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EFFECT OF ECONOMIC TECHNIQUES
ON RADIO FREQUENCY UTILIZATION

by

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The spectrum is then discussed as a resource in relation to its economic characteristics: supply, demand, opportunity costs, prices, externalities and property rights. Although the spectrum is a unique resource as compared to most other natural resources, this conclusion is no valid reason for not allowing the establishment of a spectrum market exists.

An examination of how such a market might be established and operated, and the implications of such a market are then discussed, with an example of how this market would operate in the Land Mobile Radio Services. To better illustrate this point, a brief history of land mobile radio, its technology and applications, and current allocation and assignment mechanisms is also presented.

This study concludes by discussing the importance of the frequency spectrum to economic growth, summarizes the advantages and disadvantages of both marketplace and government regulation, and proposes that a market trial be instituted to test the viability of a spectral market.

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Effect of Economic Techniques on Radio Frequency Utilization

by

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ABSTRACT

This thesis compares the efficacy of spectrum assignment and allocation using a market-based system with the current government-controlled regulatory system. In making this comparison, a brief review of the spectrum and its radio communication uses is given. An examination of the current system--historical, organizational and political--is also presented.

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I. INTRODUCTION: THE RADIO FREQUENCY SPECTRUM

For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who profit by the new order.--Niccolo Machiavelli, *The Prince*

Man has discovered and learned, in less than a century, to utilize an amazing natural resource: the radio frequency spectrum. In the early years of spectrum use, the primary limitations on exploiting the airwaves were technical naivety and lack of vision in devising new applications. Neither of these restrictions now apply. The radio spectrum has undergone intense scrutiny and study resulting in a thorough understanding of its technical characteristics and limitations and its position within the electromagnetic spectrum.

With our increased knowledge, we have extended the spectrum by enabling more systems to occupy a band and, more significantly, developed systems which can operate in previously unused bands. In fact, extensions of the useful spectrum at the upper limit have increased the occupied spectrum by 200,000 times that which was originally known to exist [Ref. 1: p. 175]. However, this has not always provided relief from congestion in the airwaves. Along with technical advancement has come ever more numerous and ingenious ways to occupy the spectrum, some of which consume spectrum space tens or hundreds of times greater than ever anticipated. Also, new regions may possess technical properties which make them unsuitable for existing services. These services must then be crowded into usable bands. To congestion caused by technological sophistication can be added congestion resulting from the inability or unwillingness to take full advantage of this revolution. Incumbent users often have been reluctant or unable to bear the expense of investing in new technologies which work in higher frequencies.

Unfortunately, even if complete utilization of available frequencies was undertaken, the spectrum is a limited resource. The ability to place an unlimited number of systems in a limited spectrum is infeasible. Therefore it is important that the spectrum which is allocated for use by the United States be used as efficiently as possible. When limited availability of more conventional resources, such as water or forests, occurs, a program of conservation is instituted or at least considered. This, of course, does not imply efficient use of the resource, only that demand is constrained. Yet given the numerous uses of the spectrum, current and unforeseen, any attempt at conservation must include the efficient use of the airwaves, rather than constraints on demand only.

While this is an obvious and desirable goal, efficient use has different meanings and objectives for different users of the spectrum. An engineer may define spectral efficiency as utilizing the narrowest bandwidth possible to transmit an intelligible signal, regardless of the technological costs. An incumbent user may define efficient use as the greatest monetary return in relation to investment. Likewise, the general public, economists, regulatory commissions and every other party interested in utilization will have a slightly different view of spectral efficiency. As William J. Hilsman, President and Chief Executive Officer of the International Mobile Machines Corporation, stated, "Despite the apparent obviousness of the idea of spectrum efficiency, there really is no common and accepted yardstick that is used today, and this can lead to considerable confusion." [Ref. 2]

While there is an intuitive awareness, or sense, of efficient use, some more concrete description is needed in determining how the spectrum will be used and by whom. For purposes of this discussion, efficient usage will be attained when the value gained by use of a specific portion of the spectrum by one particular user cannot be increased by transferring that spectrum from the incumbent to another user, whether for the same purpose or a different one. Yet even with this definition there is uncertainty in what constitutes value. Should value be measured in monetary terms, or perhaps in terms of social value? The answer to this question will depend upon the judgment of the user, and upon the situation and overall objective.

With this definition of efficiency, the question arises: which is the better method to ensure efficient utilization of the spectrum, the current regulatory system or an as yet untried marketplace mechanism? In seeking an answer, a brief review of the spectrum and its radio communication uses will be presented in this introduction. Chapter II will present the current regulatory system, viewed historically, organizationally and politically. Chapter III examines economic aspects of spectrum use, while Chapter IV attempts to apply these concepts of market approaches to spectrum management. Chapter V will show how the marketplace might work in one particular application, with conclusions and recommendations presented in Chapter VI.

A. DEFINING THE RADIO FREQUENCY SPECTRUM

The term spectrum refers to "a class or group of similar entities arranged in the order in which they possess a certain characteristic." [Ref. 3: p. 515] The electromagnetic spectrum theoretically extends from zero to infinity and is composed of all the frequencies which make up electromagnetic waves. These waves are formed of oscillating electrical and magnetic energy, at right angles to each other, which travel at the speed of light through free space.

Varying frequencies and lengths characterize electromagnetic waves. Frequency is the number of waves (or cycles) which pass a specified point per second. The common term for cycles per second is the hertz. Wave length is the distance a wave travels in one cycle, or alternatively, the distance between the crests of a wave trough.

The portion of the electromagnetic spectrum which is regarded as the radio spectrum (radio encompassing all forms of wireless communication) extends from very low frequencies of a few kilohertz (thousands of cycles per second) and wavelengths of several kilometers up to 300 gigahertz (billions of cycles per second) with wavelengths measured in millimeters. The officially allocated radio spectrum lies between 10 kilohertz (KHz) and 300 gigahertz (GHz).

The radio spectrum is considered to lie between these limits because of physical constraints. Below 10 KHz, system components, especially antennas, become prohibitively large and expensive for commercial applications. Additionally, the usable bandwidth below 10 KHz greatly restricts the amount of information which can be relayed because of extremely slow transmission rates. Above 300 GHz, atmospheric elements, such as oxygen molecules and water vapor, absorb the signal, rendering it unreliable for information transfer.

