms of information are generated, transmitted and received between distant points. It is apportioned among various telecommunication services and has applications ranging from radio and television broadcasting to land, maritime and aeronautical mobile communications. As a major input required for the production of modern telecommunication services it is an economically valuable resource, quantified in terms of "billions of dollars".<sup>[3]</sup> Its political and social value, however, are no less noteworthy. Not only is the radio spectrum essential for strategic and national defence purposes but as an information bearing medium, it is vital to public safety, cultural activities and education as we know it today. Notwithstanding its invisibility, then, the radio frequency spectrum is deemed to be a valuable resource.

### B. Physical Characteristics of the Radio Frequency Spectrum

Unlike most other resources, the radio frequency spectrum is universally managed by governments, outside the market. The reason for this is partly attributable to the unique physical characteristics of the radio frequency spectrum. In particular, the international character of the resource combined with its interference attributes have provided impetus to the current regulatory approach to spectrum management. Each of these properties is described below after the radio frequency spectrum has been properly defined.<sup>[4]</sup>

#### 1. The Radio Frequency Spectrum Defined

Electromagnetic radiation has been defined as "a form of oscillating electrical and magnetic energy capable of traversing space without benefit of physical interconnections".<sup>[5]</sup> The rate of oscillation, expressed in cycles per second, is its frequency. Of the whole range of frequencies constituting the electromagnetic

3. Promex Communications Inc., "Radio Frequency Spectrum" in First Choice Canada, vol. 5, no. 1, January 1986, (pp. 44-46).
4. For a more detailed description of the physical properties of the radio frequency spectrum see The Spectrum/Le Spectre, published by the Department of Communications Canada.
5. Levin, H.J., The Invisible Resource: Use and Regulation of the Radio Spectrum, Baltimore: Johns Hopkins Press, 1971, (p. 15).

spectrum, that portion between 10,000 cycles and 3,000 billion cycles is classified as the radio frequency spectrum.<sup>[6]</sup> Communication is the principal use of the radio spectrum, albeit technological and economic factors have precluded its use much beyond the lower end of the spectrum. Through more extensive development of the resource, however, barriers to use of higher and higher frequency bands have diminished over time.<sup>[7]</sup> At the World Administrative Radio Conference of 1979, frequency bands up to 400 GHz were allocated, representing a ten-fold increase in allocated spectrum in two decades.

## 2. Interference Attributes

Propagation characteristics of electromagnetic energy are such that potential interference between radio stations is an ever present reality. Specifically, two technical properties of the radio spectrum have historically been identified with the need for administrative control to prevent interference.

First, frequencies comprising the radio spectrum are unbound insofar as radiation on them attenuate gradually. In other words, transmissions carried on radio frequencies are not confinable and therefore can cause signal interference between users on the same or adjacent radio frequencies. Based on probabilities, establishment of standards to regulate the level of power generated and types of equipment used can reduce the risk of interference.

Second, various types of radio emissions carried by radio frequencies possess technical characteristics which are more or less compatible with each other. To the extent that compatibility between use and users is not achieved, interference results. Coupled with the fact that some frequencies are more suitable than others for use by particular services renders central control for allocation, assignment and coordination purposes more critical.

## 3. International Character

The nonconfinability of radio emissions and need to achieve compatible operation among large numbers and varieties of radiating sources and receivers applies equally in the international context as it does nationally. That much is clear. Beyond this, however, the radio spectrum can be further exemplified as an international resource. On the one hand, some users of the radio spectrum are mobile internationally and therefore must be able to use the same frequency bands wherever they are. Compatible standards between nations ensure this condition for radio operators whether in the aeronautical or shipping industry. On the other hand, it should be recognized that from the first international conference on the radio spectrum in 1906, "no nation has asserted on behalf of itself or its citizens the right to ownership of the radio spectrum. Instead

6. Frequency is also expressed in Hertz, after the radio pioneer, where one kilohertz (kHz) equals 1000 cycles per second; one megahertz (MHz), 1000 kilohertz; and one gigahertz (GHz), 1000 megahertz.
7. Extensive development, which extends the usable portion of the spectrum to higher frequencies is distinguished from intensive development which allows closer use of the spectrum by two users without undue interference.



title to the spectrum remains international social property in law".<sup>[8]</sup> In practice, this means sovereign nation states and citizens within them are not free to use spectrum without due regard to international conventions and regulations. International constraints thus provide additional justification for administrative control over the allocation and use of the spectrum.

### C. Economic Characteristics of the Radio Frequency Spectrum

Just as physical characteristics of the spectrum resource must be appreciated in order to assess both the appropriateness of current regulatory approaches and viability of market alternatives to spectrum management, its economic characteristics must also be understood. In this section of the study, these characteristics will be examined in light of normative economic theory. The question to be answered is whether or not the price mechanism should be categorically ruled out as a method to allocate spectrum based on its definition as an economic object.

There are two generally recognized rationales for possible government intervention within individual markets (Due, 1968). These are economic efficiency and social equity. In a purely competitive economy, however, an efficient allocation of resources would be attained without government interference. With no blockages preventing entry to or exit from individual markets, centralized directives about what, where or when to buy, how or what to produce, or who should produce would not be needed. Rather, individuals acting in their own self-interest would find themselves coordinated by the forces of the marketplace. Input and production costs would be kept at a minimum through competition and demand would ensure that products were made in optimal quantities with the available resources. Under such conditions, the role of government could be limited to social equity concerns.

In reality, perfectly competitive conditions do not exist. This causes problems in the efficient allocation of resources and it is these problems that government is expected to solve. Such circumstances are referred to generically as market failures. In particular, where the price mechanism breaks down as an allocator of resources, many economists call for government intervention which may include direct government regulation. Three major types of market failures are described below in an effort to consider whether the economic characteristics of the spectrum resource justify the tradition of government involvement. To the extent that they do, further rationale will be provided for current regulatory approaches to spectrum management.

#### 1. Public Goods

Public goods are goods, resources or services that when provided are available for everyone to use and where - until crowding occurs - one person's use does not interfere with another's. In other words, they are jointly consumed by everyone (e.g. national defence) or by people situated in one locality (e.g. weather forecasts and parks). Consumption of them is

- nonrival in that consumption by one person doesn't reduce the amount left for another,

8. Melody, W.H. and Smythe, D.W., Opportunity Cost and Radio Spectrum Allocation, Burnaby, British Columbia: Simon Fraser University, 1978 (p. 5).

- fixed in that the amount consumed by one person equals that used by another, and
- nonexclusive in that once a good is provided to one person, others cannot be prevented from enjoying its benefits (Due, 1968, p. 8). The fact that exclusion of benefits for some people is not generally feasible means that direct charges or voluntary contributions cannot be used for financing in the private market.

Government intervention (for example, through taxation) is often deemed necessary to maintain the provision of public goods that are mutually beneficial.

Characteristics of public goods stand in marked contrast to private goods such as food or clothing which are highly divisible and packageable. Individuals can be excluded from consuming them unless they are willing to pay the price. As a consequence, allocation of private goods can be dealt with efficiently under private market arrangements. Public action is required only to assure free market conditions, to maintain enforceability of contracts and to resolve disputes between individuals participating in market transactions. Thus, for most packageable goods where potential buyers can be excluded from use unless they are willing to pay the price to acquire them, markets can work reasonably well.

Historical and present use and allocation of the radio frequency spectrum show that it is not a public good as defined above.

- First, consumers of the electromagnetic spectrum can and do interfere with other users' capacity to use or enjoy the spectrum resource. The early history of radio development referred to earlier in this study reflects the chaos that can result from treating the spectrum as if it were a public good. Very simply, consumption of the spectrum resource by one party reduces the amount which is left to be consumed by another.
- Second, while used as an input to produce public goods such as national defence, which can be enjoyed by all equally, the spectrum is also used to produce private goods. A case in point is the provision of cellular telephone services, the benefits of which consumers are easily excluded from.
- Third, consumption of spectrum resources is very closely related to individual preferences. Contrary to the case of a public good, consumption is not equal across people; it is in direct relationship with their personal preferences.
- Finally, Canada's practice of levying licence fees for use of the radio frequency spectrum can have the effect of excluding potential users from exploitation of the resource. Moreover, these fees attach a price-tag to spectrum use implying that it is packageable as commodity which can be bought and sold in the marketplace.

Taken together, then, government allocation of the spectrum resource is not necessitated on the grounds that it is a public good, at least in micro-economic theory.

## 2. Externalities

Externalities, or third party effects, occur when individuals other than the producers or direct consumers, experience either benefits or costs resulting from the good's production and consumption (Due, 1968, p. 9-10). Free markets generally produce too little of the activities which generate positive externalities (e.g. basic research) and too much of those which generate negative externalities (e.g. pollution). Government intervention is thus considered necessary either to produce or regulate production of these goods and services where welfare costs of the market situation exceed economic costs of government intervention.

Scholarly literature on the subject reveals there are both positive and negative externalities associated with the radio frequency spectrum with costs and benefits being related to the level of use. On the positive side, it is noted by Elliot, Liefeld and Spence (1970, p. 76) that "it would probably be the judgement of most people that there are externalities in communications and they are, on balance, positive." Evidence cited for this assertion is based on deductive reasoning. At the time their report was written, not only was spectrum use subsidized but the government was investigating means for increasing communications capabilities in the far north. The existence of large positive externalities is presumed to explain government involvement in this manner.

On the negative side, it is noted by authors such as Melody and Smythe (1978, p. 33) that "in the case of the radio spectrum ... virtually every decision that is made has consequences for other users. These range from matters of congestion and technical interference to the destruction of economic values in existing equipment." Examples cited clearly imply the risk of overwhelming negative externalities in the absence of government intervention.

