OPPORTUNITY COST AND RADIO SPECTRUM ALLOCATION

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A STUDY OF THE FEASIBILITY OF APPLYING THE OPPORTUNITY COST CONCEPT TO THE SPECTRUM ALLOCATION PROCESS

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I. INTRODUCTION

The first international radio conference was held in Berlin in 1906 to allocate radio frequencies between 500 and 1500 kHz. Since that time the demand for radio spectrum has increased exponentially. The international and domestic allocation of portions of the spectrum to different uses and the assignment of specific frequencies to different users historically has been an administrative process. The radio spectrum has been recognized as a scarce natural resource that is subject to administrative allocation by national government and international agencies rather than economic allocation by private markets.

As demands for increasing use of the spectrum have grown dramatically over time, the economic value of major portions of the spectrum also has increased dramatically. In turn, the problems and costs of congestion and interference have increased significantly. Evidence has been uncovered demonstrating the inefficient use of portions of the spectrum as measured in traditional economic terms. An administrative process that allocates valuable spectrum without charging a "price" to users has come to be recognized as one that provides incentives to promote the wasteful use of the spectrum resource and to encourage uneconomic stockpiling of spectrum licenses.

For more than a decade, professional journal articles, studies and reports, in the U.S. and Canada have addressed various aspects of the problem of recognizing economic factors in the process of allocating the radio spectrum. The issue was discussed in the U.S. in the 1968 President's Task

Force on Communications Policy. It was discussed in Canada in Instant World, 1971. Most recently, it was discussed in the 1977 Options Papers of the U.S. House Sub-Committee on Communications as part of its reconsideration of the 1934 Communications Act.

Because congestion is greater in the U.S. than in Canada the problem has been addressed in more detail and depth over a longer period of time in the U.S. than in Canada, but the problems for Canada remain essentially the same. Canada's spectrum allocations are influenced significantly by U.S. developments because the same spectrum problems generally arise first in the U.S., and the close proximity of the two countries requires close coordination and cooperation in spectrum management. In addition, published information about the criteria and functioning of the process of spectrum allocation is vastly greater in the U.S. than in Canada. Thus, one finds the vast majority of the relevant material on the subject drawn from the U.S. situation, while many of the fundamental workings of the spectrum allocation process in Canada are not publically accessible.

Suggestions for modifying the existing administrative process of spectrum allocation range from the incorporation of economic criteria into the administrative allocation process to the substitution of private market allocations for the administrative process. Among these suggestions has been adoption of the concept of "opportunity cost" from economic theory as a basis for improving the efficiency of allocation of the spectrum resource.

Although approximation of the concept of opportunity cost, at least in theory, could be incorporated into administrative decisions, opportunity cost refers to opportunities in a private market place. Thus, opportunity cost must be examined, at least initially, as part of a system of spectrum allocation that relies on market forces. As a secondary application, one can examine the possible role of opportunity cost approximations in a modified administrative process. It is the objective of this paper to examine the feasibility of incorporating opportunity costs into the processes of spectrum allocation, either directly through private markets or indirectly by adjustments to the existing process of administrative allocation. As a preliminary examination of this question, this study makes no attempt to test empirically the operational feasibility of any alternatives examined here. Nor does this study attempt to pursue the details of the spectrum allocation process in Canada necessary for an examination of the specific operational feasibility of opportunity cost and other economic concepts.

This study reviews the existing literature, studies and proposals in the U.S. and Canada relating to possible modifications in the allocation process to incorporate opportunity costs or other economic criteria. This review is based upon a recognition of the evolving technical characteristics of spectrum usage and the history of the allocation process. It recognizes that the current interest in incorporating specific economic factors into the spectrum allocation process is a uniquely North American phenomenon. For the most part, most countries and international agencies involved in the allocation process have been either indifferent or hostile to such considerations. It also recognizes that the existing literature, studies and proposals relating to opportunity cost refer, for the most part, to the U.S. experience. This preliminary investigation is addressed primarily to a critical review and assessment of that material in terms of its relevance and potential applicability to the spectrum allocation and assignment process in Canada.

The concept of opportunity cost from neoclassical economic theory is reviewed in terms of its applicability and potential feasibility in the allocation process. Proposals to incorporate economic criteria into the spectrum allocation process are examined. Suggestions for more detailed research and analysis are made.

II. HISTORY OF THE ALLOCATION PROCESS

A. The Radiomagnetic Spectrum and the Process of Spectrum Allocation

The radiomagnetic spectrum consists of the frequencies of electromagnetic radiation lying between approximately 10,000 and 100,000,000,000 cycles per second. This radiation is a form of energy (analogous to light and heat) which can be transmitted through space or air. It travels at the speed of light. It is essential to realize that electromagnetic radiation is not a discrete quantity with measureable dimensions of space or time. It is a flow from its source of successive waves of energy. The radiomagnetic spectrum is the range of wave lengths of which such radiation consists. It is a unique natural resource which over the past 80 years has provided all wireless or radio communications.

As a natural resource it has a number of unique characteristics, all of them contradictions. As a resource which human beings use, human rights to its use have grown as its use has grown. It is thus a form of "property", but contradictorily it has not been treated as susceptible of being made "private" property. The essence of private property is the right to deny others the right to use something. But one's right to use the radio spectrum

imposes the obligation to use it in such a manner as to permit others to use it simultaneously. This was vividly exemplified during World War II when the warring powers continued to respect each others' rights to use the radio spectrum, and continued to notify the Berne Bureau of frequency registrations. From the first international conference on the radio spectrum (1906) onwards, no nation has asserted on behalf of itself or its citizens any right to "ownership" of the radio spectrum. Instead, "title" to the spectrum remains international social property in law. This is because, the physical character of the electromagnetic spectrum is different from other resources. Whereas rights to land, water and air are all measureable in three finite dimensions, the radio spectrum is not. Land, water and air consist of matter; the radio spectrum consists of the behaviour of energy, which moves in ways measurable ultimately in terms of probabilities. It is non-finite, and non-discrete.

A second striking contradictory aspect of the radio spectrum as a natural resource is the fact that it is not susceptible of depletion through use as are land, water and air; rather it is self-renewing. The use of the radio spectrum creates "interference" which might be thought of as "pollution" of the radio spectrum. It differs from pollution of the land, water and air, however, in that when the cause of the interference is removed, the qualities of the radio spectrum are immediately restored to their pristine condition. Moreover, this "interference" is not a side-effect of efforts to use the radio spectrum as is often the fact with pollution of land, water or air: it is the inescapable result of our increasing use of the radio spectrum. It is one form of social cost that society pays for the benefits which that use creates. And it is precisely the purpose of radio spectrum management to reduce and control that cost in order to

optimize the results of that use.

A third contradiction exists between the impossibility of owning the rights to use the radio spectrum on the one hand 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 lies very intimately with sovereignty. High national diplomatic purposes explain why foreign offices of major nation states will always control national policy on radio frequency allocation. This contradictory aspect of radio frequency allocation is a factor barring scope for market forces in spectrum management which is generally ignored by economists who promote market forces.

For present purposes, it is not necessary to spell out in any detail the breadth and depth of effects of the use of the radio spectrum in economic, political, social and cultural terms. All of the literature on TV and radio broadcasting, on communications satellites, on space programs (for every controlled object lofted into outer space is a form of communication satellite), on communications hardware of the military and intelligence communities, on computer science, on telephony, on cable TV, on "CB" radio and all applications of radio for public safety -- attests to the scope and extent to which advanced western countries have used the radio spectrum.

In simplest terms, spectrum management is a process of three mutually-determining steps. The most significant step is the determination that specific classes of use should be made of sub-sections (bands) of the spectrum resource according to specific engineering standards. Where possible these world standards are loose enough to permit variations between regions (which is why standards for TV broadcast have varied within Europe and as between Europe and North America). The second step is the determination for a given frequency band and a given class of users of the geographic locations of transmitters in light of the engineering standards to be used in a region or nation. For example, the assignment of TV stations to particular cities.. And the third step is the determination of the identity of the licensee who will use the specific location for a transmitter in a given class of service, operating according to specific standards.

The International Telecommunications Union (ITU) is a specialized agency of the United Nations which provides for international spectrum allocations. World Administrative Radio Conferences (WARC) involving the member countries of ITU, perform the international allocation function. The international assignments are made by the WARC, or more frequently by the member nations directly affected. International notification is provided through the

International Frequency Registration Board (IFRB). In addition, Canada has bilateral agreements with the U.S. for notification of spectrum use.