Different portions of the spectrum have different geographic ranges and degrees of transmission dependability. These are known as propagation characteristics. Generally, the lower frequencies are used for long-distance communications and are the most dependable, while the highest frequencies are reserved for short-range purposes and are considered less dependable.

A single frequency is not adequate for transmitting information. Radio communications requires a range of frequencies. The range of these consecutive frequencies is called bandwidth and is measured in hertz from the highest to the lowest frequency required. For example, a signal centered on the central, or carrier, frequency of 25 megahertz (MHz) with a bandwidth of 30 KHz would occupy the bandwidth between 24.97 and 25.03 MHz. This is also known as the emission bandwidth.

Weather, solar activity, the ionosphere, propagation medium (ground, sky, or space wave) all affect the propagation of a wave. However, the effect of these on radio transmission is a study in and of itself and will not be covered here.

Likewise, the effect of noise, or interference, on radio waves is a complex study, with noise characterized as either internal or external. Internal noise is generated by the transmitter or receiver itself. External noise is produced by either natural radiation, incidental man-made radiation, or out-of-band modulation radiation from other communication sources.

B. UTILIZING THE SPECTRUM

Utilization of the radio frequency spectrum requires the use of a system. A system involves the use of transmitters, receivers, antennas and associated equipment, all coordinated in order to achieve, at the minimum, a required signal-to-noise ratio with an operating frequency. That is, the man-made signal must be greater than noise introduced either internally or externally. In achieving this aim, the design of a system involves trade-offs, such as the choice of frequencies, power and bandwidth to be utilized, antenna directivity and sensitivity of the receiver to noise. High transmitter power and/or greater bandwidth is commonly used to overcome noise. However, there are practical limits to the signal intensities which are achievable [Ref. 3: p. 517].

The measure of how well a system performs its function consists of both the volume of information which can be transmitted during a specific time period and how accurately the transmitted information can be reconstructed at a receiver [Ref. 4: p. 31]. In order to transmit information, it is necessary to modulate the operating frequency of a transmitter. That is, to impose the desired signal, whether analog (such as voice) or digital (such as data), upon the radio frequency which is sent through the airwaves. This is true regardless of the modulation technique used: amplitude, frequency, phase or any other.

As mentioned earlier, this modulated signal will be composed of many frequencies besides the carrier frequency, i.e., the bandwidth. Therefore, it is necessary to know what the emission bandwidth of a signal is before assigning a bandwidth to a radio communication service. Any emission outside an assigned bandwidth can produce interference, in the form of noise, on other channels, degrading the performance of other systems. Therefore, the elimination or minimization of emissions outside an assigned bandwidth is an important aspect of optimum frequency utilization. Additionally, since transmitter power for a given design determines the power level of interfering emissions, power utilized should not be greater than that required to produce the desired grade of service established for a system of service. [Ref. 3: p. 515]

With these considerations in mind, the designer and user of a system must also be aware of the electromagnetic environment in which the system will operate. Besides the presence of noise in the system's frequency range and minimization of interference causing emissions, the effect of the earth's atmosphere on the radio frequency spectrum must be considered.

C. COMMUNICATION USES OF THE SPECTRUM

Although there are non-communication uses of the spectrum, such as radio astronomy, this discussion focuses only on the spectrum utilized by the telecommunications industry. Similarly, while electromagnetic waves used for telecommunications can be sent from one location to another in transmission lines, waveguides, or through the atmosphere, atmospheric transmission will be discussed here since problems of interference with radio frequency communications occur in atmospheric transmission.

1. Fixed

Fixed services are defined as, "A service of radio communication between specified fixed points." [Refs. 1: p. 127, 4 : p. 241] The word "specified" is used in order to differentiate between fixed and broadcast services. A fixed service includes all radio communication between established stationary communication points and through relays along established communication routes. [Ref. 1: p. 128]

Fixed services are divided into parts, depending on the particular type of service, such as aeronautical fixed, or depending on the user or service with which the fixed operation is associated, such as marine relay. [Ref. 1: p. 128]

2. Mobile

Mobile service is defined as, "A service of radio communication between land and mobile stations and between mobile stations." [Refs. 4: p. 215, 1: p. 130] While both fixed and mobile services transmit signals which are intended to be received by specific users, the fixed services' transmitters and receivers are at fixed sites, while mobile operators may move their transmitters and receivers. Fixed and mobile services also share another characteristic: similar suballocations to users and similar types of emissions. [Ref. 1: p. 131]

The mobile services are subdivided into either maritime mobile, land mobile, or aeronautical mobile.

3. Broadcast

A broadcast service is defined as, "A radio communication service in which the transmissions are intended for direct reception by the general public." [Ref. 1: p. 133] A broadcast service may include sound transmissions, television transmissions or other types of transmissions. However, auxiliary services, such as studio transmitter links, remote pickup, and the like, are included under the fixed and mobile services for allocation purposes. [Ref. 4: pp. 214-215]

Broadcasting is the most widely distributed radio service, and there can be no doubt that it is the most important means of mass communication ever devised.

4. Other

A portion of the radio frequency spectrum is allocated to communication functions which are not considered to be fixed, mobile or broadcast, such as the amateur service. The amateur service, as the name implies, is devoted to self-training, intercommunication and technical investigations by authorized persons interested in radio technique solely for personal aims, with no financial benefit sought or expected [Ref. 4: p. 217]. Other radio communication services display a wide range of applications, such as cordless phones, baby monitors and similar gadgets.

D. SUMMARY

As can be seen from this discussion, the spectrum has numerous and wide ranging uses. It is this very fact which makes the spectrum such a valuable commodity, sought after by many interests. Without some mechanism to ensure the allocation and assignment of frequencies, the airwaves could easily dissolve into chaos. It is the task of reconciling these differing uses of the spectrum which we know as frequency management. For commercial applications in the United States, this job falls upon the Federal Communications Commission.

II. REVIEW AND ANALYSIS OF FEDERAL REGULATION

A. INTRODUCTION

Federal regulation of the airwaves was instituted primarily to prevent interference of the airwaves. A second objective of the Federal Communications Commission (FCC) and its predecessors has been the prevention of congestion in the spectrum. While these goals have been achieved to a greater or lesser extent, depending on the period or service studied, the continued application of this system to the spectrum has increasingly been questioned on economic grounds.