Coupled with positive economic externalities, then, there would appear to be some grounds for government activity in the field of spectrum management in light of the spectrum's economic characteristics. However, it has been the essence of the message of Coase (1959) that the externalities could be conceived in terms of legal shortcomings in the definition of spectrum property rights. Possibly, negative externalities could be alleviated through redefined access rights to the spectrum.

## 3. Common Pools

A special kind of external effect occurs with common pool resources. "A common pool is a natural resource that is available for use but if too many use it the resource itself may be destroyed."<sup>[9]</sup> Classic examples include fisheries and wildlife, both of which may be totally depleted in the absence of government regulation to restrict use.

Like fisheries and wildlife, the usefulness of the spectrum resource can be destroyed. Over-utilization can and does lead to interference and congestion, conditions which render it useless. Unlike classical examples of common pools, however, there is no risk of depleting the spectrum resource over the long term. Restoration to its original state

9. Bish, Robert L., Local Government in British Columbia, Victoria, British Columbia: University of Victoria, 1986 (p. 10).

can be achieved simply through identifying and removing the source of the problem. As such, the radio spectrum possesses some but not all characteristics of a common pool resource implying that some government intervention may be warranted for preservation purposes.

Returning to the question of whether or not the price mechanism should be ruled out as a method to allocate spectrum, it appears that economic characteristics of the resource only partially fit into the taxonomy of specific problems that cause market failures. On the one hand, the radio spectrum is clearly not a public good. It can be packaged for the benefit of individual users and therefore appears amenable to the pricing mechanism for allocation purposes. On the other hand, certain characteristics of the spectrum resource can lead to economic externalities. If it is accepted that these externalities can be positive and negative, there would appear to be a role for government both in the promotion and regulation of spectrum use providing externalities created are sufficiently large.

Physical characteristics of the spectrum call for at least some government involvement in its management. In particular, the potential for interference and the ensuing international character of the resource suggest a role for government.

### III. THE CURRENT SPECTRUM MANAGEMENT SYSTEM

In Canada, overall responsibility for the management of the radio frequency spectrum is vested in the federal Minister of Communications.<sup>[10]</sup> Under the authority of the *Radio Act*, and to a lesser extent, the *Department of Communications Act* and the *Broadcasting Act*, access to and use of the radio frequency spectrum is totally regulated by the Department of Communications in an effort to fulfill its objective of fostering the orderly development and operation of communications for Canada. Within that department, functions ranging from policy development, planning and engineering to authorization, control and international representation are assigned to the Spectrum Management Program. These functions, whether undertaken at the local, national or international level, are aimed at ensuring the accommodation of as many uses and users of the radio frequency spectrum as possible (encouraging exploitation of the resource) while ensuring a minimum of interference (preserving the quality and integrity of the resource).<sup>[11]</sup> The purpose of this section of the study is to provide an overview of these functions and the principles and practices underlying them. Through this process the nature and extent of program operations will become apparent.

#### A. Functions

Functions of the Spectrum Management Program are broadly divided into five categories. Conceptually, these categories correspond to three levels of intervention which can be usefully distinguished for evaluation purposes. As such, each are described below.

##### 1. Policy Development

Policy development concerning spectrum allocation and use focuses on meeting Canada's long-term telecommunications needs which will facilitate the country's economic and social objectives. Based on input from representatives of operating agencies, users groups, manufacturers and research organizations, groups which may use the various

10. Authority over spectrum allocation in Canada extends both to the private and government sectors. This is in contrast to the U.S. system where four government agencies allocate spectrum for military use (DOD and NASA), other federal government uses (NTIA) and other uses (FCC).
11. Although centrally controlled by headquarters offices in Ottawa, regulatory functions are carried out to a greater or lesser extent by five regional offices and 47 district and sub-district offices situated throughout Canada.

allocations of spectrum are identified and efforts are made to balance demand for the resource by its various current and potential users.<sup>[12]</sup>

## 2. Planning and Engineering

Centralized planning is based on national spectrum policy and results in the establishment of "frequency plans and sub-allocations for the available allocated bands to match needs and facilitate efficient utilization of the allocations". Should allocations prove inefficient as trends in spectrum use develop, changes are made by those involved in the planning function.

Spectrum engineering forms a necessary part of spectrum planning particularly in establishing the national Table of Frequency Allocations. However, it can also be viewed as a distinct level of regulation. In particular, outputs of spectrum engineering include detailed restrictions on the design of radio equipment and communication systems (e.g. level of modulation, power antenna height, tolerance levels, etc.). Intended outcomes of such standards include minimization of radiation and interferences emanating from radio transmitters and receivers.

## 3. Authorization

Authorization, or the assignment and coordination of frequencies within allocated bands, represents a third function carried out by the Spectrum Management Program. At its most basic level, it involves processing applications and issuing licenses after guidance is provided to potential users in selecting spectrum specifications tailored to their needs. Additionally, however, it may also involve the conduct of specific engineering studies and co-ordination of frequency assignments with the United States. During 1985-1986, a total of 224,500 new and amended radio station licenses were issued along with 523,400 licence renewals. Of the total, the General Radio Service station population stood at 355,320 with the balance of 734,500 holding broadcast, common carrier, aeronautical, marine, and satellite licenses.<sup>[13]</sup>

## 4. Control

Radio station licenses are issued with specific conditions attached to them which are designed to prevent interference with other radio stations. Those involved in the control function carry out monitoring and enforcement activities in an effort to ensure compliance with these conditions in addition to provisions found in the *Radio Act* and related regulations. Monitoring activities range from the conduct of on-site inspections, communication system analysis and spectrum surveillance to investigating interference complaints. Enforcement activities, on the other hand, include a system of education orientated to self-discipline, issuance of warnings, licence suspensions or revocations and prosecution or forfeiture of equipment if necessary.

12. For a more detailed discussion of the policy development and planning functions, see S.H. Ahmed's article entitled Spectrum Management in Canada.

13. Department of Communications, Communications Annual Report: 1985-1986, Ottawa, Canada: Minister of Supply and Services Canada, 1987 (p. 31).



## 5. International Representation

A final function carried out by those employed in the Spectrum Management Program involves representing Canada's interests at an international level. This representation takes place in two major forms. First, along with other member countries of the International Telecommunications Union (ITU), Canada participates and makes representations at World Administrative Radio Conferences in respect to the allocation of frequency bands for various categories of communications services and the development and revision of rules governing spectrum use. Bands allocated by the ITU along with ITU regulations provide the broad framework within which Canada agrees to operate and hence representation aimed at protecting Canada's interests is considered very important.

Second, because Canada is situated in close proximity to the United States coordination of frequency assignments is often necessary to prevent signal interference between each country's radio stations. Bilateral agreements on procedures and rules to govern spectrum assignment and notification are negotiated to ensure the potential for interference is minimized.

From the description provided above, it is evident that three major levels of intervention over spectrum allocation, assignment and use can usefully be distinguished:

- at an international level, restrictions over the type of use of specific bands are formulated and implemented as are equipment standards to promote interconnectivity of radio systems;
- at a national level, restrictions over the type of users to be assigned to allocated frequencies are established and in some instances priority is given to particular classes of users (e.g. police and other essential services may be allocated spectrum ahead of competing private sector interests);
- finally, at the level of individual users, restrictions on system design are specified as conditions in radio station licenses as are operating restrictions.

Together, regulation and action at all three levels form Canada's spectrum management system. Principles and practices underlying resource allocation in this system are outlined below.

## B. Principles and Practices Underlying Spectrum Allocation

The present method of spectrum management takes into account the international legal framework, social benefits to be derived from spectrum use and engineering requirements necessitated by the nature of the resource. That much is discernable from the description provided above. What is not clear is whether or not economic criteria are incorporated into the allocation process. An examination of basic principles and associated practices underlying spectrum allocation and assignment decisions in Canada will provide this background.

There is much evidence found in the literature to support the notion that the radio frequency spectrum is conceptualized as a free good:

- ❑ first, although Canada levies licence fees on users of the spectrum resource, this fee is intended only to recover the costs associated with spectrum management. Compared to the value derived from its use, economists estimate the allocative impact of such charges to be fairly negligible.<sup>[14]</sup>
- ❑ second, in assigning frequencies, the Department of Communications uses a first-come-first-served approach. In practice, this means opportunity costs are not accounted for in the decision making process. This remains true even where there are competing interests for particular portions of the spectrum. Rather than applying economic criteria to differentiate between applicants, accommodations are generally made to ensure all parties are licenced. Such accommodations often result in less than optimal assignments from each user's perspective.
- ❑ finally, once frequencies are assigned, it is often difficult for spectrum managers to make adjustments deemed necessary to increase spectral efficiency.<sup>[15]</sup> Not only do vested interests have to be dealt with but their relocation costs rather than costs associated with avoiding change are usually the only ones accounted for.

As a free good the value of spectrum is simply not quantified.

That economic criteria do not figure prominently in allocating spectrum in Canada is not disputed. The role of the Spectrum Management Program "as the managing trustee of the free limited natural resource of the radio frequency spectrum" is clearly spelled out in the Department's operationalized objectives.<sup>[16]</sup> Reasoning for this particular approach to spectrum management is based on 1) the department's objective of encouraging exploitation of the resource, and 2) the notion that benefits derived from spectrum use cannot be measured in economic terms because of the intangible nature of many of these benefits. While this orientation may be justifiable it is nevertheless subject to much criticism in the literature. These criticisms will be summarized below along with perceived advantages of current management practices in Canada.

14. The Spectrum Management Program commanded a budget of close to \$50 million during the 1985/86 fiscal year of which 83 percent was recovered from licence revenue. Beginning in 1986/87 the program will operate fully on a cost recovery basis.
15. Spectral or technical efficiency means making more intensive use of a given frequency band. It is to be distinguished from economic efficiency which refers to processes resulting in outputs being maximized for a given level of inputs, or alternatively, minimizing the total cost of inputs for a given output.
16. Quoted from Melody and Smythe's paper entitled Factors Affecting the Canadian and U.S. Spectrum Management Processes: A Preliminary Evaluation, the department's operationalized objectives of September 15, 1981 can be found in the Spectrum Management and Government Telecommunications Sector Management Manual.