The ITU allocation decisions made at WARC's are implemented by International Radio Regulations. These regulations specify the permissible services and uses of the different radio bands, provide technical rules for particular services and establish arrangements for international notification and discussion of spectrum use. The radio regulations provides specific, detailed restraints for services that are international in character, e.g., satellite systems and aeronautical radio. They place few, if any, restraints on radio users that are solely domestic.

As a predicate for our analysis of the applicability of opportunity cost to the management of the electromagnetic spectrum, it is necessary to recognize the questions about the nature of the present problems in such management. In Canada, proximity to the United States raises policy problems in radio spectrum management caused by such proximity as well as policy problems arising from our domestic situation. Because, for a variety of reasons, radio spectrum problems arising in the United States are immediately and directly experienced in Canada, it is necessary for Canada to take account of and seek to anticipate the development of such problems in the United States. In the U.S. severe congestion has developed in two areas: (1) Land Mobile radio services and Public Safety services, and (2) the interface between satellite frequencies and terrestrial microwave services. And whatever solutions are found for these congestion problems in the United States will present repercussions immediately for Canada.

Canada's indigenous domestic problems were summarized in Instant World (1971) as follows and may represent our present problems:

1. prevention/control of man-made noise (other than from telecommunications equipment) below 500 MHz;
2. congestion in the Land Mobile services, especially at 150 MHz;
3. congestion in the microwave relay bands around major cities;
4. congestion in power line carrier frequencies in some areas;
5. congestion in maritime bands on the west coast, and
6. problems of sharing terrestrial and space frequencies. (p. 132-3)

Common to the U.S. and Canada are rigidities associated with national "block allocations," although Canada's allocation table is said to be more flexible than that of the United States. Other problems surfacing acutely elsewhere in the world will be thrust on the U.S. and Canada at WARC 1979, as noted below.

Before analyzing the reasons for these problems, a further necessary predicate is a general consideration of the "problem" of "scarcity" and "congestion" in radio frequency spectrum management. "Scarcity" is a term tied to resources with finite, discrete units. In order to avoid the confusion caused by the implications of "scarcity" it is preferable to speak of "limits" in the radio spectrum. And limits are of two kinds; those at the extensive frontier of radio spectrum R. and D., and those at its intensive margin (where all man-made interference and noise exist). W.R. Hinchman states:

> "It is important to note, however, that any number of users may radiate radio energy of identical frequency characteristics simultaneously; the radiation of such energy does not deplete the spectrum to render another use impossible. It is the interaction of incompatible uses, not physical scarcity, which may destroy or limit effective use of the spectrum.... By intensive spectrum use, we refer to the simultaneous compatible use of the same spectrum resources by more than one party; as contrasted with extensive spectrum use, which means use of

hitherto completely unused spectrum resources." 1/

The basis of the present limits on the use of the radio spectrum is: (1) willingness to apply R. and D. to permit more intensive use of the spectrum, and to explore the extensive margin (presently between 20 and 90 GHz); (2) willingness to develop and enforce discipline to develop and work cooperatively in maximizing compatible uses of the spectrum (at the intensive margin), and to accept the necessary obsolescence involved in innovating new uses and classes of users in spectrum ranges previously occupied by obsolete equipment and practices. As Hinchman observes:

> "The latent communications capacity of the spectrum far exceeds any projected demand, if one is interested in paying the price or imposing technical standards which extract the price from the user." 2/

In short, the ultimate limits on radio spectrum development and use are political and economic, rather than technical.

B. The Canadian and U.S. Heritage: What are the Allocations; Who Uses the Spectrum and How?

There is a high correlation between industrial development and use of the radio spectrum. The nations which first developed electrical, electronic, and other industry on a mass basis have made most use of the radio spectrum. The United States, Britain, France, Germany, Netherlands, and Canada have made the greatest investments in radio spectrum equipments and have led in developing the spectrum. And from 1906 on at a series of plenipotentiary international

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1/ Staff Paper Seven, The Use and Management of the Electromagnetic Spectrum, Part 1, President's Task Force on Communications Policy, Washington, D.C., June 1969, PB 184 421,, p. 73-5. Emphasis added.

2/ Ibid., p. 78.

conferences they have dominated the development of radio frequency allocation on a world scale, focussed on the International Telecommunications Union.

The process includes three interactive and mutually determining stages: (1) The identification of types of use of the radio spectrum (e.g., radio broadcasting, marine, fixed public, etc.) and determination of standards (types of modulation, bandwidth) which are applicable to both transmitting and receiving equipment. (2) Assignment of segments (containing frequency bands) of the spectrum to each of dozens of classes of users, and determination of the geographic locations at which transmitting stations may be established, taking account of the application of standards established under (1). This latter phase of stage (2) yields "frequency assignments" -- locations at which some licensees may be authorized under stage (3). (3) Licensing of individual transmitters to specific users. While ITU regulations are world-wide in scope, it was early recognized that minor differences in standards and definitions of band allocations were justified as between major regions of the world, and three such regions exist. (Region 1. Europe, plus Africa, Asiatic USSR and Near East; Region 2. The Americas; Region 3. Asia, Australia, New Zealand and Oceania). Either by regional international agreements or agreements between user groups or both, the three stages referred to above are given more precise expression appropriate to the conditions and needs within the regions. The nation states are the repositories of the function of further refinement of standards, allocation of bands to user groups, the determination of geographic locations where transmitters may be authorized, and the ultimate step of licensing the actual users of the frequency assignment. They also hold the political and economic power which such national frequency management confers. In this context, we turn to the question of who uses the spectrum.

The mere fact of United States industrial power makes it necessary to answer the question of who uses the spectrum in Canada in terms of the answer for both the United States and Canada. In both nations the table of frequency allocations runs from 10 KHz upward. In the United States, below 30 MHz government and non-government users share the frequency spectrum approximately equally. From 30 MHz to 1,000 MHz the government users have exclusive use of 28.6% and share 8.2% with non-government users (who exclusively use 63.2%). In that region of the spectrum 53% of the spectrum is devoted to broadcasting (mostly TV), while Land Mobile has 4.4%. From 1,000 MHz to 10,000 MHz the government has exclusive use of 39% and shared use of 32.3%, while non-government uses have exclusive use of 28.7%. Above 10,000 MHz the uses are chiefly experimental on the part of government and non-government uses. 3/

Overall, the U.S. Federal government is the largest single user of the radio spectrum based on the investment in equipment and amount of spectrum space. In 1968 32 percent of the spectrum space between 30 and 10,000 MHz was allocated for Federal government use exclusively, with a further 46 percent for shared use with non-government users. The U.S. military uses 57% of all government spectrum assignments. In addition, more than 28 other federal departments and agencies use the spectrum. Some 118,000 frequency assignments ("stations") were licensed to Federal government at the end of 1967. At that time the Office of Telecommunications Management stated that the then depreciated

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3/ Ibid., p. 36, and Appendix B, Figure D-9. Data are as of 1968.

investment in spectrum-dependent equipment owned by the Federal government was $20.5 billion, as compared to $18 billion for non-federal government users. Further that annual purchases of such equipment had a factory sales value of $13.4 billion for the Federal government and $13.6 billion for non-Federal government users. 4/

Information is lacking with respect to profitability of the users of the radio spectrum, as well as more recent information on spectrum related investment and sales in the United States. Similarly data are lacking on developments concerning allocation decisions of the FCC following 1968.

The Canadian frequency allocation table bears a strong resemblance to that of the United States. When one recalls that the majority of the Canadian population lives within 200 miles of the U.S. border, the fact that Canada and the U.S. have an agreement which governs the frequency assignments of TV stations up to 250 miles from the border reveals Canada's dependence on the U.S. allocation plan. Other similar agreements between the two countries restrict Canadian discretion according to the frequencies and services involved at various distances from the border.

4/ A further non-spectrum-dependent investment (depreciated) by the Federal Government in electronic products was $28.7 billion and of non-Federal government users, $25.1 billion. For both Federal and non-Federal users, the spectrum dependent investment does not include value of antennas, buildings, land, etc. necessary to operate electronic communication systems. Office of Telecommunications Management, The Radio Frequency Spectrum: United States Use and Management, Appendix B, Ibid., September, 1968, p. F-6.

At the end of 1976 Canada had 515,222 radio stations licensed, of which the "General Radio Service" (including CB) accounted for 210,571. Information is not readily available from which one can analyze the Canadian table of allocations. In part this stems from the fact that Canada has no counterpart to the Administrative Procedures Act in the U.S., which requires the FCC to hold a public rule-making proceeding in matters like spectrum allocation. Such a proceeding permits all to become informed about the relevant situation. More time would be required than is presently available in which to assess the extent to which Canada has any discretion in the basic elements of radio frequency allocation, e.g. dealing in terms of its own interest with definitions of classes of users, the bands of frequencies assigned to them, and the pertinent engineering standards. Accordingly we are unable at this time to answer such questions as e.g., how much of spectrum space is assigned to the government and non-government users? How much of the former is assigned to the Canadian military? How much to the American military in Canada?