Before any exploration of alternate regulatory methods occurs, however, it is instructive to examine the history of regulation, the role of the FCC, and the institutions which affect the FCC.

B. HISTORY OF REGULATION

The circumstances and history regarding regulation of the airwaves in the United States have been recounted in numerous articles, books and digests [Refs. 5: pp.16-24, 6 : pp. 424-429, 1: pp. 42-60, 7: pp. 100-102, 8: pp. 97-103, 9: pp. 656-658, 10: pp. 24-30]. The purpose in recounting it here is not to present new insights, but rather to briefly provide an introduction into the conditions which fomented a regulatory system of management.

Use of the spectrum began around the start of the Twentieth Century, primarily for communications with sea-going vessels. Aside from naval forces, the other major user of the airwaves at that time was amateur radio operators. When the amateur transmissions began interfering with U.S. naval communications, the U.S. Navy demanded federal regulation to prevent this interference.

The direct consequence of this action was the Congressional Radio Act of 1912. With this legislation, certain frequencies were delineated for commercial operators and others for amateur operators. Additionally, all radio operators were required to obtain a license from the Secretary of Commerce, the designated authority for accreditation.

In 1920, the first commercial radio station began broadcasting. Within a few years, several hundred commercial stations were in existence and with them came piracy of the airwaves, monopolistic conditions, offensive advertising, interference, and other undesirable industry elements. To combat this situation, interference in particular, several conferences were held in the early 1920's, without much impact upon use of the spectrum.

Property rights were established in a de facto sense during this period and confirmed in a 1926 Chicago court ruling. However, the federal government took steps to declare the airwaves public property. The Radio Act of 1927 declared that the spectrum belonged to the public, and no property rights could be assumed by users. To manage this public resource, the act created the five man Federal Radio Commission (FRC) and empowered it to allocate frequencies, issue non-transferable broadcast licenses for a period of three years, establish qualifications for broadcasters, set technical standards for equipment, and determine hours of operation and transmitter power for stations. After the establishment of the FRC, interference of the airwaves was significantly reduced.

The FRC held the power to grant, renew or revoke any broadcast license, until Congress replaced it with the Federal Communications Commission in the Communications Act of 1934. Whereas the FRC had dealt primarily with the broadcast industry, the FCC's power was extended to other communications methods, such as telephone and telegraph. As far as the airwaves were concerned, the new act retained the basic tenets established in the Radio Act of 1927. It is the act of 1934 which basically determines spectral use, even to this day.

C. ROLE OF THE FCC

The FCC is the agency which controls all civilian use of the spectrum. Federal use of the airwaves is controlled by the Interdepartmental Radio and Advisory Committee (IRAC), which receives technical support from the National Telecommunications and Information Administration (NTIA). The International Telecommunication Union (ITU) is the worldwide agency which provides overall rules for the utilization of the spectrum and assigns different portions of the spectrum for designated uses. Therefore, FCC (and IRAC) rules reflect the allocations made by the ITU.

The FCC is composed of seven members who are appointed by the President and confirmed by the Senate for seven-year terms. These commissioners hold jurisdiction over all nongovernment spectrum such that no user (other than a federal agency) may occupy spectrum without the FCC's permission. Under the charter of the Communications Act of 1934, as amended, the Commission regulates the radio communication activities of all state and local governments, as well as the activities of private and nonprofit broadcasters, communications common carriers, industry, transportation, business, and other safety and special radio users.

The Executive branch of the government provides recommendations to the FCC as to what should constitute U.S. regulatory policies. However, the Commission is under no obligation to conform to these recommendations. The Commission regulates civilian communications by a process of rule making. Once a policy decision is reached, the FCC is also the agency required to implement and enforce the decisions. [Ref. 9: pp. 171-172]

The fundamental responsibilities of the FCC can be divided into three parts: allocation, assignment and setting technical standards. In allocation, a block or band of frequencies consisting of a number of channels is designated for the use of a particular service, such as television or cellular phone. Assignment is the process of determining which particular user will be granted the use of a portion of the spectrum allocated to a designated service. The assignment process itself can be divided into two phases: user classification by service and the actual selection of the user. In setting technical standards, the FCC is attempting to increase the overall utility of the spectrum by ensuring efficient use and preventing spectral interference. This is accomplished by the promulgation of detailed instructions to individual users concerning equipment parameters, such as modulation techniques and harmonic emissions. Standards are set both to limit out-of-band interference and also in-band interference. [Refs. 11: pp. II-3-II-4, 12: p. 24, 13: pp. 4-7]

D. POLITICAL ASPECTS OF SPECTRUM MANAGEMENT

Political processes relating to spectrum regulation are just as important, if not more so, than the administrative proceedings associated with regulatory control. Indeed, one author has gone so far as to state that:

> Communications in many respects has become politics, and politics has become communications. Therefore communications policy is every bit as contentious, all-encompassing, obscure and fast-changing as U.S. federal politics itself. [Ref. 14: p. 6]

Before the Commission makes significant policy changes, a political process as well as an organizational and intellectual process occurs. Major players on the political side of decisions include the Congress, President, courts, the regulated industries, Political Action Committees, lawyers, and of course, the public.

1. Congress

Any major policy changes undertaken by the FCC are subject to congressional scrutiny. In this process, both Houses, each with up to a dozen committees and subcommittees granted communications policy oversight, have the capability to shape spectrum management. Congressional spectrum management reflects, at least in part, the public nature of the spectrum and recognizes that the spectrum possess unique properties in furthering social, political, cultural, educational and recreational goals [Ref. 15: p. 35]. Congress wields influence over management policy by virtue of its ability to revoke or overrule the Commission through law, the power to confirm or deny the appointment of commissioners advocated by the President, and most significantly, the power of the purse strings. Congress controls the FCC's budget [Ref. 3: p. 77].