#### IV. CONSIDERATIONS TO EVALUATE THE CURRENT SYSTEM

Different approaches to resource allocation imply different results in terms of what activities are encouraged or even permitted and the efficiency with which they are carried out. This is because the factors which govern allocation decisions differ from one approach to another. For instance, the structure of incentives in a market system are such that economic factors are critical in resource allocation decisions. Meanwhile, non-economic objectives of society are not automatically attended to as they would be under centrally controlled allocation methods. This section of the study focuses on the results of spectrum management through administrative regulation by the federal government. In taking this particular focus both the advantages and disadvantages of centrally controlled allocation and management will be enumerated.

##### A. Advantages of the Current Management System

Advantages associated with the current system of spectrum management are generally not cited as such in the literature. This lack is not to imply there are none associated with central planning and control over the spectrum resource. Rather, it is only to point out that proponents of this approach generally provide evidence which justifies spectrum regulation and follow by delineating disadvantages associated with market alternatives. Professor McManus of Carleton University departs from this course and identifies the advantages summarized below.

According to McManus (1973, p. 24), potential advantages of the current management system flow from "having all rights to the spectrum centralized in the licencing authority". Under this system users are denied enforceable rights with respect to spectrum use. The major outcome of this is that wide discretionary powers are afforded to spectrum managers. Associated advantages are threefold:

- first, licence-holders can be required to share channels, move to different frequencies, or otherwise change their transmitting activities without legal recourse. Such reallocation of spectrum rights may be required when technical changes occur or if unpredictable interference results from someone's transmission. If spectrum rights were not centralized reallocation decisions could be effectively opposed through the court system. It has to be remembered though that spectrum reallocation is difficult and relatively rare.
- second, although not required to protect the quality of the spectrum, it may nonetheless be desirable to reallocate rights to increase spectral efficiency. In the absence of centralized rights over spectrum, flexibility to initiate such changes would be hampered.

- finally, in allocating or reallocating spectrum, administrative discretion allows a free hand in pursuing the non-economic objectives of society. Essential services, for example, can be guaranteed access to spectrum use. This is not to say that administrative controls always provide the best allocation of scarce resources, however.

These advantages, combined with more traditional reasons for government intervention as outlined earlier, seem to support the case for the current regulatory system. As will be shown below, however, there are also many costs associated with centrally controlled administration of spectrum.

## B. Disadvantages of Spectrum Management by Regulation

In general, criticisms of the existing system of spectrum management are based on observations that maximum value for the spectrum resource is not being attained and the allocation and assignment techniques do not lead to the most efficient use of the spectrum. These observations translate into a number of specific concerns, the most important of which are listed below.

### 1. Distorted Demand

In a market economy, allocative functions are normally determined by market forces of supply and demand. When economists speak of "the demand" for a resource they refer to the connection between the quantities that consumers are willing to buy at various possible market prices. In other words, price is considered to be the primary factor affecting consumption levels even though demand is also influenced by factors such as the availability of substitutes and consumer incomes. As such, when resources are made available free of charge it is generally observed that over-utilization results. This is thought by some to be the case in respect of the radio frequency spectrum (Coase, 1959). More specifically, because economic factors that would play a predominant role in allocating spectrum are notably absent in its treatment as a free good, demand for the resource is said to be distorted in favour of over-utilization.

Distorted demand is not necessarily a bad thing particularly in light of the departmental objective to encourage exploitation of the resource. However, there is some evidence to suggest there are costs involved and the potential for these costs to spiral upwards in the future is great:

- first, supply relative to growing demand for a share of the spectrum is diminishing. This is particularly true in densely populated areas of the country such as Toronto, Montreal and Vancouver, and for specific services. Although not yet critical in Canada, congestion is the result.<sup>[17]</sup>
- second, because spectrum is essentially treated as a free good, those with access to it lack incentives to economize use. In fact, it has been observed by Levin (1969, p. 59) and others in the United States that in the absence of price con-

17. Congestion refers to the situation that exists when demand for spectrum exceeds what the spectrum can support at a given acceptable level of interference, and for a given quality of service (e.g. access time).

traits "irrational hoarding for strategic purposes results". Practically speaking, this means assigned frequencies can go unused.

- a third and related concern, of course, is that while spectrum may not go unused it may be used inefficiently. With low price-tag attached, investment in new equipment which allows more intensive use of the resource is avoided.
- finally, substitutes which would be less expensive than spectrum at a market-determined price are normally not considered. Those with access to spectrum need not consider alternatives and those applying for access have thus far been accommodated. That this may not be the case in the future underlies the concern with distorted demand created by treating spectrum as a free good.

## 2. Rigidities

A second disadvantageous outcome associated with current methods of allocation and assignment pertains to rigidities created therefrom. S.H. Ahmed (1977, p. 135) illustrates the nature of this problem in his description of classical methods of assignment in allocated bands and sub-bands:

Historically, when a number of communications channels ... have been identified in a given frequency band, the first users are allocated what are known as "clear channels". That is, they are the sole initial users of their assigned frequencies. For many services, where the messages are reasonably short, it possible to have several users on the same frequency. Initial assignments of clear frequencies, if maintained for a long time, create the expectation of the right of exclusive use of an assigned frequency. What is more, such a method of assignment also fills the frequency band completely at an early stage of the evolution of demand for a given service. If future events should necessitate readjustment of frequency allocations, this is made extremely difficult - as the frequencies close to the boundaries of the allocated band would already have been assigned and the re-allocation would mean disruption and financial hardship to the users of such frequencies.

Practically speaking, financial hardship caused to spectrum incumbents by re-allocation or assignment decisions is often delayed or avoided altogether. Pressure exerted by users coupled with a general reluctance on the part of spectrum managers to impose unforeseen costs on their clients act to retain the status quo. Although well-intentioned, rigidity is the result. Less efficient uses are not replaced and spectrum newcomers are assigned to areas of the spectrum that are more costly to exploit.

## 3. Opportunity Costs Not Considered

A third major criticism levelled against existing management practices is that opportunity costs are not considered in allocation and assignment decisions. The word, "opportunity" used in this sense implies that for every economic action contemplated there are alternative actions or opportunities that the decision maker must forego. The real economic cost associated with any action is therefore the benefit that the decision maker could have attained by taking the best alternative action.



In relation to spectrum, the opportunity cost of using the resource in one activity is the value foregone by not using it in the best alternative activity. But what is the foregone value? At present spectrum managers do not know the answer to this question. Normally, in a capitalist system, resources allocated by a market system are assigned to their highest valued economic use by the very nature of the market process. Value under such circumstances is reflected in price, or at least, this is the basic principle of micro-economics. When allocated outside the market, however, there is no easy method to measure economic worth which is in direct relationship with scarcity of the resource and competition for it. As already shown, though, spectrum managers do not pretend to measure economic worth nor do they employ economic criteria in assigning spectrum. Spectrum is simply parcelled out on a first-come-first-served basis. Risks inherent in this practice are that spectrum may not be allocated to its highest economic use. Considering spectrum's treatment as a free good, the likelihood of uneconomic assignments is even greater since spectrum users who place lower value on spectrum use compete equally for access with those valuing it more. Where less than optimal assignments are made, then, opportunity costs are borne by society in terms of the value that the spectrum would have in its highest valued use in a market environment.

#### 4. Economic Rent Not Derived

If maximum benefit for the spectrum resource is not accruing to the public because opportunity costs are ignored, the problem is compounded by not deriving an economic rent from the resource. Economic rent, very simply, refers to the difference between what a productive factor returns and what it could return in the best allocative alternative. If the resources could be purchased at a higher price in another use, then the economic rent is the difference between the price paid and the price that would be paid in the best alternative use.

In relation to natural resources held in the public domain, society expects compensation from resource users in exchange for the privilege of using it. Oil, coal, timber and grazing land are all examples of public property from which society expects to share in the economic rent. In some cases, bids are solicited; in others, lease fees are based on the appraised market value of the resource. In no case are natural resources treated as a free good. Clearly, this is in contrast to the spectrum resource which is also held in the public domain. On this basis, it is argued by many analysts that the benefits derived from spectrum use should accrue to the public in the form of economic rents (Coase, 1959, 1965; Levin, 1966, 1968, 1970, 1971).

#### 5. Government Administration

A final criticism levelled against central planning and allocation of spectrum pertains to problems inherent in government administration. These problems are obvious but not very often mentioned. Literature in the field of Public Administration provides useful insight into disadvantages of bureaucratic management of the spectrum resource:

- first, management through regulation requires the acquisition and use of human and financial resources. During the 1985-86 fiscal year, the Spectrum Management Program commanded a budget of close to \$50 million and a person-



year allocation of approximately 872.<sup>[18]</sup> Users of the spectrum incur these costs through licence fees under the cost-recovery scheme of the Department of Communications.<sup>[19]</sup>

- second, personnel employed in government organizations are not generally subject to the same incentive systems as those in the private sector. As Bish (1984, p. 207) puts it:

An egalitarian civil service ethic where professionals are expected to work in the public interest and where sanctions for poor performance are so time-consuming that many managers ignore substandard performance rather than try to do anything about it...is the norm. The net result is a work environment where organizations continue along habitual lines with little innovation or adaptive behaviour unless they are subjected to major externally generated shocks. Such organizations are likely to lag, rather than lead, in innovation and productivity increases.

To compound this problem, there may actually be disincentives to increasing efficiency. The best known theory of this type is Niskanen's budget-maximizing theory of government administration (Friedman, 1984, p. 345) which assumes that:

the motivations of upper-level bureaucrats are like those of the sales-maximizing private firm ... That is, if bureaucrats are interested in maximizing their salaries and prestige, one way to do so is to maximize the budgets of their bureaus.