C. Criteria for Allocation: Administrative and Economic Factors

In all nations the management of the radio spectrum is tightly controlled by national governments -- the U.S. and Canada, especially the former, being by far the most open to public knowledge. In the United Kingdom, for example, the table of allocations is not public information, nor is the basis of frequency allocation policy. The organization for the management of the spectrum is the most significant aspect of spectrum management policy. In the United States it is quite visible, having been the object of many published

studies. The very substantial amount of frequency space used by the Federal Government is managed by the Office of Telecommunications Policy in the Executive Offices of the President. It uses the Interdepartmental Radio Advisory Committee (IRAC) -- representing the Federal agency users of the spectrum -- for the coordination of requests for frequency assignments and the enforcement of standards and allocation policy. It processed some 35,000 applications a year with the aid of a 38-man technical staff in DTM (1968), though benefitting from the technical expertise of assorted agency staffs (the military, the National Bureau of Standards, the FCC).

For non-Federal government users, the FCC has been the spectrum manager, aided by the Joint Technical Advisory Board (representing industry trade associations and the IEEE). A significant contradiction is imbedded in the U.S. Federal government's organization for spectrum management. If and when the FCC and IRAC disagree on an issue there is no organizational means of resolving the issue short of appeal to the President in person: the DTM has no such power. For decades this contradiction has plagued the radio spectrum managers in the U.S. and recommendations that a single radio spectrum manager be created have peaked recently in urgent proposals to this end. 5/ Nevertheless there is a powerful centralizing tendency evident even under existing organizational arragements. The position to be taken at ITU conferences is determined by the FCC, the DTM and the Department of State and is treated as a matter of prime diplomatic importance. The incongruity of the relatively decentralized organization and the importance of radio spectrum policy is high-lighted by Hinchman:

5/ See Report of the President's Task Force on Communications Policy and the Hinchman staff report cited above.

> "The lack of sufficient staff and funding is a frequent complaint in administering agencies, and is therefore generally viewed with skepticism. In the base of spectrum management, however, the situation does indeed appear incongruous. As noted, this is the one resource over which the Federal Government has maintained--and for technical and social reasons must continue to maintain --virtually absolute control of allocation and use. Thus, decisions taken by spectrum management authorities have far-reaching consequences for a telecommunications complex which now contributes over $20 billion annually to the GNP, which affects the social, political and economic well-being of virtually every citizen; and which is a vital element in our national security." 6/

It is not possible in this research effort to ascertain the analogous information about the organization of government and non-government spectrum management in Canada. Public awareness does not extend, for instance: to the merits or demerits of whatever changes were made in Canadian spectrum management organization when that function was transferred from the Department of Transport to the Department of Communications; to how the military and non-military government spectrum organized; to how disputes are resolved between claimants in the non-government sector and those in the government sector; to how the Canadian position to be taken at ITU conferences is arrived at?

What is the procedure for determining the allocation of bands of frequencies to classes of users (including engineering standards for transmitting and receiving equipment)? In the United States the procedure has a significant formal character. As indicated above, the FCC conducts public, formal rule making hearings at which all aspects of the issues may be explored. For government users the procedure is similar except that it is not as formal and is not open to the public.

6/ Hinchman, sup. cit., p. 108-9. Emphasis added.

The essence of the procedure, however, is approximately as follows. The issues involved have been:

(a) Whether the service in question really requires the use of radio or whether wire line is a practical substitute;

(b) Radio services which are necessary for safety of life and property deserve more consideration than those which are more in the nature of conveniences or luxuries;

(c) Where other factors are equal, the Commission attempts to meet the requests of those services which will render benefits to the largest segment of the population;

(d) Where the service meets a substantial public need and has a reasonable probability of being established on a viable basis;

(e) Consideration of the most suitable place in the spectrum to satisfy the requirements of each particular service;

(f) Consideration of industry and public investment already committed to a particular frequency band. 7/

It is termed an "administrative" rather than an "economic" set of issues. It is also intensely a political and pressure-group exercise. The "market" only enters into it through the fact that the industrial organizations which have developed the necessary equipments and are interested in supplying or operating them are typically oligopolistic large scale corporations, typically organized in a trade association which vigorously supports their economic interest.

7/ Robinson, J.O., "Spectrum Allocation and Economic Factors in FCC Spectrum Management," IEEE Transactions on Electromagnetic Compatibility, Vol. EMC - 19, No. 3, August, 1977, p. 185.

D. Problems and Difficulties: Past, Present and Future

The most serious problem today as presented by the electronics industry and spectrum managers, is that the existing national block frequency allocations are too rigid. They make insufficient provision for frequency assignments in some of the Land Mobile services, while other Land Mobile services have unused frequency assignments and while potential frequency assignments which could be transferred to them remain unused in the VHF and UHF TV bands. "Congestion" (1958), "extreme congestion" (1962), "acute frequency shortage" (1964) are the terms in which the FCC evaluated the plight of the Land Mobile and CB services. The number of Land Mobile stations trebled between 1957 and 1967, while CB grew from 28,000 systems to 850,000. Together these two classes accounted for 90 percent of all transmitters (6 million) in the United States in 1968. In addition there are problems of accomodating satellite service with terrestrial services, particularly microwave relay in the spectrum above 1 GHz.

The prolonged debate about the "Silent Crisis" as it is sometimes known, has for the first time attracted much attention from academic economists, indirectly stimulated by the participation of RAND economists in studies of the economic aspects of communications satellites in the early 1960s. The thrust of the economists' argument has been that "market forces" should be introduced into the process of allocating the radio spectrum. Their hardest position is that outright private property rights should be staked out in the radio spectrum. Failing this, then "shadow prices" or "auctions" should be melded into the "administrative" process of radio frequency allocation. The President's Task Force on Communications Policy in the late 1960s gave

guarded encouragement to further exploration of the possibilities of introducing some "economizing" elements into the decision-making in radio spectrum management. There has been a spate of literature in the economics journals, and a number of conferences directed toward this objective.

In Canada, according to Instant World the problems of congestion are not as severe as in the United States, but it was acknowledged that the "national block" allocation process was too rigid. And Instant World followed the United States lead in endorsing the re-examination of the process of spectrum management to determine if economic factors might not be incorporated in it. This is the perspective on the genesis of the problem to which this report is addressed, looked at from the standpoint of the interests of Canada and the United States in changing the process and the results of radio frequency allocation.

But the critical examination of radio frequency allocation must be kept in a broad, historical perspective. The 1979 WARC will be the first general review of radio frequency allocation at the world level since 1959. In that 20 year period there has been much technical progress in capability and need to change the concepts and methods used in radio spectrum management at both the intensive and extensive margins of spectrum use (e.g. roughly below and above 1 GHz). It is necessary to recall that this has happened principally because of the R. & D. applied in the interest of the "Space Race," with the "ripple" effects of applications for civilian uses (e.g. the Land Mobile Services). High on the agenda of WARC are three problem areas: (1) Pressures (presumably most urgently expressed by nations other than the U.S. and Canada)

for changes in the HF region (increased spectrum space for maritime and international broadcasting, and reduction of spectrum space for the fixed point to point service). (2) The struggle between Land Mobile and TV broadcasting services in the VHF and UHF regions. (3) The struggle above 1 GHz between the rapidly growing fixed satellite service (both international and domestic) and microwave radio relay service, space research, earth exploration satellite services and radio astronomy. [8] The preparations for WARC in the major powers follow a scenario which began as early as 1974 in the U.S. (with the creation of the structure of coordinating committees known as "Ad Hoc 144" by IRAC, and with Docket 20271 by the FCC in 1976). The schedule procedurally which will eventuate in September, 1979 at WARC, testifies to the intense national political concern with Spectrum Management.

Third World nations have begun to assert their political interests in the issues in unprecedented ways. Of the 153 member nations of ITU, 85 are nonaligned or developing nations. [9] Their point of view was articulated at the 1977 World Administrative Radio Conference on Broadcasting Satellites (WARC-BS) where detailed and specific agreements produced:

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[8] Probst, S.E., "International and U.S. Preparations for the 1979 World Administrative Radio Conference", IEEE Transactions on Electromagnetic Compatibility. August, 1977, p. 166-170.

[9] Ibid., p. 166.