However, Congress, and even the public, tends to give the FCC only occasional attention. Thus, it often fails to wield its considerable power over the Commission. Additionally, the diffuse interests of Congress, and again the public, tend to mitigate control over the Commission. [Ref. 3: p. 75]

2. The President

As stated before, one basis of presidential control in spectrum management policy is the chief executive's authority to nominate commissioners to the FCC and name the head commissioner. Congress has somewhat limited this power of appointment by decreeing that no more than four members of the Commission may be of the President's political party. A second influence granted to the President over the FCC is the ability "to make communications policy through channels which are competitive with the FCC." [Ref. 3: p. 79]

3. The Judiciary

While the judicial system is not a policy making body, nor was it ever intended to be, it does have an impact upon spectrum management. This occurs through the process of interpreting statues and ruling upon the legality of cases brought before it. The judiciary, although not subject to the same political lobbying process as Congress, the President or the FCC, is nonetheless an arena for politics where different interests seek vindication or a favorable policy ruling. [Ref. 16: p. 68]

4. The Telecommunications Industry

While Congress, the President and the public exert pressures upon the FCC, the influence they bear pales in comparison to that wielded by the regulated industry itself. Although this was not intended when the Commission was formed, this situation is obvious for at least two reasons. First, unlike Congress and the public. the industry concentrates its attention on the actions of the Commission. Constant, informal contact between the industry and the FCC often gives the industry significant influence over the Commission. Second, Congress and the general public have exceedingly diffuse interests concerning utilization of the spectrum. The industry's interests are much more narrowly focused (though not always coinciding).

Although the FCC was established to regulate the airwaves in the "public interest," the inability to define this nebulous concept often leads to regulation based on considerations which are only ascribed to public interest. In light of the influence industry exerts on the Commission, the public interest is often seen as being in the best interest of the industry, or a compromise between industry and other stakeholders, such as citizens groups. [Refs. 3: p. 75, 16: pp. 60-61]

Industry involvement in FCC policy making is also enhanced by the fact that the industry is extremely wealthy and controls vast technological resources. Wealth enables the industry to hire many former commissioners and their staff after leaving the FCC, either within the industry or within law firms supporting the industry. "Of the 33 commissioners who left the FCC between 1945 and 1970, 21 went to work for the communications industry or communications law firms." [Ref. 3: p. 74] Industry influence also slows the implementation of spectrum technology. The industry is naturally interested in protecting technology which represents heavy investment. If the FCC protects existing economic investment to satisfy the industry, as has been claimed, then it must favor current systems, rather than promoting new systems however more technically advanced. This protection continues until the industry itself seeks the change. [Ref. 3: p. 75]

5. Political Action Committees

Another powerful influence acting upon the FCC is that of Political Action Committees (PACs). Communications industry related PACs are among the richest special interest groups in Washington. They are typically interested in preserving the status quo of the industry. PACs often accomplish this end through the help of congressional incumbents who are dependent upon the PACs for financial support. Incumbents, obligated by money, often:

> . . .fight changes in radio-band allocations and work to preserve the current division of the radio market. They push for the retention of advantageous government subsidies and close government regulation of competitors. [Ref. 17]

6. The Legal Community

Given the importance of the liaison between industry (including PACs), the Commission and Congress, it is now easy to understand the role of attorneys in this process. It is the lawyers who represent those organizations interested in influencing management policy.

Regulation, to a large extent, depends upon law school educated personages: lawyer-politicians, lawyer-aides and lawyer-lobbyists. The reason for this is, for better or worse, that regulatory law is communications law. Those most versed in its application will be the most successful. However, there is one other aspect--the old adage that it is not just what you know, but who you know. This can explain the large number of former FCC employees who later work for either law firms or the industry, as mentioned above. [Refs. 14: pp. 24-25, 3: p. 75]

E. CRITICISMS OF FCC MANAGEMENT

Critics of the FCC's ability to manage the spectrum are not shy in voicing their points of view. An examination of these criticisms reflects one major point: inefficient use of the spectrum. However, this criticism has many different aspects, depending upon an author's particular concerns and point of view. Following are some of the more common complaints.

Efficient use of the spectrum is hindered by the cost and delays of hearings, national instead of regional allocation, restrictions on technically possible use and the treatment of the spectrum as a "free good." [Refs. 11: pp. II-2-II-7, 18 : p. 1500]

That Commission hearings on spectrum use cause delays and are expensive to the government is an obvious point. A review of the history of regulation shows instances where years passed before the resolution of allocation hearings were finalized. As to the cost of hearings, a House of Representatives Report accompanying House Resolution 2965, commonly called the Emerging Telecommunications Technologies Act of 1990, provides an example of the monetary costs incurred in spectrum reallocation (the bill proposes to move 200 MHz of the spectrum from government users to the FCC for assignment):

> The cost of such a change is highly uncertain, because it would depend on the choice as to which portions of the spectrum would be reallocated. Costs to federal agencies for property, equipment and facilities could total hundreds of millions of dollars--though the DOC (Department of Commerce) and FCC presumably would seek to minimize both cost and disruption in their selection of frequencies to be reallocated. Other costs to the government would total about $3 million over the 1991-1995 period, assuming appropriation of the necessary amounts. . . .Based on information from the FCC, CBO (Congressional Budget Office) estimates that preparation of the plan for distributing the specified frequencies would cost about $300,000 in both 1993 and 1994. Finally, it would cost the FCC about $50,000 in 1994 and $100,000 in 1995 to monitor the implementation of the distribution plan. [Ref. 19: pp. 9-10]

From this estimate it can be deduced that the historical costs of FCC management of the spectrum has been astronomical.

The problem with the current national allocation plan is that some bands are extensively used in specific areas of the country, and thus very valuable, while in other areas the same bands have little or no use. For example, the Forestry Radio Service is extensively used in rural timberlands and national parks, but of little use in urban areas. However, under national allocation, those bands can not be used by overcrowded services in urban areas, such as land mobile radio. Airwave characteristics and geographical separation would argue for regional allocation in some bands, to allow spectral reuse or sharing. While national allocation was administratively simple when the practice was instituted, its inflexibility in relation to today's spectrum needs contraindicate its continuation.

Inefficient use of the spectrum is also promoted by another licensing-allocation practice, that of "first come, first served." The problem with first come, first served is that it is often nearly impossible to reallocate the spectrum to take advantage of technological advancements that would benefit spectrum utilization. As discussed earlier, this situation arises because of the political situation surrounding the FCC and the incumbents' heavy equipment investments in the current band. The consequence is that new services tend to be allocated bands which are not appropriate for those services. [Ref. 15: p. 55]

Restrictions on technically possible use, critics contend, also produce less intensive or less profitable spectral use. This situation occurs because of the FCC's power to set technical standards. Standards to prevent interference are based on the technology of that era. Technical advances in spectrum saving equipment can and has made these standards obsolete. For example, television and FM radio broadcasting areas were established to prevent interference. However, because of technical advances, more stations can now be added without interfering with the established broadcasters. Yet new stations are not added, not because they would be unprofitable, but rather because current rules prohibit new stations under older interference standards. Petitions to amend these rules are quite expensive. [Ref. 11: p. II-7]

The "free good" aspect of spectrum management is a criticism exposed by many economists. Under the current system, the cost of spectrum is zero. In other words, it is a free good. This means there is usually no incentive to reduce equipment bandwidth requirements since this would increase equipment costs. For certain industries, as long as the spectrum is a free good, bandwidth will substitute for sophisticated technology.