If this theory is true in respect of the Spectrum Management Program, spectrum users may be incurring some unnecessary administrative costs. These costs are in addition to those which may be involved with general avoidance of innovation which may lead to more efficient use of the spectrum.

- government organizations are also subjected to less than efficient working rules for the sake of transparency and accountability.
- finally, by definition, a bureaucracy generates an administrative burden to the client-user. In relation to spectrum management, it is represented by forms and briefs to be submitted, technical standards to obey, delays in processing applications, etc. This administrative burden is difficult to quantify but it is nevertheless a cost of spectrum management by regulation. The exact cost is difficult to establish since some of this burden would still persist even under an alternate spectrum management system.

Inefficiencies associated with government bureaucracy, congestion caused by distorted demand, lack of incentive to economize or use substitutes and limited return of private

18. The source for these figures is the Main Estimates for the 1985-86 Fiscal Year.

19. See a counter-argument to the government burden in section C.2 of Chapter V.

benefits to the public are some of the major theoretical consequences identified with current spectrum management practices in Canada and elsewhere. Over time, these problems have been regarded as more serious in light of an ever-increasing demand for the resource. This has resulted in a rather large and growing number of proposals being made to alter the existing regulatory structure governing allocation and use of the radio frequency spectrum. The purpose of the remainder of this study is to critically review these proposals in terms of their relevance for spectrum management in Canada. A pure market approach will be considered first, followed by approaches which combine some aspects of the free market approach with the current method of regulation.

## V. THE PURE MARKET ALTERNATIVE

The most extreme alternative to the present system proposed in the literature is the establishment of a completely free spectrum market. A pure market alternative, as it is referred to here, would involve the establishment of exclusive, transferable rights to the spectrum that could be traded among individuals through the mechanism of the price system. Spectrum allocation<sup>[20]</sup> and assignment decisions would be made by buyers and sellers of spectrum rights with price reflecting the economic value of the resource. Government involvement would be limited to providing a legal framework for the enforcement and official recording of these rights. Fundamental to the transition to this system of resource allocation, then, would be the clear definition of property rights. As such, this issue will be dealt with first. Operating on the premise that property rights can indeed be established in relation to spectrum, the advantages of this approach will then be delineated.<sup>[21]</sup> Finally, the most frequently heard criticisms of a property rights system for spectrum allocation will be discussed. Through this process it will become evident that the most extreme alternative to the present system may not in fact be a viable one for Canada.

### A. Establishment of Property Rights to the Spectrum

To work smoothly and efficiently, the pure market alternative requires that property rights be properly defined. In particular, the nature of the commodity being exchanged must be readily identified by buyer and seller. As noted by Robinson (1985), "just as no one would purchase a home or invest resources in home production if home ownership did not convey the right to exclude others from use of the property, so too would effective electronic communication be impossible without some elaboration and enforcement of rights of spectrum resource usage."

Accordingly, parameters for the definition of property rights have been set forth by a number of analysts in the field. Apparently, improvements in our understanding of radio transmission and our ability to measure spectrum outputs is now sufficiently sophisticated to allow for this type of property rights definition.

As one of the earliest proponents of the free market approach to spectrum assignment, Coase was the first to specify conditions for the definition of property rights. He notes in his 1959

20. This section discusses the pure market approach. In a less perfect case, only assignments could be traded. Allocations would be excluded.

21. Some argue that property rights can not be sufficiently defined to enable the operation of a market in spectrum rights. See, for example, Melody, W.H. and Smythe, D.W., 1978.

article (p. 25) that "the main reason for government regulation of the radio industry was to prevent interference". He then infers that the rights of operators to transmit signals which interfere, or might potentially interfere, with those of others can be delimited on the same basis in defining property rights as they are in establishing radio standards and licence conditions. In other words, "Coase seemed to accept the FCC standards for transmitter characteristics as the property rights to be defined." (Small, 1982, p. 5) Since that time, Coase's particular approach to defining property rights has been criticized and alternative approaches have been put forward. The approach given most prominence in the literature is reviewed below.

Rather than establishing a property rights system based on the input characteristics of transmitters, DeVany, Eckert, Meyers, O'Hara and Scott (1980) advocate the definition of output rights as the basis of property rights. More specifically, they construct a package of rights for spectrum use situated along the dimensions of time, area and spectrum. Time rights would indicate when the owner/lessee would be authorized to utilize spectrum; area rights would specify the locality in which operations could be conducted subject to the constraint that the field strength achieved by this radiation would not exceed specified limits; and spectrum rights would specify out-of-band limits on radiation for the user and his/her neighbors. All operators' rights would be coordinated through the definition of these dimensions. As property rights, they would be enforceable upon bringing action against transgressors. The overall advantage associated with defining output rather than input rights cited in the literature is that the rights holder is allowed to achieve the least cost alternative. In other words, limitations on inputs, such as transmitters, which lead to inefficiencies would be avoided.<sup>[22]</sup>

The point here is not to come down on one side or the other with respect to the optimal method of defining property rights. Rather, it is only to point out that their definition is viewed as plausible by many experts in the field. Moreover, it seems there is wide agreement that a necessary prerequisite to the effective operation of a completely free spectrum market rests on the definition of property rights which are unambiguous, exclusive, transferable and enforceable. Working from the premise that this is achievable, advantages of shifting to a pure market alternative are discussed below.

## B. Advantages of the Pure Market Alternative

Advantages associated with the pure market alternative can be viewed from two perspectives - that of the spectrum user and that of society as a whole. Turning first to the perspective of individual users, the major advantage of spectrum deregulation would be the newly found freedom that would be afforded to them. Although it has been pointed out that those wishing to use the spectrum are rarely turned down in Canada, it is also true in some cases that (1) applicants are licenced in an area of the spectrum which represents a less than optimal assignment; (2) they are sometimes requested to accept allocations smaller than that which they applied for; and (3) they may be required to have their name placed on a waiting

22. For a more detailed description and analysis of the approach proposed by DeVany et al. refer directly to their 1969 article and pages 5-9 of Small (1982)

list until such time as spectrum in congested areas becomes available.<sup>[23]</sup> Whatever the scenario, there are costs incurred by the user in waiting for or in receiving less than optimal assignments. Under a system where rights to spectrum could be purchased, spectrum users would be freer to decide which area of the spectrum they would like to operate in and how much spectrum they would like to use in preferred locations. The cost, of course, would be the price they would have to pay for spectrum but that price presumably would be recoverable upon sale of ownership rights. Freedom from regulation would thus appear to hold advantages to spectrum users.

From the perspective of society as a whole there are many welfare gains anticipated from allocating spectrum by using the pricing mechanism. Most importantly, the economic worth of spectrum would be revealed if traded in a market environment. Economic worth would constitute the primary criterion by which society would determine the use to which the resource was to be committed. Providing those purchasing spectrum property rights were operating on correct information, the resource would be allocated to its highest valued economic use. Increased economic efficiency would result since those valuing the resource most would acquire the rights over it. Concomitantly, society would enjoy welfare gains from the most efficient use of the resource possible.

To clarify the precise nature of benefits associated with using the pricing mechanism it is useful to examine how the structure of incentives would change for users and the expected outcomes derived therefrom. First, in view of the fact that users would pay a price for spectrum, they would be motivated to economize its use. They may achieve this by replacing old equipment with new that allows for more intensive use of the resource or by sharing under-utilized portions of the spectrum with others. Second, where there were substitutes available, they would be used where costs were lower than market price for spectrum. Third, those who place a lower value on the use of the spectrum will be excluded either by refusing to pay the market price for spectrum or through willingly selling their rights to others. In theory, the expected outcomes of economizing practices, use of substitutes and excluding low preference users should be a situation where demand for spectrum will be reduced where demand exceeds supply. In turn, congestion caused by over-consumption will be eliminated. Taken together, then, many of the inadequacies and inefficiencies attributed to current management practices would be overcome through introducing market-type incentives.

It should be noted that reduced access to the spectrum would occur only where demand exceeds supply. Elsewhere, low demand would necessarily generate low prices and would not hinder spectrum use.

### C. Difficulties Associated with Property Rights

Notwithstanding the advantages outlined above, there are a number of difficulties associated with assigning property rights to the radio frequency spectrum. On the one hand, there are constraints which preclude the operation of an unfettered market system and on the other there are costs involved in allocating spectrum through market forces. Constraints and costs, as identified in the literature, are summarized below.

23. This information was provided to the author by personnel employed in the Spectrum Management Program of the Canadian Department of Communications.



## 1. Constraints

Beginning with the presumption that property rights can in fact be unambiguously defined, there are still operational constraints to implementing a pure market alternative. The most obvious of these pertains to the international legal framework within which Canada has agreed to operate. In particular, it has been noted elsewhere that Canada has been participant in the development of a complex set of international conventions, treaties and regulations to govern spectrum policy domestically. While restrictions to the type of use allowed in specific bands and international equipment standards are an important outcomes of Canada's participation in international regulatory agencies, so too is an obligation on the part of Canada to operate within these constraints. At best, Canada could have to attempt to negotiate less restrictive allocation of spectrum internationally if it wished to support a freer market alternative. More likely, however, international constraints will remain in effect. A more thorough assessment of this constraint falls outside this discussion.

From the perspective of analysts such as Melody and Smythe (1978, p. 5), a less obvious, but equally important, operational constraint is the contradiction between private ownership of spectrum and "the highly sensitive relationship which exists between the right to allocate and use the radio spectrum for defense, intelligence and diplomatic purposes on the part of the nation state. The power to control allocation of the radio spectrum" according to these authors "lies very intimately with sovereignty". On this basis they conclude that "foreign offices of major nation states will always control national policy on radio frequency allocation". If this argument is accepted, issues of national sovereignty in addition to international obligations are significant constraints to the operation of an unfettered market in spectrum rights, to the extent that the market is given responsibility for allocations. A more restrictive market alternative could see the deregulation of assignments only within a fixed allocation scheme.