> "...,a comprehensive plan assigning to administrations in ITU Regions 1 and 3, individual channels (that is, frequencies) and polarizations at specific orbital locations for coverage of prescribed service areas on the ground."10/

As reported in the United States, this result was principally to satisfy

> "...the concern of the developing countries that not enough frequencies and orbital positions would still be available by the time they were ready to launch and use broadcasting satellites". 11/

This decision represents a major change in ITU policy, away from the first-come first-served policy desired (and long practiced) by the Western advanced economies and toward a policy of positive planning. It was taken in face of opposition from the U.S., Canada and Brazil which succeeded in preventing a similar plan for Region 2 from being adopted. If, as seems probable, the more positive planning approach favoured by the developing nations gains further ground at WARC 1979, this would mean

> "...the adoption of similarly structured plans for other services and for other bands. This would mean a significantly more ordered and regulated use of the orbit and spectrum than heretofore." 12/

Broadcast satellites, even at the planning stage, are expressing the world-wide interest of all nations in using their common property, the radio spectrum.

10/ Gould, Richard G. and Reinhart, Edward E., "The 1977 WARC on Broadcasting Satellites: Spectrum Management Aspects and Implications", IEEE Transactions on Electromagnetic Compatibility, August, 1977, p. 171-178, 171.

11/ Ibid., p. 171

12/ Ibid., p. 171.

A preliminary review of the history of radio frequency allocation suggests that the moving force in creating and solving crises in radio frequency allocation has been the waves of activity by nation states and their military and industrial structures expressed in World Wars I and II, and the Cold War. The R. and D. attendant on these wars, it may be hypothesized, generated the crises which compelled the solutions for the crises in radio frequency allocation. Thus it would appear that the radio allocation agreements which solved the crises (in the 1920's, in the late 1940s) represented new plateaus in the application of the art of radio, while simultaneously implicitly establishing planning ceilings (e.g. the National Block allocations of the late 1940s). If this is so, the present crisis represents the pressures on the ceilings built into the planning for spectrum management after World War II.

Extrapolating experience, one would look for a new kit of tools to emerge for conducting radio spectrum management in the next few years and for a new plateau for spectrum development to be created. Prominent amongst these tools will probably be the "next generation" of spectrum engineering proposed by the JTAC report, 13/ and the introduction of license fees on a substantial scale for the joint purpose of (1) introducing economizing pressures on spectrum use, and (2) producing public revenues. The frame of such developing spectrum management policy must be a broad historical process which places the engineering-administrative organization and policy for frequency management in a flexible setting, capable of growth as the future rushes toward us.

13/ Spectrum Engineering--The Key to Progress, Summary and abstract from Joint Technical Advisory Committee, March, 1968, in The Use and Management of the Electromagnetic Spectrum, Part 2, PB 184-422. And see Hinchman report, sup. cit.

III. OPPORTUNITY COST AS A BASIS FOR SPECTRUM ALLOCATION AND ASSIGNMENT

A. The Nature of the Spectrum Efficiency Problem

The problem of spectrum efficiency thus arise because of the failure of the existing spectrum management process to solve certain allocation problems which it is alleged could be solved by economic valuations as part of the process. The existing administrative process does not employ prices as a means of allocating the spectrum resource. The economic principle of market exchange is, in most circumstances, deemed neither feasible nor permitted.

In economic terms, the spectrum tends to become viewed as a "free good". The spectrum resource has economic value. Some portions of the spectrum are enormously valuable in economic terms and promise to increase in value at a substantial rate over the future. This state of affairs can lead to circumstances where the demand for the rights to the spectrum considerably exceed any economical use that might be made of the spectrum.

Any attempt to introduce criteria for economic efficiency into the spectrum allocation process would have to recognize the distinct two-step character of this process. The fundamental allocation problem by which portions of the spectrum are allocated to particular uses and services is essentially the problem of long-run analysis in neo-classical economic theory. These allocations relate to fundamental decisions that are made relatively infrequently but which have a major impact in determining spectrum use. The long-run allocation decision must reflect considerations of planning

for growth in the utilization of various portions of the spectrum as well as improvements in technology. The allocation decisions must be based upon a comparison of a wide diversity of heterogeneous - and not easily comparable - uses and services.

In economic terms the problem of assigning spectrum to users is a problem of intermediate run analysis. Assignments are constrained by the allocation decisions previously made. Assignments are made to particular users in a class of service who are likely to be relatively homogeneous in their use of the spectrum. Thus, comparison among different users is more easily done. However, the assignment process can be for a relatively long period of time depending upon the terms and conditions of the licenses granted.

Once the spectrum allocations and assignments have been made, there remains the short-run economic problem of using the assigned spectrum efficiently. Economic analysis can be brought to bear on all three problems in an attempt to improve the efficiency of the process.

It is not difficult to find examples of apparent inefficiency in the existing system of spectrum allocation. There is congestion in some bands and idle spectrum in others. In some instances, spectrum assignments are "banked" for future use simply because there is no cost involved and competition for the assignment would likely be more severe at a later date. Decisions to use the spectrum are made in the face of substitute technologies (e.g. cable) because the cost of the spectrum is near zero. The design and use of equipment frequently is based on the use of relatively large portions

of the spectrum so as to conserve on material and labor inputs to the equipment manufacturing process which carry very definite economic costs.

Finally under the existing system of administrative allocations, where market exchanges - either direct or indirect - are permitted to take place, the substantial value of the social resource is appropriated by private interests which are in a position to exploit the imperfections in the market place created by the characteristics of the spectrum and the administrative process. For example, commercial broadcast licenses are allocated by administrative decision. Recipients of broadcast licenses generally receive a substantial economic value because of their monopoly right to that spectrum assignment. When the broadcast station and its license are sold in private markets to a new owner, the market price reflects the value of the spectrum resource in a marketplace where active competition is severely restricted.[14/]

In each of the above illustrations, one could claim that recognition of the cost of alternative uses of the spectrum theoretically could lead to a more efficient result. However, one must be careful not to attempt to generalize from isolated examples. It is questionable whether an attempt to implement economic principles would result in improvements in the allocation, assignment and utilization of the spectrum resource. Such a change may improve efficiency in one small area while creating inefficiency in other areas. The system of administrative allocations and assignments came about in North America after the market failed as an efficient allocative device. The question to be addressed is not whether the market or administrative allocations would

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14/ In both Canada and the U.S., the transfer of licenses is subject to approval by the appropriate regulatory authority, the CRTC or the FCC. However, the conditions of the transfer do not include regulatory intervention in determining the transfer prices.

lead to improvements relating to a single problem. Clearly, one can find examples for each. The matter to be examined is whether the adoption of economic criteria and market exchanges are likely to bring about improved efficiency in the entire spectrum allocation system.

B. Existing Administrative Criteria for Allocation

The great difficulty with comparisons between the existing administrative system and a market system is the lack of specified information about the administrative criteria now applied. On the one hand we have an existing administrative system where the criteria for allocation are not specified. On the other hand, the proposed market systems generally are based on ideals that could not possibly be approximated in the marketplace.

A detailed specification of the criteria employed as a basis for spectrum allocation cannot be found in either Canada or the U.S. The closest that can be obtained is that specified by the FCC in its report in Docket 6651, January 15, 1945, and specified at p. 17 above.

Although the FCC did not spell out the manner in which it attempted to operationalize its principles, it is important to note that they did recognize economic considerations. Much of the criticism of the existing administrative process assumes that economic considerations are not a part of this process. Although not specified, we find no reason to believe that economic factors are not a part of the existing administrative process. Economic factors have always played an important role in the allocation judgments of the administrative process. The important point is that the existing administrative criteria are not operationalized in an effective manner and information relating to the operation of this process is substantially deficient.

The major problem that is stimulating concern about the failure of the administrative process in the U.S. relates to spectrum assignments under conditions of competitive applications. At present, this problem delay and costs of hearings is unique to the U.S. system.

In services where licenses are limited, e.g., television broadcasting, radio common carrier services, multipoint distribution service, business radio service, etc., there are frequently competing, mutually exclusive license applications. When mutually exclusive license applications occur, the Commission chooses from among the applicants the one best suited to serve the public interest. Under such conditions, the FCC is required to hold a hearing before it can grant any one of the several mutually exclusive applications.[15/]

As demands for spectrum assignments have increased, and the value of spectrum assignments has also increased, the hearing process has become time consuming, burdensome and expensive. The general vagueness of the administrative criteria for selecting among competing applicants has compounded the problem.