F. SUMMARY

The evolution of the telecommunications industry and government regulation, while having a profound influence upon each other, have not proceeded apace.

The development and expansion of radio led to increasingly chaotic conditions early in this century. This led to regulation of the airwaves, based upon the "public interest." While this has and will continue to be difficult to define, it basically requires that the communications industry provide efficient and responsive service to the public. This has often meant the introduction of new technology. Herein lies the problem.

Regulation of the industry based on the technological knowledge and equipment at a particular time is not necessarily the best regulation when technological innovation and advancement occurs, especially when it occurs at a rapid rate. The inability of the Commission to keep pace with technological improvements can not be blamed entirely on the failure of the Commission to anticipate future needs and developments. The communications industry itself has and continues to play a significant role in its own regulation through the political process.

The shortcomings imposed by current spectrum management practices have been the object of several reform proposals. These include organizational, managerial and political improvements. However, the most sweeping proposals involve the use of market forces. Before examining this significant change, it is useful to examine the economic aspects of spectrum utilization.

III. ECONOMIC CHARACTERISTICS OF SPECTRUM USE

A. INTRODUCTION

The frequency spectrum is a natural resource which is primarily valued for its social contribution. While many other resources have social advantages--waterways and forests for recreation, public land for minerals--they are also viewed with an eye towards economic applications. Any non-economic use of such resources is always balanced by the knowledge of opportunity costs foregone. [Ref. 15: p. 34]

Why is the frequency spectrum exempt from economic scrutiny? Is it that the spectrum does not share economic characteristics indigenous to other natural resources? The answer to this must be no. While in some respects the airwaves are a unique resource, the exclusion of the spectrum from economic analysis is not based upon any inherent economic deficiencies. Social factors of spectrum use are currently seen as being more important than economic ones.

But in denying spectrum a place in the public market, we fail to define the intimate relationship between supply, demand and prices. The cost of supplying a good is the value of other opportunities foregone by the conscious act of supplying that good over another. That is, supply is based on opportunity costs. Demand is based on value to a consumer. It is the interaction of these two factors which determines a market price. Therefore, it is the market price which links the opportunity costs of the resource to its value to consumers. When this relationship of opportunity costs to value is maintained, a market is in equilibrium and supply will equal demand. However, the collapse of this relationship results in a disequilibrium market where either supply or demand will be in excess.

B. SUPPLY AND DEMAND

Scarcity in the radio frequency spectrum is evidenced by the fact that demand for spectrum usually exceeds supply, though spectral scarcity does not exist across the entire spectrum. Scarcity exists primarily in certain frequency bandwidths for specific uses of a regional, geographic and economic nature. Technically or economically unusable regions are not affected by the problem of scarcity. But in those bandwidths which are exploitable, demand continues to grow as new uses are developed and old uses retained.

1. Nature of the Resource

The primary economic value of the spectrum resides in its ability to transmit various types of information over varying areas at differing rates in an intelligible manner. Excessive demand creates interference, which leads to signal degradation, or in the worst case, to an unintelligible signal. This devalues the spectrum, which eventually reaches zero when the signal is unrecognizable at the receiver. [Ref. 15 : p. 15]

That demand exceeds supply is not exclusive to the radio spectrum nor is devaluation of a resource by overuse restricted to the spectrum. However, unlike other natural resources, the spectrum has some unique attributes:

- It is used, not consumed.
  When the spectrum is not used, it is being wasted. In this respect, allowing frequencies to lie fallow for intended future uses, given spectrum scarcity, is wasteful. However, the extent of capital investment required for utilization of currently unoccupied spectrum could preclude future, more economical uses of that spectrum, or a loss of current investment. In this respect, "hoarding" is economically rational and would be observed in a market setting.

- Dimensions of space, time and frequency are interrelated.
  Different spaces, or geographical areas, can use the same frequency at the same time, given enough separation. Similarly, the same space can use the same frequency, given different times. Alternatively, the same space can use different frequencies at the same time, given enough separation.

- Spectrum is a resource available to all.
  Given investment in the proper equipment, which ranges from the inexpensive to multimillion dollar systems, anyone can have access to the spectrum as a sender and or receiver. For example, the purchaser of a twenty dollar transistor AM/FM radio, the purchaser of a $1,000 stereo system and the purchaser of a million dollar radio station each use the same portion of the spectrum, albeit for different purposes.

- The resource is wasted when it is used for tasks which are as easily done in other ways.
  Given spectrum scarcity, the use of substitutes, such as cable, fiber optics, wire or waveguides, could be used to reduce demand on the spectrum. Alternatively, while there are some arguments that there are always substitutes for the spectrum, communications with moving vehicles such as ships, planes and motor vehicles would be convoluted at best by the use of substitutes.

- Spectrum is used inefficiently when its parameters are incorrectly applied.
  Parameters in this instance refer to propagation characteristics of frequencies within the spectrum. For instance, while AM frequencies between 550 and 1640 KHz are utilized for local broadcasting, the skywave characteristics of this band at night causes signals to be transmitted far beyond a "local" area.

- The resource is subject to pollution.
  Pollution in this case refers to interference of the intended signal. This can be caused by other signals, man-made electrical noise, or even cosmic or metrological noise. [Ref. 4: pp. 4-6]

The radio spectrum also differs from other natural resources in that it exhibits characteristics of both "stock" and "flow" resources. [Ref. 15 : pp. 26-29]

The spectrum is a stock resource in that it is finite. The more which is used, or occupied today, the less is available for use tomorrow. This is a general statement which may be said to have many exceptions, but given the fact that intensive capital investment for equipment is required to occupy the spectrum, enormous pressures are thereby created to retain any particular portion of the spectrum to which an incumbent has gained access. Therefore, there is less available for tomorrow. As stated earlier, although the AM band is not particularly suited to local broadcasting, the investment in equipment for that particular purpose on that band has precluded its use for other purposes. To prevent such diseconomies as this in the future, the practice of stockpiling frequencies has arisen.