## 2. Costs

Supposing that the constraints outlined above could be dealt with effectively, there are still identifiable costs in adopting the pure market alternative.

- First, under the current system of allocation non-economic objectives of society are attended to. Essential services such as national defence, police and fire protection services receive spectrum space necessary for their operations on a priority basis. Under a pure market system there is fear that the socially optimal amount of these types of services would not be forthcoming. Of course, given appropriate resources, non-economic services could still compete for spectrum access.
- Second, and most importantly, even the strongest advocates of the pure market alternative acknowledge the costs of redefining and enforcing spectrum rights may be so overwhelming as to render the pure market alternative infeasible. Coase (1959, p. 29) stated:

When the transfer of rights has to come about as a result of market transactions carried out between large numbers of people or organizations



acting jointly, [as could be the case in respect of spectrum rights] the process of negotiation may be so difficult and time-consuming as to make such transfers a practical impossibility. Even the enforcement of rights through the courts may not be easy. It may be costly to discover who it is that is causing the trouble. And, when it is not in the interest of any single person or organization to bring suit, the problems involved in arranging joint actions represent a further obstacle. As a practical matter, the market may become too costly to operate.

Since these concerns were initially raised by Coase they have been repeated by virtually every analyst in the field.

To summarize, it is clear the most obvious method by which to introduce economic factors into spectrum management would be to open the spectrum resource to the market. To do so would require a clear definition of property rights and it appears that this might be achieved by defining either input or output rights. There are many advantages associated with taking this course, both from the perspective of the user and society as a whole. Ultimately, however, analysis indicates that international constraints may preclude this option and in any case it simply may not be practical because of the cost of defining and enforcing property rights in the spectrum. In light of this, other means by which to derive the economic worth of the resource and provide market-type incentives that will lead to improved spectrum management are investigated below.



## VI. HYBRID APPROACHES

A range of techniques which promise increased, but not necessarily maximum economic efficiency in spectrum allocation, assignment and use is presented in the literature. All combine aspects of a free market approach with centralized administration in an attempt to capture the benefits of both approaches. Of the many alternatives proposed, three major techniques are given prominence. These emerge as promising techniques sharing a common goal: to incorporate economic factors into spectrum management. The are: shadow pricing, application of user charges, and assignment by auction.<sup>[24]</sup> Each will be described below with consideration also being given to combinations of the three techniques.

### A. Shadow Pricing

A shadow price is defined as the value attributed to a factor where there is no price or its market price is not equal to its social cost or benefit (Levin, 1971). It is derived through various analytic methods and its calculation is justified on the basis that the shadow price more appropriately reflects the economic value than its existing price. For example, in evaluating a project, an economist may effectively "correct" a number of market prices by attributing prices to unpriced gains and losses that the project is expected to generate. These adjustments would ensure that externalities were properly accounted for in the "corrected" price. In respect of goods or factors that have no market price, such as the spectrum resource, the more likely course would be to assign a value most reflective of the price the commodity might command in a market environment. Shadow pricing in this instance would involve collection and analysis of data aimed at determining the amount individual users would pay for a marginal unit of spectrum if it were competitively priced. Shadow pricing theoretically offers a technique to incorporate economic factors into spectrum management.

Practically speaking, shadow pricing is acknowledged as being a very expensive method of ascertaining spectrum value, if indeed it is possible to arrive at reasonably accurate estimates at all (Melody, 1978; Robinson, 1976). Nevertheless, it is regarded by many as preferable to doing nothing. On that basis, shadow pricing is analyzed in respect of how it might be most usefully employed by spectrum managers.

As noted by Melody and Smythe (1978, p. 43), "shadow pricing has been recommended [in the literature] as both a basis for making administrative allocations and as a basis for setting user charges". Respecting the former, it is argued that in ascertaining the economic value of various portions of the radio frequency spectrum, shadow prices could be used to distinguish

24. A fourth major technique considered in U.S. literature involves use of lotteries for assignment purposes. It is proposed in light of specific problems in the U.S. assignment procedures which do not apply in Canada.

between high and low-value uses of the spectrum. Allocation decisions could subsequently be based on this information, with those services willing to pay the highest price for particular frequency bands being allocated spectrum accordingly. Respecting the latter, shadow prices could be used in establishing user charges. To the extent that they reflected the economic value of the resource, users placing a lower value on their access to the spectrum would be excluded. In combination, the result would be increased economic efficiency with spectrum allocated to the highest valued uses and assigned to those who valued it most.

## B. User Charges

A second hybrid approach proposed in the literature involves charging fees for use of the radio frequency spectrum. There are many variations of this approach, but the basic idea is to charge users a fee which reflects spectrum value either partially or in total. To some extent, Canada's practice of funding spectrum management activities from licence fee rather than taxation revenues can be viewed as a system of user charges. Those benefitting from using the resource are held financially responsible for its management. Beyond this, however, a system of charges could be implemented which would more accurately reflect the economic value of the resource. Whereas charges based on shadow price estimates provide one method of deriving economic value, other techniques have also been suggested. Several analysts have proposed auctioning portions of the spectrum to derive its economic value while others prefer arriving at such fees on the basis of benefits received from spectrum utilization (e.g. profits). Whatever method is used to calculate user fees, it is acknowledged that the task will not be an easy one. Not only are private and public valuations of the spectrum likely to be different but the value of different bands may be highly divergent.<sup>[25]</sup>

Notwithstanding the difficulties associated with formulating user charges to reflect spectrum worth, there are many advantages associated with this option.

- ❑ First, application of user charges which more closely reflect free market value would create incentives to conserve the resource. The result would be increased economic efficiency in its use.
- ❑ Second, administering user charges allows for the retention of central control over spectrum policy and assignment. Depending on the criteria used to set fees, social priorities could be still be pursued by applying higher user rates to profit-making organizations than to non-profit public service organizations.
- ❑ Third, user fees more in line with market value obviously would create a new revenue source for government. As noted elsewhere, licence fees are currently unrelated to and fall short of spectrum value.
- ❑ Finally, in and of themselves, user charges appeal to one's sense of fairness. Considering that spectrum is held in the public domain, it makes sense that those benefitting from using it also pay for it. User charges would ensure a return to society for granting privileges to individual users. In sum, user charges appear not only to be

25. For a more complete discussion of various systems of charges that might be considered, see Melody and Smythe, 1978, pp. 44-50.

a potentially useful management tool in terms of promoting social goals, efficiency and equity concerns but they also provide a viable means to raise government revenue.

### C. Auctions With Lease

A final major approach considered in the literature is that of assigning spectrum through auctions. As was the case with applying user fees, there are many variations on this theme but auctions allow for retention of central control spectrum management functions while introducing economic criteria into the selection process, without awarding property rights. In particular, auctions accompanied by lease arrangements would involve a competitive bidding system where spectrum would be awarded to those willing to pay the most for particular assignments and where operating conditions would be conveyed by lease agreement. Although never used to assign radio licenses, precedent for auctions with lease arrangements can be found in the manner by which other resources in the public domain are allocated among private users. Presumably, reference to what is involved in establishing and maintaining these systems would provide insight into the radio frequency spectrum.

Auctioning off spectrum available in specific bands with attached operating conditions is viewed as being advantageous for several reasons.

- First, it is seen as a means to improve the assignment process. Where there are potentially a large number of users that would apply for licenses in a particular area of the spectrum, auctions provide an objective means of selecting between applicants. Presuming they are all able and willing to meet conditions set by the central authority, assignments would be awarded on the basis of the highest bid.
- Second, substituting decisions of regulatory agencies with those of the market in this manner would increase economic efficiency by allowing resources to go to their highest valued use. Concomitantly, spectrum managers would be provided with information on the value of various portions of the spectrum which could be used for decision making purposes concerning spectrum allocation.
- Finally, as is the case with applying user fees, auctions allow the government to capture some of the value of the spectrum resource. In allowing users to decide how much they were willing to pay, however, the pitfalls entailed in calculating user fees would be avoided.

For this and other reasons enumerated above, auctions with lease arrangements are favoured by many analysts in the field.

From the discussion above, it would appear that hybrid approaches such as auctions, user fees and shadow pricing are promising means by which to incorporate economic factors into the administrative process. Regulatory functions ranging from policy development to international representation could remain essentially intact. In as much as this is deemed important in terms of pursuing non-economic objectives, retention of such control would appear desirable.

On this basis, it would appear justifiable to conclude that adoption of any one of the hybrid approaches presented, or a combination thereof, would offer the best of all worlds. In fact, however, such conclusions may be premature. The caveat, of course, is that the claims made

by advocates of hybrid approaches are not supported by empirical evidence, as in the case of the pure market approach. Until such time as they are, it is not possible to reach any final conclusions on the matter. With this precautionary note in mind, the following section will address policy considerations involved in making a choice between the major alternatives available.



## VII. POLICY OPTIONS AVAILABLE TO GOVERNMENT

Thus far the analysis has been largely descriptive. It has focused on capturing major themes found in the literature and bringing some coherence to the debate on the relative merits of different approaches to spectrum management. By virtue of the task undertaken, which was to examine the rationale for the current system of spectrum management and evaluate alternative approaches in terms of their relevance for Canada, theoretical disabilities associated with current management practices were revealed and approaches which offered solutions were explored. Because promised improvements of alternative approaches have not been demonstrated empirically, however, final conclusions respecting which approach should be adopted have not and will not be reached in this study. What remains to be addressed, therefore, pertains to those factors that need to be considered in contemplating change. This section which will begin by listing the three broadly conceived policy options available to government and follow with a discussion of implications of these alternative strategies.