It is as a resolution to this particular problem of administrative regulation by the FCC that many analysts have proposed various market oriented allocation criteria. In these instances, the market solution is proposed not as a basis for improving the efficiency of resource allocation but rather as a basis for eliminating a costly and time consuming process of selection from among competing applicants. Thus, not only have market proposals such as an auction been offered but also a simple lottery as a solution to this

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15/ This is known as the Ashbacker Doctrine. Ashbacker Radio Corp v. Federal Communications Commission, 326 US 327.

problem.[16]

C. Opportunity Cost in Economic Theory

The economic concept of opportunity cost measures the cost of supplying anything in terms of an alternative use that was foregone. The alternative use that is relevant is the "best" alternative available.[17] The best alternative use will depend of course on circumstances. Mishan observes:

> "The opportunity cost of the current use of some good or of some input is its worth in some alternative use...either the definition has reference to the alternative having the highest value for the individual, or else the particular alternative use is determined by the problem." [18]

The major problem in any attempt to measure opportunity cost is selecting the relevant alternative foregone. The best alternative is heavily influenced by the structure of the market. In actively competitive markets, alternatives are substantially different than they are in monopoly markets. Moreover, the alternatives available for short term immediate solutions to problems are substantially different than those available for longer term solutions to problems. Thus, any opportunity cost calculation depends entirely upon the structural conditions of the market and the constraints assumed for the opportunity cost calculation.

In addition, proper interpretation of the opportunity cost concept requires detailed specification of what it is that is being costed as well as

16/Dissenting statement of Commissioner Glen O. Robinson, Cowels Florida Broadcasting Inc. et al, 60 FCC 2d, 435, 442.

17/See Samuelson,P.A,,Economics (Third Canadian Edition, p. 573)

18/Mishan, E.J., Cost - Benefit Analysis, 2nd Edition (1975) p. 65

whose opportunity cost is being measured. The opportunity cost of using a resource for a particular use may differ greatly depending upon whether the opportunity cost is that of the owner or society. The benefit that an individual might receive from transferring a portion of the spectrum resource to another use may be quite different from the benefit to society. In sum, opportunity cost is determined directly by the definition of the problem.

According to neo-classical economic theory, the relevant opportunity cost for economic efficiency is the opportunity cost that would prevail under perfectly competitive market conditions. Theoretical resource allocation efficiency would be optimized under the conditions of "Pareto Optimality." Under conditions of Pareto Optimality, all prices in the economy are set equal to their respective marginal costs, which are the opportunity costs associated with the marginal units of output under conditions of perfect competition. Thus, the relevant opportunity costs are those that satisfy the conditions of Pareto Optimality.

However, Pareto Optimality is not achieved unless there is a simultaneous determination of all prices in the economy at their appropriate marginal costs. If some prices in the economy deviate from their appropriate marginal costs, it cannot be demonstrated that marginal cost pricing in the remainder of the economy will necessarily be optimal, or even closer to optimal than prices set on any other basis.[19/]

19/ R.G. Lipsey and Kelvin Lancaster, "The General Theory of Second Best," Review of Economic Studies (1956), XXIV, 11-32.

Major questions must be raised about the applicability of the opportunity cost concept of neo-classical theory to problems of spectrum allocation in light of the substantial constraining assumptions of the theory. The theory is static and is directed toward determining optimal rules for allocating a fixed amount of resources among competing uses at a particular moment in time. Its relevance and applicability to conditions where the resource is being expanded, oligopoly and monopoly the rule and competition the exception, new technology is being introduced, uncertainty is significant and growth rates are important to reallocation decisions is extremely questionable.

In addition, the term opportunity cost in this context is sufficiently general that the variety of interpretations of its meaning is virtually infinite. To give it a somewhat more specific content, economists traditionally apply further definitional restrictions such as short-run and long-run. But even these terms do not provide restrictions upon the interpretation, selection and valuation of opportunity costs. There are as many opportunity costs as there are conceivable sets of alternatives to be considered, and their values can range from very high to extremely low.[20/]

As a theoretical construct, the opportunity cost concept does not come to grips with the problems created by the continuity and incomplete nature of the firm's activities. Within the framework of neo-classical economic theory, the concept assumes that the decision to be made involves a single complete venture. There are no constraining conditions of past decisions

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20/ Melody, W.H., "The Marginal Utility of Marginal Analysis in Public Policy Formulation," Journal of Economic Issues, June 1974, p. 294 and foreword.

and events that will influence the decision alternatives. The firm is in a completely uncommitted state. Moreover, the evaluation of the alternative decision possibilities reflects all effects through the completion of the activity under consideration. Hence, the framework for decision is closed. At this theoretical level, there is no need for an evaluation of the state of affairs before the effects of the decision are complete. There will be no modification of the decision as reality unfolds.

In the neo-classical model, theoretical optimization can be a very misleading concept. The decision maker is deemed to have optimized if he does what he thinks is best in light of the alternatives that he perceives. But if his best turns out to be in reality an obviously wasteful investment, the decision was still optimal according to the opportunity cost criteria. What is generally more important is the market test of whether management decisions made in an uncertain environment with limited information turned out to be prudent, responsive to consumer demands and tolerably efficient in light of the reality that developed.

In any real world situation, the firm has an infinite variety of opportunity costs, opportunity cost functions and families of opportunity cost functions with values covering a wide range of cost variation. Different opportunity costs can be derived for every pair of alternatives being considered; for every conceivable increment in output; for every difference in the amount and/or structure of inherited capacity; for every difference in the actual planning period employed in the analysis; for every change in the relative proportions of the various services being supplied; for every

different forecast of future events; for every possible and feasible combination of technical inputs, and for every different perception of the timing, location and impact of following an alternative path. In addition, since units of output are far from homogeneous, different opportunity cost functions will be obtained as the dimensions of the output unit are varied.

In the final analysis, it must be recognized that opportunity costs are entirely bound up in the personal judgment of the analyst, the "arbitrary" decisions that he makes in defining the problem, and his changing expectations. Optimists will have quite different opportunity costs than pessimists. Opportunity costs cannot be viewed as facts for which objectively valid values can be known. The opportunity cost values will depend upon who applies the theory and the incentives under which he works in the environment in which it is applied.

We must conclude, as did J.M. Keynes, over thirty years ago, that the neo-classical theory of economics, and the opportunity cost concept that is fundamental to it, is simply not relevant and applicable to a resolution of the problems of spectrum allocation.

> "Our criticism of the accepted classical theory of economics has consisted not so much in finding logical flaws in its analysis as in pointing out that its tacit assumptions are seldom or never satisfied, with the result that it cannot solve the economic problems of the actual world. 21/

21/ J.M. Keynes, The General Theory of Employment, Interest, and Money, (1936) p. 378.

If the opportunity cost concept of neo-classical theory does not provide a demonstrated basis for improving the efficiency of spectrum resource allocation, does the opportunity cost notion provide any practicable guidelines for spectrum management? As a social resource, it must be recognized that the social opportunity cost of the spectrum (however measured) is likely to differ substantially from the private opportunity cost. Economic "externalities" are overwhelming 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. Even under the best of circumstances, one cannot expect the prices of private exchanges to reflect in any way the social consequences for society.

Another formidable difficulty of employing the market mechanism is the fact that freedom of entry to spectrum markets will in most cases, need to be restrict Therefore, market exchanges - assuming all other difficulties could be overcome - would tend to be at monopoly rather than competitive prices. Thus, the argument for the adoption of market exchanges for spectrum allocation must be based upon monopoly markets as superior to the existing administrative system and not competitive markets as a basis for efficient resource allocation.

Even more severe problems are created by other imperfections in the marketplace. Major users of the spectrum are regulated monopolies such as Telesat, Bell Canada, ATT and other carriers. These carriers not only have substantial monopoly power, their rates are regulated on a cost/plus basis. Thus, they have a reservoir of monopoly power that can be used to charge

higher rates for their telecommunications services. Moreover, they can use this monopoly power to pay whatever prices are necessary in order to capture that portion of the spectrum that they desire. Under this system of regulation, a spectrum market could lead to major distorted allocations.

Finally, one must recognize that many public agencies which provide social services do not operate in markets. They do not sell services. Although a market in the use of the spectrum may force such agencies to make economic tradeoffs between spectrum using equipment and other equipment in some circumstances, these agencies do not have the opportunity to participate in the marketplace in accordance with the private or social values of the services they provide. The introduction of a spectrum market cannot be said to improve the efficiency of resource allocation under these conditions.

In conclusion, it is apparent that a change in spectrum allocation policy from the current administered system to one based on opportunity cost as determined in the marketplace is not likely to improve the situation overall. There may well be isolated instances where improved efficiency in the allocation, assignment and/or use of the spectrum may occur. But almost certainly there would be many cases where inefficiency would be created. On the basis of this preliminary analysis, it would appear that direct application of the opportunity cost concept through the market is neither justifiable nor feasible. Unfortunately, the substantial literature on this subject succumbs to the idealists dilemma. It compares the deficiencies of the existing system with a theoretical ideal that is neither relevant nor applicable.