The spectrum's attribute as a flow resource resides in the temporal nature of the airwaves. The spectrum has a time aspect, much like the flow of a river. If water is not drawn from the river at one time, the use of that particular water which has flowed past is lost. However, different water is still available a moment later. So it is with the spectrum. Abstention from spectral occupancy at one moment causes the errant user to lose the benefits which could have been derived at that time, but does not preclude future benefits of occupancy. Also much like water, the spectrum displays the qualities of a shared resource. Users have no incentive to refrain from using the resource, even to the detriment of others. Without the assurance that others will not use the resource, denying its optimum or desired use to the initial user at a future time, the initial user has no recourse but to obtain the maximum benefit of the resource, regardless of whether he has an immediate need.

Even among flow resources, however, the spectrum is unique. Depletion of this resource requires no reinvestment for its maintenance. Once a signal ceases, the spectrum returns to its original state, on the condition that no other signal invades the vacated frequency. That is, this resource renews itself given the opportunity. However, the opportunity of renewal should not be overestimated. Extensive investment in equipment, the myriad uses of the spectrum and the possibility of non-intentional interference mitigate a return to a pristine state.

2. Extending the Supply

It is possible to either administratively or technologically expand the amount of spectrum available, to a point. Administratively, the use of a particular portion of the spectrum may be withdrawn from one user in order to give it to another. This does not, of course, expand the resource but it does extend the spectrum of a heavily used bandwidth at the expense of a service which places a lesser demand on the spectrum. Obviously, this technique has limited applicability. [Ref. 12 : p. 51]

Technologically, the supply of spectrum may be extended on the "intensive" and "extensive" margins. Expanding the intensive margin involves advances which allow more users or services to occupy the same amount of spectrum than is currently done today. Reducing equipment bandwidth requirements is an example. Expansion on the extensive margin seeks to extend the total amount of spectrum available. The use of higher and higher frequencies is an expansion of the spectrum on the extensive margin. Expansion in either of these margins will account for more usable frequencies for more users. [Ref. 15: pp. 15-16]

This does not mean, however, that there is an unlimited supply of the spectrum. Eventually, a point is reached where it is no longer feasible to technologically reduce frequency bandwidth and still retain an intelligible signal, nor is the spectrum infinitely extendable.

3. Identifying Substitutes

In the strictest sense, every resource has substitutes. For the radio spectrum, wire, cable, waveguides and fiber optics are obvious alternatives. Less apparent is that people, storage spaces and motor vehicles are also substitutes. For example, mobile radio reduces the quantity of vehicles, drivers and fuel needed in trucking and taxi services because of coordination efficiencies. Thus, spectrum can be replaced by the use of those same resources.

Even in the field of broadcasting, significant substitutes have arisen in the form of cable and videocassette recorders. While cable has long presented an alternative to broadcasts in metropolitan areas, and indeed has surpassed the airwaves as the primary method of delivering home entertainment, the past diseconomies of cabling rural areas has kept broadcasting a viable option. However, even this last argument has lost ground with the commercially successful cabling of Montana. [Ref. 20]

These insights recognized, the true test of the suitability of a substitute is based on economic rather than technological grounds. The exception is when the issue is related to safety--maritime, police, fire, etc.--where the use of spectrum is adjudged appropriate on social and political grounds, rather than economic. The test must ascertain if the cost of a substitute is less than that of the original resource. Although it is difficult to quantify costs in most cases, the fact remains that substitutes are available which satisfice to varying degrees.

Yet the user is at a disadvantage: he is not allowed to strike a balance between spectrum and its substitutes. A lack of price incentives prevents the creation of an optimum balance. [Ref. 15: p. 25]

4. Optimal Allocation

One measure of optimal allocation is when productive factors are distributed so that the marginal value of productivity of all ends is equal. Thus any change in assignment will not increase economic value.

A better mechanism for identifying efficient, or optimal, allocation of the spectrum is to determine whether the benefit gained from any reallocation is greater than the benefit lost as a consequence. If this is the case, then the resource was not optimally allocated. However, to make this type of efficiency judgment requires some objective measure of value. If some standard of value were common, such as monetary or social value, it would be a relatively simple matter to determine optimal allocation by identifying the greater benefit. However, in the absence of such common values, the process is exceedingly difficult.

Therefore, perhaps a better mechanism for identifying efficient allocation without a value-based system would be to determine whether any reallocation of the spectrum benefits one spectrum user at the expense of another user. Using this measure of optimal allocation, it can be said that some spectral bands, such as mobile land radio, are efficiently allocated. Spectral scarcity is such that moving frequencies from one user to another benefits the new user at the expense of the former user. However, this same argument, if used with the television industry, would show inefficient allocation. Unused TV bands if transferred to mobile radio would greatly benefit that industry without affecting television if the frequencies reallocated were used in the same geographic area and had sufficient separation from bands in use so as not to cause interference. Similarly, unused frequencies held by the government for future allocation are not being efficiently used, unless the bands are currently technologically unusable. Unusable frequencies do not meet this criteria since even if they are assigned, they do not benefit the new user and their allocation is not detrimental to the former holder.

However, given a value market, if the economic input of one service is less than that of another, then a change would certainly be in order. If the financial benefits of mobile radio in a given area outweigh its pre-emption by broadcasting, then spectrum should be reallocated. This, of course, necessitates a financial definition only, undoubted by social concerns. But, it does illustrate the difficulty in determining an "objective" definition of most "valuable" use. A market would have no such difficulty. The highest bidder would have the greatest monetary return on investment.

C. OPPORTUNITY COSTS AND PRICES

The economist defines the opportunity cost of any resource as the measured difference of its use for one particular purpose in lieu of its next best alternative use. Using the frequency spectrum as the input to production, the problem is to determine the opportunity cost of using a frequency or band of frequencies for a particular purpose.

The opportunity cost of spectrum will depend upon the amount of bandwidth used, area covered by the signal and the length of transmission time. Additional factors include technological aspects, such as the suitability of the frequency for its intended use, and the size of the population in the area which the signal is intended to reach. The difficulty in measuring many of these variables often leads to the conclusion it is impossible to place a price on the spectrum, at least a price based only on opportunity costs. [Ref. 21: p. 66]

However, a price derived within a market does not have the same complication. It is not necessary to identify opportunity costs to in order to set a price.Without the requirement to establish opportunity costs in order to set a price, the market relationship between supply and the cost of suppling remains intact.