### A. Policy Options

There are countless variations in methodologies which might be employed to assign frequencies and coordinate spectrum use. Some of these have been discussed in this study. However, the concern here is with the three mainstream approaches to spectrum management rather than particular variations on these themes. To summarize, these include centrally controlled allocation, assignment and management of the spectrum resource; the pure market alternative where spectrum would be allocated in a market environment with individuals exchanging exclusive, transferable rights; and middle-of-the-road approaches which combine elements of each of the first two options. Given Canada's current approach is that of central control over the resource, policy options available to government are:

1. keeping the current system;
2. the adoption of the pure market alternative; or
3. the implementation of a hybrid approach which combines elements of an administrative approach with a free market approach.

It has been shown that there are foreseeable costs and benefits associated with each of these three policy options. Specific issues to be considered in making the choice are raised below.

### B. Considerations

There is no single, well-defined set of values which analysts must use in attempting to evaluate policies. The choice of criteria is discretionary. In practice, however, certain criteria are common to most analyses and include efficiency, equity or fairness, and political

feasibility. These criteria, in addition to social, legal and cost considerations will be used as the benchmarks by which to compare the relative merits of each of the three options available.

## 1. Efficiency Considerations

The radio frequency spectrum is allocated in a manner radically different from that for most other resources in our economy. It is allocated by administrative authorities on a first-come-first-served basis and is essentially treated as a free good. From the standpoint of economic efficiency, this method of allocation is considered by many to be highly questionable. It is held to result in (1) a misallocation of spectrum rights since the regulator has no way of discriminating between users placing a high or low value to access to the spectrum, and (2) over-consumption of the resource which leads to inefficient congestion in certain frequency bands. It is believed that as demand for spectrum resources increases these deficiencies will become more critical. Solutions are not expected to be found in merely increasing spectral efficiency. Rather, it is forcefully argued by many that more efficient assignment of the radio frequency spectrum will require a change in the method of administering the resource.

One alternative, that of establishing marketable spectrum rights, is offered as a way to increase economic efficiency. Predicated on the notion that unrestricted or minimally restricted markets allow resources to move from lower to higher valued users and uses, economic efficiency is the expected result. However, the effectiveness of this approach depends on the costs of redefining and enforcing transferable rights to spectrum. Even the most avid supporters of this option conclude that these costs may be prohibitive. On this basis, hybrid approaches which introduce market incentives while retaining central control over the resource are considered.

Although it is acknowledged that new inefficiencies may be introduced, on balance, these approaches are supported in the literature on efficiency grounds. Not only does administrative control ensure the capability to pursue socially desirable goals but market incentives would ensure economy in the use of the resource. However, the benefits of this alternative have not been quantified and the dimensions of new inefficiencies which may arise are unknown.

## 2. Equity Considerations

On equity or fairness grounds, the status quo does not appear to fare any better than it did on efficiency grounds. Equity is defined in various ways, but in respect of the spectrum resource, the issue pertains to the distribution of benefits derived from utilizing the resource. Under the present method of allocation, spectrum users are unequivocally the net beneficiaries. That this is the case does not imply unfairness. However, being in receipt of payments that far exceed the opportunity costs of supply leads to abnormal profits due to abnormally low input costs. Under such circumstances, consideration must be given to sharing the economic rent with the owner of the resource: the public.

Selling spectrum rights would also ensure some economic rent would flow to society but great care would have to be taken not to sell below market value. Otherwise, windfall gains would flow to initial owners of the resource. The alternative most likely to

achieve the equity end on an ongoing basis is that of employing hybrid approaches where government would be in receipt of user fees or auction revenues.

What is fair and equitable from society's perspective may not be seen as fair from the users viewpoint. Although licensees would be afforded more freedom in use of the spectrum under either alternative approach, they would invariably see themselves as losers. What hitherto had been provided free of charge they would be required to pay for and in some instances this payment might be substantial. While this need not be of concern from an equity standpoint, if the outcome is only to remove economic rents from users, there is reason for some reservation. That is, where spectrum users have invested heavily in equipment which is comparatively inefficient, they may suffer unjust losses if charged the same fees as those utilizing newer, more efficient equipment at the time of the change. Where such injustices are perceived, consideration may have to be given to compensating users at least until the useful life of their equipment has expired. To do otherwise would be to risk dislocation and inequities during the transitional phase from one approach to another.

### 3. Social Considerations

Under the current system of spectrum management, the government is afforded complete discretion in pursuing socially desirable goals. Such discretion would obviously be attenuated if the pure market alternative was adopted. To some, consequences of changes may involve the underproduction of socially valued services. The casualty most often cited in the literature pertains to essential services which rely on spectrum for communication purposes.

It should be pointed out however that there is no obvious reason why non-economic services or safety related activities should be subsidized in their use of spectrum. Other necessities (e.g. trucks, clothing, equipment) are obtained at market prices. So could the spectrum. This could allow for a more enlightened decision process when spectrum resources are distributed.

As an alternative to a free market in spectrum, hybrid approaches offer greater flexibility in terms of exercising administrative discretion. For example, in setting user charges, those services using spectrum that produce social benefits without deriving profits from their activities may be assessed fees below market value although this could represent an incentive to over-use the resource. Alternatively, if auctions were used for assignment purposes, certain areas of the spectrum may be set aside for government-type services. With restrictions as to what services would be allowed to participate in auctions for given channels, socially desirable services would still be produced at the same time that the market would determine price.

In establishing either type of system, there would be opportunity costs to be accounted for. Moreover, if auctions were the preferred approach, consideration would have to be given to the inherent inflexibilities of government budget cycles to determine whether or not government could participate fully in the auctioning process. In any case, if either the second or third option were to be implemented, it appears special arrangements may be needed to accommodate governmental interests in spectrum use to ensure achievement of society's non-economic goals.

#### 4. Legal Considerations

At a minimum, implementation of hybrid approaches or the pure market alternative would require legislative revisions. For instance, user fees could not be applied nor could auctions be conducted without authorizing legislation. To implement a pure market alternative, where spectrum would be assigned and allocated by market forces, would also require the complete renegotiation of Canada's obligations under international law. The implications of this are difficult to assess at this point but certainly very far-reaching.

#### 5. Financial Considerations

Any departure from the current system of spectrum management will incur start-up costs ranging from those associated with developing new legislation, policy and procedures to educating users, manufacturers and the general public on new management systems. Most of these costs would involve one-time expenditures the magnitude of which would have to be determined. Over the longer term, revenues generated from applying user charges, selling or leasing spectrum rights would stand to increase funds flowing to the national treasury. However, if government users were to fully participate in a market for spectrum, the costs of some individual departments such as the Department of National Defence would increase accordingly. Presumably, revenues derived from the resource could fund these extra costs and net benefits would still be realized.

In any case, cost-benefit analysis would be required to determine the extent to which added revenues would outweigh public and private costs of enforcing spectrum rights in the case of the pure market alternative or costs entailed in hybrid approaches. Based on the literature, it would appear that user fees and auctions with lease arrangements would result in net financial benefits over the current system whereas the pure market alternative may not.

#### 6. Other Considerations

No matter how great the promised improvement, change to current practices will engender opposition. This opposition can be reasonably be expected from three or four quarters, depending on whether the pure market alternative or hybrid approaches were to be adopted.

Over and above those licenced to use the resource, which number in excess of one million, vested interests include those of clientele purchasing services which utilize spectrum and those of personnel employed in the Spectrum Management Program. In the event that Canada decided to opt out of the international allocation scheme, further pressure would likely be brought to bear by other countries. In light of these kinds of considerations, Robinson (1976, p. 2) notes that "the present allocation of the spectrum, with its associated multibillion dollar investment in radio equipment and immeasurable public vested interest, must be accepted as the initial condition for analysis". He goes on to state that "any proposed change in spectrum management... will not be accepted if it seriously disrupts the operation of the present in-place telecommunication services". He does not conclude that changes in spectrum management should be precluded on this basis but does indicate "...it [would] require the introduction of such changes in an



orderly manner". Careful attention to initiating change will thus be needed and political will has to be sufficiently strong to withstand anticipated opposition.

From the preceding examination of issues, it would appear there are a number of questions which would have to be properly addressed prior to implementing change to current management systems. In terms of efficiency and equity concerns, gains to be realized might best be projected by testing proposed alternatives on an experimental basis. The same might be true of financial considerations, although cost-benefit analysis would also be required to ensure an accounting of all public and private costs and benefits. Finally, even if implemented on an experimental basis, legislative authority would be needed to introduce alternative management systems; explicit attention to social considerations would be required; and education aimed at informing potential opposition groups of benefits to be realized from change would be prudent.

### C. Conclusions

Over the past three decades, substantial literature comparing the relative merits of alternative approaches to allocating and coordinating spectrum use has accumulated. In general, it has reflected a concern about the deficiencies of current management principles and practices and an expectation that future growth in demand for the resource will intensify the negative consequences of these deficiencies. In as much as there is expressed agreement on the inherent problems of treating spectrum as a free good, there is much less agreement reflected in the analysis of the problem. That is, in analyzing and contrasting the current method of spectrum management with a free market approach it has been shown there are some who believe a free market in spectrum rights is possible and others who do not. While those found in the latter camp continue to cite the technical nature of the spectrum, market externalities, international constraints and social considerations as realities which preclude effective operation of the pure market alternative, those found in the former camp dispute these claims. In the final analysis, however, it is nevertheless acceded by most that costs of redefining and enforcing property rights in spectrum *may* be so prohibitive that alternative methods of introducing economic criteria into the allocation process may be preferable.

The conclusion of this study is that for all practical intents and purposes one's particular approach to problem definition and analysis may not matter. Whether beginning with the presumption that administrative control is desirable to ensure flexibility in pursuing non-economic objectives or the premise that such control is desirable only to the extent that it facilitates the free working of a market in spectrum does not result in fundamentally divergent conclusions. For different reasons, and based on different analyses, the solution advocated most in the theoretical literature is that of combining elements of an administrative approach with a free market approach. That this is the case should not be surprising. Considering there are costs and benefits associated with either alternative and hybrid approaches appear to offer a way of capturing the best of all worlds, it would seem to be the most logical policy approach. As noted elsewhere in this study, however, the benefits to be derived from implementing hybrid approaches remain speculative.