If the opportunity cost notion is to be usefully applied to improve the process of spectrum allocation and assignment, it will have to be broadly interpreted and selectively applied in very careful limited ways. This is really not surprising. The administrative allocation process is a direct result of market failure. The DOC, FCC and ITU came about because of the breakdown of private markets as a basis for allocation and assignment. Clearly, the administrative allocation process can be improved significantly. However, a blind leap to the market based upon the precision of neo-classical theory would likely to be destructive.*

IV. PROPOSALS TO INCORPORATE ECONOMIC CRITERIA INTO THE SPECTRUM ALLOCATION PROCESS

Over the past twenty-five years, a substantial literature exploring the possibility and desirability of incorporating economic criteria into the spectrum allocation process in various ways has developed. This literature reflects a concern about the deficiencies of current allocation methods and an expectation that future growth and shifts in demand will intensify the negative implications of these deficiencies. This perceived inadequacy of the existing system reflects in part disagreement as to the functional efficiency of the current administrative system, in part different views of the political, technical and economic parameters of the process, and in part differing views as to the appropriate objectives of the spectrum allocation process.

The fundamental objective, stated or assumed of most economic reviews of the spectrum allocation problem is the promotion of allocative efficiency in the economic sense. In its broadest sense, allocative efficiency requires that no reallocation of spectrum from one user to another be possible so at a given point in time that the net benefits to society of such a reallocation are positive.

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* A selected bibliography on opportunity cost in economic theory is provided in Section I of the Bibliography.

To move toward this goal, it is necessary that the value of spectrum in alternative uses be fully considered in allocative decisions. Although the appropriate measure of value (as measured through some definition and measurement of the opportunity cost concept) may be disputed both conceptually and in specific instances, the recognition of the relationship of value to allocative efficiency remains fundamental. In more concrete terms, considerations of allocative efficiency must include: the gross value of spectrum in various uses; the availability of spectrum substitutes in particular uses; the level and nature of spectrum-related development undertaken by users; desirable levels and patterns of interference, and the impact of the chosen allocation process on administrative, transaction, enforcement and system costs.

An additional objective assumed by many authors is equity in the distribution of the benefits of using the spectrum. Since spectrum is a publically owned resource, the benefits arising out of spectrum utilization should accrue to the public rather than to private users. A subsidiary concern is that where the benefits of spectrum use are retained by private users, such users should as a minimum be required to bear the administrative costs associated with according them user status.

It should be observed at the outset of this section that the injection of economic criteria into the allocation process does not necessarily imply the replacement of administrative decision-making by market exchange relations. Whereas the creation of transferable private property rights would remove administrative control over the allocative process from the central authority, all other proposals considered are characterized by continued centralized control of the process. In the case of shadow pricing, user charges and

auctions, the central authority may choose to retain a large degree of discretion as to the application of these methods. In the case of bandwidth auctions, for example, the spectrum manager could presumably establish bidder qualifications and reserve prices in accordance with those objectives that it determined the market could not further. Even in the extreme case of a market in transferable private property rights, the administrative authority would not be prevented necessarily from exercising a measure of control over the process by, for example, instituting zoning requirements or restricting the degree of transferability of the rights.

In reviewing the range of proposals for introducing economic criteria into the spectrum allocation process, we must emphasize the following strictures. The oft repeated claim that the adoption of economic concepts automatically will improve resource allocation efficiency is not demonstrable. The introduction of economic criteria into the allocation process will change the structure of benefits and costs associated with the spectrum throughout society. There will be gainers and losers. The net effect for society will depend very heavily on the value judgments incorporated into the weighting of the gains and losses to different groups in society.

Within this framework of analysis, the useful application of opportunity cost can only be made in terms of a common sense definition, as noted above, and not in terms of optimization as defined in neo-classical theory. The problem of developing operational procedures for defining and applying a relevant conception of opportunity costs is one that has not been explored in depth in the literature.

This more modest pursuit of the incorporation of economic criteria in the allocation process should then be seen as a step toward increasing the role of economic criteria in an administrative process that already has been influenced significantly by economic circumstances, if not by the explicit application of economic measures.

Finally, we must not lose sight of the fact that the process of spectrum allocation encompasses much more than economic objectives. If the narrow concept of allocational efficiency as defined in economic theory is sacrificed to achieve broader social and political objectives, the process is superior to one that would achieve only economic efficiency. The unfortunate aspect of the present system is that neither objectives nor the specific criteria for obtaining them are specified in ways that appear to be operational or which are visible to outsiders.

A. A Market in Freely Transferable Spectrum Rights [22/]

The most radical of the proposals to inject economic criteria into the spectrum allocation process is that of creating a market of transferable spectrum rights. First suggested by Herzel, the proposal has been considerably refined by such writers as Coase, Minasian, and Meckling. The basic rationale of the suggestion is founded in neo-classical economic theory as to the allocative efficiency of competitive markets, as refined by Coase in his paper on the role and allocative function of property rights.

22/ See Levin (1971), DeVany et al (1969), Minasian (1975), Coase (1959), Rose (1969).

The fundamental requirement of such a system is that property rights must be defined and privately transferable. In the case of the spectrum, the probabilistic nature of emission patterns and the interference problems thus created raise serious doubts as to whether it is possible to define private property rights in spectrum in a fashion that does not imply transaction and enforcement costs and loss of spectrum use in excess of any claimed allocative efficiency benefits of such a system.

Even if one were to concede that it may be possible to resolve the above problem of rights definition, the desirability of a market system remains extremely questionable. Major obstacles that have not been addressed include:

(1) Such a market system would fail to take into account the very substantial externalities associated with the provision of spectrum using services. This divergence between social and private valuations of spectrum worth in a particular use implies that market allocation would be socially inefficient even when considered on its own terms;

(2) The non-competitive nature of the markets in which spectrum users operate may imply a further divergence between social and private valuations of spectrum worth in particular uses. The implications in this regard are particularly serious when monopoly users regulated on a cost-plus basis are involved.

(3) The nature of the fiscal budgetary system may preclude government offices and agencies from equal market participation.

(4) International constraints on spectrum use may effectively prohibit national spectrum markets in a country such as Canada where the population is centered in proximity to the U.S. border.

(5) Benefits of equipment standardization, from the point of view of both manufacturing economies and equipment mobility, may be lost. While a market system might take the former point into account, the fact that receivers and transmitters are separately owned may prevent it from so doing in respect to the latter.

(6) Administrative discretion would be severely narrowed. It would restrict, and could render the system incapable of achieving broader economic, social and political objectives.

In addition, there would be severe problems encountered in the transitional period. And from the viewpoint of distributional equity, future increases in spectrum value that were not capitalized at the point of initial rights sale, would be retained by private users.

The above obstacles are sufficiently serious to preclude consideration of a full market system in spectrum rights, even if one views the objective of the spectrum allocation process to be only narrowly economic. However, more limited applications of a market system is worthy of detailed investigation. The rental of spectrum rights in bands where there are a large number of relatively homogenous users operating in comparatively competitive markets is one area where a market system might be seriously considered (e.g., in certain of the Land Mobile areas.)

B. Auctions [23/]

The auctioning of spectrum rights has been proposed as a means of both efficiently allocating spectrum and recovering its value in use. Levin (p. 86) identifies three levels of auctioning:

1. Interband contests to determine reallocation as between different services, in addition to intraband contests limited to like users within the same service.
2. Interband contests to ration grants among like users, within different services competing for the same spectrum, with managers free to utilize the resultant values in further reallocation between the two services.
3. Intraband contests within a single service to ration rights there, with results used to set user charges elsewhere too.

Auctioning in principle differs little from the pure market concept. By retaining spectrum ownership in public hands, however, it might be possible to so devise the auction process as to avoid at least some market pitfalls. Specifically, by restricting transferability and establishing appropriate bidder qualifications for each bandwidth section to be auctioned, the obstacles to a market system theoretically can be overcome. The spectrum management authority would continue its current function but in those cases where a large number of potential users equally satisfy the other criteria, the auction process could be used to select between such users. Further, auctions in limited spectrum areas could produce competitive market valuations for spectrum that might aid in both the overall allocation process and in

23/ See Levin (1971), Robinson (1976), Smythe (BC Memo)

determining user charges.

Even within this limited application, the auction approach is not without special problems. The nature of the technical interference problem implies that in practise it would probably be necessary to limit the process to license assignments between like users in a single band and then only when the market was reasonably competitive and bidder collusion could be forestalled. Multi Point Distribution Service is one such area that Robinson suggests as a candidate for the auctioning approach.