1. Costs of Free Spectrum

If, as is the current situation, a service does not pay for spectrum used, there is no incentive to adopt a system design which uses the least possible amount of spectrum. Rather, there are incentives to use more spectrum so that the system may use fewer resources in areas for which the user is charged. For example, given two specific spectrum uses, one designer may utilize more spectrum in order to save money on the transmitter or receiver by utilizing simpler, and hence less expensive, technologies. Extending this analogy, it is obvious that the total amount of spectrum needed will eventually exceed the spectrum available. At that point, one or both users must adopt spectrum saving designs, accept substitutes, or exit the industry. If spectrum saving designs are adopted as a strategy, then:

> The opportunity cost of the spectrum to the first system is the cost saving that the second system obtains if a small amount of spectrum were transferred to it. A symmetric definition applies to the second system, and it can be shown that the economically efficient designs for both systems occur when their respective opportunity costs are equal. [Ref. 11: pp. II-13-II-15]

A second facet of an essentially free spectrum is that because users have been able to obtain spectrum at no cost, paying only nominal licensing fees, no incentive exists not to horde more spectrum than is currently needed. The rationale being that at some future time, the bandwidths may be needed. It is better to obtain and retain unused spectrum than to allow others to gain control of them. [Ref. 21: p. 65]

This behavior is exemplified by the television industry. Whereas the FCC has allocated 82 channels (bandwidths) to television, only a small fraction of that number are in use at any particular geographic location. Yet the industry has successfully lobbied for years to retain all bands even in the face of spectral scarcity by other users in the same bands (land mobile radio for example). Only recently has the television industry stated a need for this unused spectrum. The industry now claims those bands will be needed when High Definition Television (HDTV) is introduced in the U.S. That event is expected to occur before the turn of the century (the FCC intends to announce industry standards mid-1993). Prior to the advent of HDTV, the industry had retained large portions of the spectrum for no other reason than that it was costless to them, regardless of the opportunity costs to others.

This does not imply that nonuse of spectrum is always wasteful. Vast portions of the spectrum are currently unused because of technological constraints, upper portions of the gigahertz range being an example. In this sense, portions of the unused spectrum are not being wasted. The spectrum is wasted only when potential users exist and are excluded.

2. Distortion by Price

Prices are an essential element in coordinating the users' demand to scarcity. The cost of a good compels us to weigh the economic value to alternatives against the cost of obtaining the primary resource. It is in this way that we make choices which are most beneficial to ourselves.

Since there is no price associated with spectrum use, or non-use, there is no incentive to utilize spectrum saving technology. As a rule of thumb, the more efficient a system is in utilizing spectrum, the more expensive is the technology used in building that system.

This is not to imply that the use of sophisticated equipment in and of itself should be the only criteria associated with determining who should have use of the spectrum and the amount that they should have access to. An approach such as this merely replaces associated spectrum opportunity costs with the substitution costs of other resources, such as technological innovation. This is the substitution of one resource for another, and may fail to remedy total opportunity cost of all inputs. [Ref. 11: pp. II-13-II-15]

Therefore, more efficient technology should only be used if the economic benefits of the technology outweigh the costs associated with using it. However, as long as prices are disassociated from spectrum use, current users will have no incentive to invest in frequency saving technology even when economic benefits justify higher costs for equipment.

D. RECOGNIZING EXTERNALITIES

Consequences of an action not taken into account when making a decision are known as externalities. The consequences may be either beneficial, harmful, or, as is usually the case, a combination of both.

Beneficial externalities of spectrum use are easily recognizable. Safety of water, air and surface travel is greatly enhanced through the use of navigational and activity-coordinating radio frequencies--an obvious benefit, though not necessarily the primary goal. Positive externalities include national and international connectivity, and a host of other obvious advantages.

Against beneficial externalities must be balanced negative externalities. These are more difficult to address, but are more important in establishing the economic viability of the spectrum. The costs of using the airwaves must account for costs incurred by the use of that spectrum, especially since no price is associated with it.

Major negative externalities of the spectrum may be divided into three classes: propagation uncertainty, restriction of a signal, and complex interference. Propagation uncertainty defines the inability to ensure that a transmitted waveform will retain the characteristics of its intended form. An example is afforded by a local AM broadcast. For this purpose, the signal is transmitted as a ground wave. However, because of ionospheric differences between day and night, a ground wave during the day may become a sky wave at night. This extends the range of the signal far beyond its intended area, unless other factors (specifically power) are changed.

This is related to the second major externality, restriction of the signal, although not in the same manner. With current technology--which is unlikely to change significantly in the future--it is impossible to confine a signal to a precisely defined geographic area or to create a situation where a signal stops propagating once it passes its intended receiver. In one sense, this may be considered a benefit for use of the spectrum. But, as is usually the case, the inability to restrict a signal results in interference to other signals because of frequency compatibility or compatibility of some harmonics of a signal with the interfered signal. The use of directive antennas can mitigate, but not eliminate, this problem.

The third major externality, complex interference, is the interference between two different frequencies whose transmitters are located in the same place. These frequencies do not interact until a third, different frequency begins radiating from a transmitter in the same location. Each externality alone, and especially in combination, must be addressed before a viable market for spectrum can be developed. [Ref. 12: pp. 69-72]

E. OBSTACLES TO PROPERTY RIGHTS

While defining negative externalities presents problems in establishing a market, an even greater obstacle is presented by property rights. Property rights may be broadly defined as the legal justification given to an owner of a resource or good to dispose of that resource in the best benefit of that owner. That is, no imposition should be placed upon an owner as to retaining, selling or leasing of that good. While property rights have traditionally been associated with such resources as land, water, and the goods taken from them, the spectrum presents a unique case.

From soon after its discovery, the spectrum has been declared the property of the people, a public resource. Therefore it cannot be owned by a specific person or organization and no property rights have been associated with it. Just as the majority of the public would be loath to sell Yosemite National Park because of its special attributes, this same feeling does not extend to the majority of land in the United States. Reluctance to relinquish the public property rights to Yosemite to a single person or organization also extends to the spectrum because of its special attributes.