## VIII. APPENDIX

### A. CSP International Report (1987)

The first version of this study did not include an analysis of the CSP International Report (1987), *Deregulation of the Radio Spectrum in the U.K.*, because of the newness of this report. This appendix attempts to fill this gap.

First, it should be mentioned that the direct application of the Report is very limited. It is true that the Report is related to subjects of this study; however, the main object of the Report does not greatly overlapped with the intention of this study. In other words, the current study is a general sketch of the economic nature of the spectrum while the CSP International Report is a disaggregated analysis of individual submarkets, namely T.V., stereo radio, data, video conferencing, cellula, wide area mobile, P.M.R. (normal service) and P.M.R. (trunked). Secondly, the method of research are quite different. While the U.K. Report is trying to project possible gains from deregulation (by econometric forecasting) in terms of numerical values, this study has sought to find theoretical ground for policy options by reviewing the economic literature.

Despite these differences in lines of research, it is true that the U.K. Report could provide the adequate guideline for the future studies. If convinced that deregulation is the option to follow, the U.K. Report's analytic tools, measuring the benefit and the cost of deregulation in monetary terms for disaggregated sectors, might be conveniently employed. Nonetheless as it is indicated in the conclusion of this study, total regulation has not proven to be the best policy option for Canada. This conclusion induces circonspection on applying the CSP International Report any further.

### B. Illustrated Market Structures

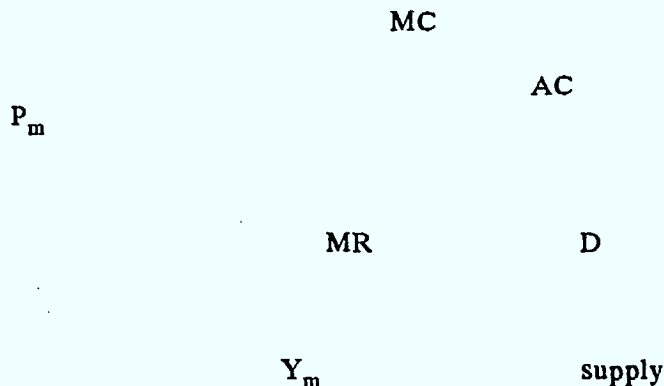
This study retained three possible policy options: (i) current policy, (ii) pure market approach, and (iii) hybrid alternative. Up to this point, the structures of the markets which are related with these policy options have been described in somewhat general terms. This appendix briefly illustrates the markets associated with policy options with standard diagrams commonly used in microeconomic analysis.

#### 1. Current policy - regulated market

Under the current management system, the market for the spectrum can be described as a monopolistic one. As it is the case in the present system, the price will be set by the lone supplier. Figure I illustrates the simplistic structure of the monopoly. In this diagram  $Y_m$

and  $P_m$  represent optimal supply of spectrum and price charged, respectively. A shaded area shows the profit generated by the management system. As already mentioned in the text, this system could arbitrary set the price to maximize revenues (and profits, in turn).

price, AC & MC



*Figure I. Monopolistic Market*

D - demand for spectrum

MR - marginal revenue

MC - marginal cost

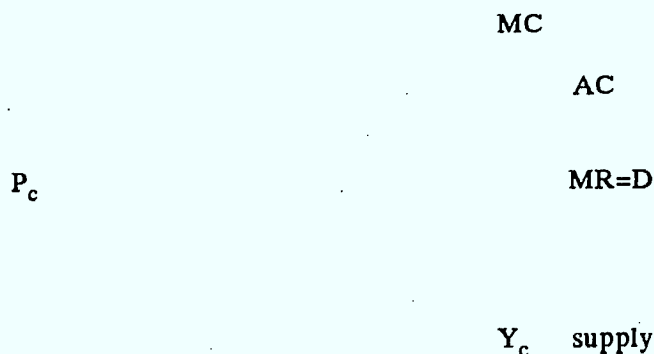
AC - average cost

## 2. Pure (competitive) market approach - competitive market

Opposite to monopolistic management is the pure market system. One of the most obvious results of this total deregulation would be the fall in price. This change in price and other impacts of the change in market structure are illustrated in Figure II. In particular, Figure II shows the individual supplier in the long run where the market is loaded with all potential profit oriented competitors and in turn profit is driven to zero. In comparison to Figure I,  $Y_c$  (supply of spectrum under deregulation) is greater than  $Y_m$ , and  $P_c$  (new price charged) is lower than  $P_m$ . This is an expected result of deregulation; a extended volume of service and a decrease in price.

Îf Figure I and Figure II were the "true" pictures of the current and deregulated systems, there would be no dispute in policy decision. As is implicitly assumed in the CSP International Report, deregulation would create more benefit to the society as a whole. However, Figure I and II do not adequately reflect the existence of externality and/or public good. In other words, without proper self regulation, the benefit of extended service with lower price would be offset by negative externality and/or selfish behaviour.

price AC & MC

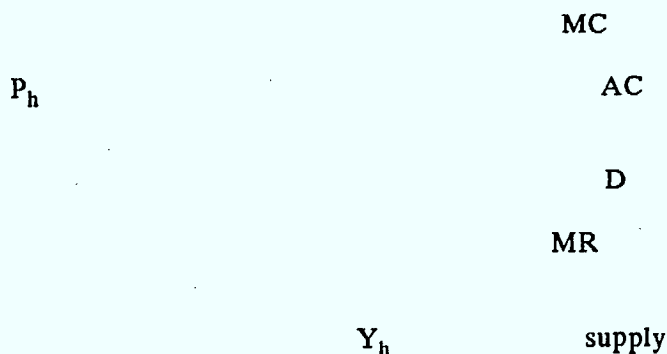


*Figure II. competitive market*

### 3. Hybrid alternative - monopolistic competition

In order to illustrate the hybrid alternative, we can draw a diagram somewhat similar to Figure I. The main difference between Figure III and Figure I would be the slopes of demand and marginal revenue curves. As it can be seen from the comparison of two figures, immediate consequences of this policy option would be  $Y_h$  (supply of spectrum under monopolistic competition) and  $P_h$  (price charged by new market participants), where  $Y_h$  is between  $Y_m$  and  $Y_c$  and  $P_h$  is between  $P_c$  and  $P_m$ . Also, in this policy option, optimized profit would coexist with optimal welfare. The loss of the monopoly profit would be compensated by increased positive externality and lowered price offered by a few newly qualified participants.

price, MC & AC



*Figure III. monopolistic competition*

### C. Future of the Study

As it has been explained in the text, the conclusions of this study were drawn from the economic literature. It was tentatively argued that hybrid alternative would be the option to follow if the gains from partial deregulation proved to be optima.

Hybrid alternatives would have to be tested by empirical studies before any wide implementation. This is why the conclusion mentioned that the benefit generated by hybrid approach are still speculative. The obvious next step of the research should be the application of quantitative studies. The CSP International Report (U.K., 1987) might be more useful for those studies than for this one; disaggregation of the field into a few submarkets is desirable in order to make empirical result of the studies more sensible and applicable.

A caution, though. The intention of this study was not to test the suggested options; rather, theoretical ground for these policy options has been sought. This study confirms the theoretical superiority of the hybrid alternative over all the other policy options listed in the literature. Therefore, with the confidence obtained from literature review on hybrid approaches, extended quantitative studies are required before the current management system adopts new policy options.

## BIBLIOGRAPHY

- Agnew, C.E. (1979), Dunn, D.A., Gould, R.G. and Stibolt, R.D., *Economic Techniques for Spectrum Management*, Princeton, New Jersey: Mathtech, Inc., December 1979.
- Agnew, C.E. (1981), *Alternative Licensing Arrangements and Spectrum Economics: The Case of Multipoint Distribution Service*, Stanford California: Stanford University, 1981.
- Ahmed, S.H. (1977), "Spectrum Management in Canada" in the *Telecommunication Journal*, vol. 44, No. 3, Geneva, Switzerland: International Telecommunications Union, 1977 (pp. 130-136).
- Bellchambers, W.H. (1983), "Regulation and Utilization of Radio Spectrum for Mobile Services" prepared for the *Second International Conference on Radio Spectrum Conservation Techniques*, in Birmingham, England, September 6-8, 1983.
- Bish, R.L. (1984), "Improving Productivity in the Government Sector" in *Responses to Economic Change*, Toronto, Buffalo and London: University of Toronto Press, 1984 (pp. 203-237).
- Bish, R.L. (1986), *Local Government in British Columbia*, Victoria, British Columbia: University of Victoria, 1986.
- Canadian Radio Technical Planning Board (1971), *Re-appraisal of the Present Management of the Radio Spectrum*, Ottawa, Canada: Information Canada, 1971.
- Coase, R.H. (1959), "The Federal Communications Commission", in the *Journal of Law and Economics*, vol. 2, Chicago, Illinois: The University of Chicago Law School, October 1959 (pp. 1-40).
- Coase, R.H. (1965), "Evaluation of Public Policy Relating to Radio and Television Broadcasting: Social and Economic Issues" in *Land Economics*, vol. 41, no. 2, Chicago, Illinois: The University of Chicago, May 1965 (pp. 161-166).
- Committee on Telecommunications (1970), *The Application of Social and Economic Value to Spectrum Management*, Washington, DC: National Academy of Engineering, June 1970.
- CSP International (1987), *Deregulation of the Radio Spectrum in the UK*, London, England: Her Majesty's Stationery Office, 1987.