We must note that the auctioning approach has resulted in a substantial retreat from full market allocation. It is proposed not for spectrum allocation, but for spectrum assignments in limited circumstances. And where it is seriously being considered for implementation, it is to provide administrative cost savings more than improved efficiency in economic resource allocation.

C. Shadow Pricing [24/]

While the term 'shadow pricing' is used in numerous and many very different contexts, the three definitions that are most germane are: (i) the price that would obtain for a good in a competitive market, (ii) the maximum amount that a firm would be willing to pay for an additional resource unit and (iii) social valuations being the price that would obtain in a competitive market with adjustment made for both public and private externalities. Clearly the use to which a shadow price is to be put must

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24/ See Alleman (1974), Mishan (1975), DeVany et al (1968), G. Robinson (1969), J. Robinson (1976)

determine which of the above definitions is relevant.

In the context of spectrum allocation, shadow pricing has been recommended as both a basis for making administrative allocations and as a basis for setting user charges. Its applicability to the latter function will be discussed in a later section. From the standpoint of allocative efficiency the relevant shadow price measure is type (iii). Ideally making allocations such that the type (iii) shadow price measure was equalled for all spectrum users would maximize allocative efficiency. Unfortunately the measurement of such prices is problematic in that it requires that the calculation be made on an individual firm basis and that the administrator be able to attach values to unpriced externalities that enter the shadow price. The letter task is unfeasible and in its application would probably be limited to the explicit recognition that social factors will in some cases provide a justification to override calculations ignoring such factors.

The remaining calculation, which must be done on an individual firm basis, is the measurement of the amount that the firm, if competitive, would pay for a marginal unit of spectrum. While such calculations are theoretically possible, the cost of obtaining reasonably accurate estimates is likely to be prohibitive. As an instrument for fine tuning the allocation process, shadow pricing is patently impractical. At best, shadow pricing might provide a rough guide for the judgments of administrative authorities. At present, even this general application is limited by the overwhelming difficulties of implementation.

D. Fees to Cover the Costs of Administration [25/]

Currently spectrum license fees in both Canada and the U.S. are set at minimal levels designed only to recapture a portion of the costs incurred in spectrum administration. As such costs are very low in relation to total spectrum value it is likely that the allocative impact of such charges is fairly negligible. Our discussion of this subject will therefore emphasize the distributional aspects involved.

Given that under such a system of charges spectrum users and the users of the services that they provide retain the principal benefits associated with spectrum availability, considerations of distributional equity mitigate in favour of them bearing the costs of spectrum administration. Given also that the allocative effects of such charges are likely to be negligible, the design of such a system of fees should attempt to ensure that the administrative and collection costs associated with it are minimized. We will examine three possible systems of charges with this in mind.

1. Charges based upon ability to pay: In that the fee to be levied is to be levied in respect of a particular benefit, i.e. spectrum use, and its associated costs of administration there does not appear to be any priori rationale for favouring such a fee basis. Further, given that the appropriate measure of ability to pay is profit, and that the calculation of profit is problematic, such a fee basis should not be favoured. The argument is strengthened by the realisation that profit is unlikely to be closely related to either spectrum utilization or its associated administrative costs.

25/ See DOC (1976)

2. Charges based upon related administration costs: While both a distributional equity and allocative efficiency argument can be used to support basing individual license fees upon the administrative costs associated with that licensee, the necessary costs involved in making such calculations may well be needlessly large.

3. Charges based upon Spectrum Utilization: The allocative efficiency benefits, while still small, of such a fee system are likely to be greater than the other two possibilities mentioned. Given also that the costs of administering such charges should be small and that such a system is supportable on distributional equity grounds, this may constitute the preferred method.

While a system of fees designed to recover administration costs can be designed to incorporate several desirable properties, such levies fail to address the fundamental issues raised by the need to inject economic criteria into the allocation process.

E. User Charges Unrelated to Administration Costs[26/]

The application of license fees and user charges need not necessarily be limited to covering only administration costs. User charges may be established to meet other criteria, including efficient resource allocation or social objectives. In general terms, proposals in this category can be broken down into those which vary with usage and those which are independent of usage levels. By charging users a cost penalty for additional spectrum units used, users are given an incentive to restrict spectrum use, consider input substitution possibilities, and to undertake R. & D. to allow them to economize on spectrum use. The magnitude of these incentives will vary according to the relationship between the spectrum value to the user and the charge levied upon his use.

However this type of user charge has its limitations. Perhaps the most significant is that there are difficulties in defining the resource unit upon which the charge is to be levied; there are many alternative definitions that could be employed. In addition, uniform unit charges, based on marginal valuations in many cases will fail to recover the full value bestowed by spectrum use on the licensee.

Charges based independently of useage levels on the other hand fail to provide as significant an economizing incentive, as the charge applies to the fact rather than the level of usage by the licensee. Theoretically it would however be possible to levy lump sum charges to recover full value to user within current allocations.

26/ Smythe (B.C. Government Memo), Webbink (1971), Levin (1971)

In addition, given that social and private valuations of the worth of spectrum in different uses vary as a result of market externalities and imperfections, the appropriate allocations must be based on social valuations whereas user charges would be based on private valuations given the desired allocation pattern. Any system of charges must therefore be considered in conjunction with a complementary, e.g. administrative, allocation mechanism. In theory, such a system could both discriminate between users whose social worth valuations are equivalent and aid in remedying some of the practical difficulties surrounding the achievement of efficient administrative allocations.

We now examine some specific user charge proposals

1. Charges based on shadow price estimates: Assuming that type (2) shadow price estimates were obtainable at reasonable accuracy and cost, their direct translation into user charges would entail severe allocative and distributional deficiencies. As an allocative mechanism they would tend to favour inefficient producers. (Levin, p. 136). Alleman (p. 18) concludes that such charges would tend to keep current allocations essentially unchanged, and thus their use presupposes acceptable allocations. Being marginal valuations we have already noted that they would fail to recover the total value that the licensee obtains from his spectrum use. Given the difficulties involved in obtaining useful shadow price estimates, their utility as a basis for setting charges is further called into question.

2. Charges based on auction values: While several writers have suggested that auction values obtained in selected spectrum areas be used as a basis for establishing user charges, scant analysis has been done as to the implications of so doing. First we may note that spectrum is nonhomogenous and that its value is likely to vary with its several dimensions. Second, in that the reason for excluding particular users from the auction process may well have been a result of externalities or market imperfections surrounding such uses, charges levied on this basis could have undesired allocative effects. Thirdly, because the amount of bandwidth used per licensee is likely to vary greatly and for the above two reasons, such charges are unlikely to provide a reliable measure of the value of spectrum to the licensee either in total or at the margin. With these qualifications noted, if limited auctioning were to be undertaken, the spectrum valuations thereby obtained might nonetheless provide rough guidelines to be employed for the purpose of considering user charges and of planning allocations.

3. Other: Other possible bases for levying charges include revenue, profits, per unit rates set at arbitrary levels, rates based on specific industry analysis and objectives etc. Rates could also be multi-tiered with, for example, a lump sum charge levied in respect of obtaining a license and a further set of charges that varied with usage levels. Per unit rates could be regressive, constant or progressive. The complete evaluation of these and other possibilities would require a much more complete discussion of spectrum management objectives and user industry structure.

In addition to those proposals discussed above, other less significant proposals for incorporating economic criteria into the spectrum allocation process including the following.

Other Proposals to Incorporate Economic Criteria

(i) Insurance Fund: One of the principal faults often cited with the current spectrum management process concerns the unwillingness of the spectrum authority to undertake desirable reallocations, even where the evidence suggests that all parties to the process could thereby reap potential benefits. The principal obstacle to achieving such benefits is often that no mechanism exists to compensate dislodged incumbents for the loss that they incur from resulting equipment obsolescence. A general insurance fund to which all licensees contribute has been proposed to provide a pool of funds available to compensate dislodged users for such incurred costs.

(ii) Levin Proposal: Levin (pp. 144-7) has suggested that one possible solution to the problem of compensating dislodged incumbents would be to require newcomers to reimburse incumbents 'for any costs incurred in vacating, sharing, or lending space to them'. However, should incumbents prefer not to accommodate, then they in turn pay "rent" to the spectrum manager equal to the extra costs imposed on newcomers through exclusion. While the theoretical allocative advantages of such a scheme are obvious, the administrative costs surrounding its application could well prove prohibitive.

(iii) Redefinition of User Rights: Redefining user spectrum rights in terms of permitted output rather than allowed input mix, it is argued, would serve economic efficiency by allowing the user to determine the most efficient mix of inputs to achieve the desired output. The practicability of such

an approach is hindred by the problem of technical interference which it is sometimes claimed would be unduly intensified were users free to select their input mix.