- Department of Communications (s.d.1), *The Spectrum/ Le Spectre*, Ottawa, Canada: Minister of Supply and Services Canada.
- Department of Communications (s.d.2), *International Conferences on Spectrum Regulation: The Canadian Presence in Perspective*, Ottawa, Canada: Minister of Supply and Services Canada.
- Department of Communications (s.d.3), *A Radiocommunications Perspective*, prepared for a Briefing Session to Municipal Planners.
- Department of Communications (1979), *Canada and the 1979 World Administrative Radio Conference*, Ottawa, Canada: Minister of Supply and Services Canada, 1979.
- Department of Communications (1980), *Radio Inspectors Manual of Instructions: RIM-1-1 Consolidation of Legislation and Regulations Concerning Telecommunications*, Third Edition, Part 1 and 2, Ottawa, Canada: Telecommunication Regulatory Service, January 1980.
- Department of Communications (1985), *Policy Manual: Third Edition*, Ottawa, Canada: Telecommunication Regulatory Service, August 1985.
- Department of Communications (1986a), *Table of Frequency Allocations: 9 kHz to 275 GHz*, Ottawa, Canada: Minister of Supply and Services Canada 1986.
- Department of Communications (1986b), *Canada, World Leader in Spectrum Management*, Ottawa, Canada: Minister of Supply and Services Canada, 1986.
- Department of Communications (1987), *Communications Annual Report: 1985-1986*, Ottawa, Canada: Minister of Supply and Services, 1987.
- DeVany, A.S. (1980), Eckert, R.D., Meyers, C.J., O'Hara, D.J. and Scott, R.C., *A Property System Approach to the Electromagnetic Spectrum: A Legal-Economic-Engineering Study*, San Francisco, California: CATO Institute, 1980.
- Due, John F. (1968), *Government Finance: Economics of the Public Sector*, Homewood, Illinois: Richard D. Irwin inc., 1968.
- Eden, D. (1984), "Radio Regulatory Aspects" prepared for the *I.E.E. Vacation School on Satellite Communication System Planning* in Guildford, England, September 2-7, 1984.
- Elliott, A.R. (1970), Liefeld, J.P. and Spence, R.J., *Spectrum Management: An Integrated Model of Management Alternatives and Their Economic Implications*, Hamilton, Ontario: Centre for Applied Research and Engineering Design Incorporated, July 1970.
- Felker, A.D. (1985) and Kwerel, E., *Using Auctions to Select FCC Licensees*, Washington, DC: Federal Communications Commission, Office of Plans and Policy, May 1985.
- Friedman, L.S. (1984), *Microeconomic Policy Analysis*, New York: McGraw-Hill Book Company, 1984.



- Fuss, M. (1987) and McFadden, D., *Production Economics: A Dual Approach To Theory and Application*, New York, North Holland, 1987.
- Goldin, H.H. (1965), "Discussion of Evaluation of Public Policy Relating to Radio and Television Broadcasting: Social and Economic Issues" in *Land Economics*, vol. 41, no. 2, Chicago, Illinois: The University of Chicago, May 1965 (pp. 167-168).
- Government of Canada (1986), *Main Estimates, Part III, 1986-87*, Ottawa, Canada: Minister of Supply and Services Canada, 1986.
- Green, J.R. (1979) and Laffont, J.J., *Incentives in Public Decision Making*, New York, North Holland, 1979.
- Laffont, J.J. (1988), *Fundamentals of Public Economics*, Cambridge, Massachusetts: MIT Press, 1988.
- Levin, H.J. (1966), "New Technology and the Old Regulation in Radio Spectrum Management" in the *American Economic Review*, Hempstead, New York: Hofstra University, May 1966 (pp. 339-357).
- Levin, H.J. (1968), "The Radio Spectrum Resource" in *The Journal of Law and Economics*, vol. XI, Chicago, Illinois: The University of Chicago Law School, October 1968 (pp. 433-501).
- Levin, H.J. (1969), "There is Always a Substitute for Spectrum" in the *Telecommunications Journal*, vol. 36, no. 1, Hempstead, New York: Hofstra University, 1969 (pp. 33-35).
- Levin, H.J. (1970), "Spectrum Allocation Without Market" in the *American Economic Review*, Hempstead, New York: Hofstra University, May 1970 (pp. 209-224).
- Levin, H.J. (1971), *The Invisible Resource: Use and Regulation of the Radio Spectrum*, Baltimore and London: Johns Hopkins Press, 1971.
- Manski, C.F. (1981) and McFadden, D., *Structural Analysis of Discrete Data with Econometric Application*, Cambridge, Massachusetts: MIT Press, 1981.
- McManus, J. (1973), *An Economic Analysis of Alternative Methods of Allocating the Radio Spectrum*, Ottawa, Ontario: Carleton University, January 1973.
- Meckling, W.H. (1968), "Management of the Frequency Spectrum" in the *Washington University Law Quarterly*, Washington DC: Resources for the Future Inc. and the Brookings Institution, Winter 1968 (pp. 26-34).
- Melody, W.H. (1978) and Smythe, D.W., *Opportunity Cost and Radio Spectrum Allocation*, Burnaby, British Columbia: Simon Fraser University, 1978.
- Melody, W.H. (1979), Smythe, D.W. and Oliver, A., *Economic Analysis and Radio Spectrum Licence Fees: The Microwave Band*, Burnaby, British Columbia: Simon Fraser University, March 1979.

- Melody, W.H. (1980), *The Level and Structure of Licence Fees in the Microwave Band*, Burnaby, British Columbia: Simon Fraser University, March 1980.
- Melody, W.H. (1983) and Wedemeyer, D.J., "Economics of Spectrum Allocation" prepared for the *Pacific Telecommunications Conference* held January 16-19, 1983.
- Melody, W.H. (1985) and Smythe, D.W., *Factors Affecting the Canadian and U.S. Spectrum Management Processes*, Burnaby, British Columbia: Simon Fraser University, March 1985.
- Nieduszynski, A.J. (1986), "Regulation of the Radio Spectrum" in the *Journal of Institutional Electronic and Radio Engineering*, vol. 56, no. 4, London: Radio Regulatory Division, Department of Trade and Industry, April 1986 (pp. 139-141).
- Nutter, W.G. (1968), "The Coase Theorem on Social Cost: A Footnote" in *The Journal of Law and Economics*, Chicago, Illinois: The University of Chicago Law School, October 1968 (pp. 503-507).
- Olms, K. (1985), "Radio Frequency Spectrum Management" prepared for *Electromagnetic Compatibility 1985*, Zurich, Switzerland: Sixth Symposium and Technical Exhibition, March 5-7, 1985.
- Owen, B.M. (1972), *Spectrum Allocation: A Survey of Alternative Methodologies*, Washington, DC: Office of Telecommunications Policy Report, April 1972.
- Parlow, R.D. (1985), "Management of the Radio Spectrum to Achieve More Efficient Utilization, Access and Network Growth" in *Telematics and Informatics* vol.2, no. 1, 1985 (pp. 47-54).
- Perrakis, S. (1978), Silva-Echenique, J. and Zerbinis, J., *The Economic Value of the Spectrum Resource in Broadcasting and Land Mobiles*, Ottawa, Ontario: University of Ottawa, March 1978.
- Promex Communications Inc. (1986), "Radio Frequency Spectrum" in *First Choice Canada*, vol. 5, no. 1, January 1986 (pp. 44-46).
- Reams, D. (1984), "Regulation and Competition in Cellular Radio" in *Telephony*, vol. 206, no. 7, Chicago Illinois: Telephony Publishing Corp., February 1984.
- Robinson, J.O. (1976), *An Investigation of Economic Factors in FCC Spectrum Management*, Washington, DC: Federal Communications Commission, Office of Plans and Policy, August 1976.
- Robinson, J.O. (1985), *Spectrum Management Policy in the United States: An Historical Account*, Washington, DC: Federal Communications Commission, Office of Plans and Policy, April 1985.
- Rudd, D. (1986), "A Renting System for Radio Spectrum?" *IEE Proceedings*, vol 133, Pt. A, No. 1, London, England: Department of Transport, 1986 (pp. 58-64).

- Segal, B. (1980), *The 1979 World Administrative Radio Conference: International Negotiations and Canadian Telecommunications Policy*, Ottawa, Canada: Minister of Supply and Services Canada, 1980.
- Small, R.T. (1982), *A Comparison of Alternative Spectrum Regulatory Approaches*, Washington, DC: Federal Communications Commission, Office of Science and Technology, September 1982.
- Solomon, A.E. (1987a), *The Role and Services of the Regional Spectrum Services Centre*, Acton, Ontario: Department of Communications, February 1987.
- Solomon, A.E. (1987b), *Department of Communications Ontario Region District Office Familiarization Course*, Kitchener, Ontario: Department of Communications, February 1987.
- Stibolt, R.D. (1979), *Economic Aspects of Spectrum Management*, Stanford, California: Stanford University, October 1979.
- Task Force on Program Review (1986), "Federal Communications Regulation" in *Management of Government: Regulatory Programs*, Ottawa, Canada: Minister of Supply and Services Canada, May 1986.
- Trans-Canada Telephone System (1970), *Economic Aspects of Frequency Spectrum Management*, Ottawa, Canada: Submitted to the Telecommission for Study No. 2(c), June 1970.
- Varian, H.R. (1984), *Microeconomic Analysis*, New York: Norton and Company, 1984.
- Webbink, D.W. (1980), *Frequency Spectrum Deregulation Alternatives*, Washington, DC: Federal Communications Commission, Office of Plans and Policy, October 1980.
- Woodward, J.P. (1980), *A Market Pricing Method for Spectrum Allocation*, Monterey, California: Naval Postgraduate School, March 1980



94519

--Radio frequency spectrum  
management program evaluation :  
economic nature of the spectrum...

HE  
8679  
C2  
L49  
1989

DATE DUE

NOV 19 1995

[illegible]