(iv) Frequency Clearance: By requiring spectrum users to obtain clearance to use a particular spectrum region prior to their investment in related equipment, administrative authority would decide upon allowed allocations with fewer constraints imposed by past investment decisions.

V. CONCLUSION

While the preceding discussion indicates that there is no shortage of schemes designed to inject economic criteria into the allocation process, there is also no single proposal that dominates all others in terms of potential net benefits to society. In conclusion we will briefly review the merits and possible role of the major proposals and their implications in terms of the current administrative structure and its requirements. In the absence of any empirical analysis of the alternatives it will of course not be possible to reach any final judgements.

Social considerations, market externalities, international constraints, the technical nature of the spectrum and current political realities would appear to imply that a free market in spectrum rights is not a realistic option and that the decisionmaking role in allocating spectrum should remain in the hands of a central administrative authority. At the same time there is a clear need to inject an increased consideration of economic criteria into that process. This goal may be achieved through explicit regulatory

recognition of economic values and/or by injecting incentives into the system such that spectrum users more fully take such values into account.

At the level of allocation of frequency bands to specific user classes, the need for administrative control is probably greatest and the obstacles to market exchange type determinations most severe. The major issue raised is the means by which the regulator can obtain estimates of the economic value of particular spectrum regions for particular types of use and then incorporate such criteria into an operational decisionmaking process. In the absence of actual competitive market exchanges the estimation of such values is clearly problematic. Crude shadow price estimates, industry analyses, auction values obtained in the license assignment process and user consultation may furnish guidelines, albeit rough ones, in this regard. The same information can also be used in the process of setting user charges designed to recover at least a portion of the benefits that licensees and their customers obtain from spectrum access.

With regard to the licensing of frequency assignments to particular users, the greater degree of homogeneity between users in each class implies that the obstacles to market based exchange determinations are considerably weakened. User charges designed to discriminate between applicants, auctions and modified market type arrangements can be considered as potential regulatory instruments. These mechanisms can be applied within a framework of administrative decisionmaking designed to ensure the attainment of non-economic as well as economic objectives. If, for example, the auctioning of selected assignments is to be undertaken there would have to be administrative specification of both bidder qualifications and license qualifications. This would apply to initial license grants, transfers and renewals.

Apart from their potential allocative role relating to license assignments, and their information role relating to allocations of frequency bands to user classes, user charges may be employed as a mechanism to recover for the public the value that spectrum use bestows upon the licensee and his customers. In theory, such charges could be determined on the basis of shadow price estimates, auction values, or at any other level. However, care would need to be taken that the allocative function is not subverted. There will be information deficiencies and the valuations provided will not only be extremely subjective, but also subject to manipulation by vested interests.

It is unfortunate that a major portion of the literature on the subject of incorporating economic valuations into the spectrum allocation and assignment process simply assumes at the outset:

1. That market determined decisions are automatically superior to administered decisions;
2. That opportunity costs, however defined and measured, automatically will improve the efficiency of resource allocation;
3. That any proposal to make greater use of markets and opportunity costs is automatically a move toward optimal efficiency, as defined in neo-classical economic theory;
4. That optimal efficiency as defined in neo-classical theory either is, or should be the objective of spectrum allocation and assignment.

This paper has demonstrated that none of these assumptions is true.

A change in spectrum allocation policy from the current administered system to one based on opportunity costs as determined in the marketplace cannot be demonstrated either to improve the efficiency of resource allocation

or to more satisfactorily meet the objectives of spectrum allocation. Our analysis demonstrates that direct application of the opportunity cost concept through the market is neither justifiable nor feasible. If the opportunity cost notion is to be applied usefully to improve the process of spectrum allocation and assignment, it will have to be broadly interpreted and selectively applied in very careful, limited ways. This paper has provided a first step in that direction, but much more needs to be done. The useful application of opportunity cost can only be made in terms of a common sense definition, and not in terms of optimization as defined in neo-classical theory. The problem of developing operational procedures relating to the definition and implementation of relevant conceptions of opportunity cost is one that has not been explored fully to date. This is an important area where research should be directed in the future.

An examination of the history of the spectrum allocation problem demonstrates a series of quantum jumps in spectrum capacity as a result of changes in technology over time associated with modifications in the policies for spectrum allocation and assignment. The 1979 WARC will be the first general review of radio frequency allocation at the world level since 1959. Technical progress has changed the capabilities for using the spectrum significantly, influenced the nature of spectrum demands and raised many issues that will require change in the concepts and methods used in radio spectrum management at both the intensive and extensive margins of spectrum use. Canada will need to assess fully the economic, social and political consequences of possible changes in spectrum policy being considered by 1979

WARC, by the U.S. as a result of 1979 WARC and by the DOC.

Important issues that must be addressed by spectrum policymakers in the immediate future include:

1. The role and operational basis of the economic criteria to be incorporated in the spectrum management process (reviewed in part in this paper);
2. The relation between R. & D. directed at technical improvement in spectrum utilization and the costs of obsolescence of inherited equipment which has increased at every stage of growth and expansion of spectrum use; and
3. Problems of spectrum discipline and the creation of cooperative groups to coordinate their common interests in using a portion of the spectrum. In each instance, detailed examination into the operational aspects of the issue is clearly needed.

Further study on the role of opportunity cost and other economic and social criteria in the spectrum management process could benefit significantly by pursuing the following questions.

1. The existing literature addressed to the problem of incorporating economic criteria into the spectrum management process is focussed almost exclusively on private markets and opportunity costs. Of more direct relevance may be economic theories of rent and taxes. Pursuit of these theories may shed more light on problems of incorporating economic criteria into the process of administrative decision-making. Market theory and opportunity costs find their heritage in theories of free markets, not administered decisions.
2. What changes have been made in Canadian spectrum management policies and practices since 1966? Why were these changes made? What have been the effects and consequences? The present information available on this

subject is extremely limited and not fully informative.

3. To what extent does Canadian spectrum management adhere to specified criteria in allocating bands of frequencies to classes of users? What are the criteria applied? What are the grounds for exceptions from the criteria? What is the detailed administrative process that is applied? The available information provides a very partial and incomplete explanation of how the existing spectrum management process actually works in Canada.
4. Reports of the industry advisory committees on spectrum management policies should be examined to determine the trend of problems and policy recommendations over the past thirty years.
5. What work has been done in Canada since 1968 on the development of the "next generation" of spectrum engineering? This is discussed in the report of the JTAC in connection with the U.S. Report of the President's Task Force (1968). Equivalent information should be obtained for Canada.
6. To what extent does Canada have sole discretion in defining classes of users, frequency bands assigned to them and relevant engineering standards. There appears to be no public information in this important area.
7. To what extent do agreements between Canada and the U.S. limit Canadian discretion with regard to the points raised in Question 6 above?
8. Is there a Canadian counterpart to IRAC? Is there information available on its history and its functions?
9. How is the Canadian position at ITU Conferences arrived at? In particular, how is the Canadian position regarding 1979 WARC being formulated? Effective pursuit of the operational aspects of any economic concepts will require a detailed understanding of these current processes?
10. To what extent is R. & D. a barrier to the resolution of the major problems in spectrum management today? To what extent is unwillingness on the part of classes of spectrum users to accept obsolescence in their investment in

radio equipment a barrier to the resolution of the major problems in spectrum management today?

11. Relating to point 10 above, what is the present gross and net investment in spectrum related equipment in Canada? This information is crucial to a complete assessment of the obsolescence issue?

12. What has been the pattern of expenditures for (a) equipment, and (b) maintenance and repairs by classes of users of the radio spectrum in the civilian, military and non-military government sectors in Canada over the past 10 years? A complete economic analysis must consider this important economic data relating to investments and ongoing expenses of using the spectrum.

13. How is the spectrum now allocated between civilian, military and non-military government users in Canada? This information would be most useful if it were categorized according to: below 30 MHz; from 30 MHz to 1,000 MHz; from 1 GHz to 10 GHz; above 10 GHz. Effective pursuit of operational questions requires this information as a base for analysis.

The significance of posing these questions as pointing the direction for future research is not simply to obtain the answers. For some of them answers can be readily provided. Rather, it is the supporting information, the trends over time, the criteria for decisions and the data employed in applying those criteria that are crucial to an in-depth examination of the operational feasibility of employing economic criteria in the Canadian spectrum management process. This information would provide a useful basis for building on this report toward a more detailed examination of the economic issues, emphasizing their operational aspects and addressing the problems of implementation.

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