However, until property rights for the spectrum are defined, the establishment of a market is not viable, and without a market there is no assurance that a resource is being employed in its best value. For the essence of property rights is the ability to transfer those rights to those who value them most--for a price.

F. CONCLUSION

The frequency spectrum displays economic characteristics of other natural resources, yet has unique differences. These differences are not so great or so unusual to economic theory, however, as to preclude the development of a market which will establish costs and prices for the spectrum. Once this is done, supply and demand will reach an equilibrium promoting economic efficiency which now does not exist.

The primary deterrent to this objective is the lack of a coherent definition of property rights. There are serious obstacles to overcome in its definition, but these are surmountable--once negative externalities have been mitigated.

IV. MOVING TOWARDS A MARKETPLACE FOR THE SPECTRUM

A. INTRODUCTION

Currently, no market for the spectrum exists. The closest approach to it is a market for technological assets, such as broadcasting facilities. While it often appears that purchase of the equipment carries with it the right of radiation, this is not a viable spectrum market.

The establishment of a marketplace for the spectrum will be a difficult task for a variety of reasons: resistance to paying for what is now free, social concerns, political pressures and the general difficulties of defining a market.

However, there are some means to reduce these obstacles. Political and practical objections could be mitigated if a market was close to the current system. Likewise, any system must be responsive not only to economic concerns but also to social concerns. Lastly, the market should allocate spectrum to those who most efficiently use it, not just to those most able to purchase it. [Ref. 15: p. 87]

B. MITIGATING MARKET IMPERFECTIONS

1. Negative Externalities

As explained earlier, negative externalities can be broadly grouped in one of three categories: propagation uncertainty, signal restriction and complex interference. Only when the effects of negative externalities, alone and in conjunction, are mitigated will a viable spectrum market be possible.

While this is a straightforward statement of the problem, its resolution is not simple. Propagation uncertainty can never be entirely eliminated. Such is the nature of the beast. However, selection of a frequency bandwidth whose characteristics are most suited to the task at hand can moderate the effects of uncertainty. For example, local broadcasts would tend to remain localized if FM instead of AM bands were employed for the purpose.

Restriction of a signal to an area and complex interference similarly are not easily solved. Various schemes have been proposed for signal restriction. The most workable of these plans in terms of legal and economic viability involve either defining the inputs to radiation (time, power and antenna height/directivity), or measuring the strength of a signal at a given distance. Likewise, negating the effects of complex interference has no one perfect solution. The central problem is deciding exactly which component of which system is creating the interference. The simplest answer is that the last system which radiates before the problem appears is the cause of the interference. Several options are available to correct the situation. Changing frequencies, better insulation of equipment, or reimbursements to others for tolerating the interference are feasible solutions. [Ref. 18: pp. 1519-1529]

Basically, what is being described in these solutions is a method of frequency coordination aimed at eliminating or lessening the effects of interference. Currently this is the goal of the FCC since there is no other mechanism for attaining these ends. These proposals attempt to establish an economic basis for removing the causes of interference. The liability for interference is to be borne by the rights-holder of the cause of the interference. Interference raises the total cost of the system by requiring compensatory payments to rights-holders of systems which are being interfered with. Thus, when the cost of modifying the offending system is less than the cost of punitive damages to other systems, the offender will seek to invest in innovations which increase the economic benefit of the system. Thus, spectral efficiency is enhanced, not through governmental involvement, but through the marketplace.

If a rights-holder of a portion of the spectrum is expected to sustain the liabilities associated with negative externalities, then the benefits that accrue from ownership should also be his. Until property rights are defined, this will not be the case.

2. Property Rights

There are difficulties in defining rights. Utilization of the frequency is not an absolute science. The energy of a signal is subject to many variables--water vapor, rain, the sun--which can affect its strength negatively or positively. Noise, either natural or man-made, can also affect the quality of a signal. The ill-defined nature of signal propagation thus argues against the establishment of property rights, as opposed to defining rights of more tangible goods.

Yet at least four conditions have been proposed as necessary for the establishment of spectrum property rights: emission rights, admission rights, use rights and rights of transferability. Emission rights refer to the justification of using a frequency with clearly recognized characteristics, such as whether a band is suitable for long or short range transmission. The next condition is the ability to refuse spectrum admission to another whose use could cause interference. Both of these depend upon the next right, the ability to choose the bandwidth which best satisfies the need for which spectrum is desired. Last, and most important, is the capability to transfer rights of emission and admission to others. [Ref. 22: p. 232]

These conditions are not absolute and may be exchanged by other concepts, such as defining rights as a relationship between time, area, space and frequency compatibility [Ref. 18: p. 1501]. Others have advocated using the technical characteristics of the transmitting equipment to define rights associated with the spectrum [Ref. 4: pp. 209-210]. Several alternative proposals exist, but either share similar arguments to the proposals already outlined or are vaguely defined [Ref. 12: pp. 64-69].

Potential problems of defining property rights exist in all proposal concepts because of costs involved in latitude or enforcing these rights. Given these difficulties, any definition of rights may seem to be a hopeless cause. Yet until some definition concerning property rights is defined and accepted, no market can be established. The question should not be which is the best proposal, but rather what is a workable proposal which can be the basis for refinement. If this seems to be an arbitrary decision, recall that rights currently associated with tangible resources, such as land or water, were not established overnight. From some mutually agreeable starting point--some centuries old--these rights have evolved into their current forms. The spectrum can benefit by the same process.

Part of this process will be the determination of the time period for which these rights will be granted. That is, should rights be granted in perpetuity or for a limited period? Additionally, what latitude will be granted for transferability of rights associated with the spectrum? Any market proposal must grant an "owner" the ability to transfer all associated rights, otherwise economic incentives for efficient occupancy of the spectrum will not exist. As for the period of occupancy, the federal government's policy on oil leases offers one sensible example. In federal oil leases, the purchaser of the rights maintains control for as long as the resource (oil) is being exploited, either through exploration or actual pumping of petroleum. A lease expires when the resource is not used. The extension of this policy to spectrum occupancy is obvious.

However, if a market exists with transferability, then a period of occupancy wouldn't be needed. As long as spectrum is transferable, owners would not allow it to go unused. Rather, they would sell or lease the spectrum.

Once rights are established, the problem then becomes one of assigning and allocating the spectrum.

C. ALLOCATING AND ASSIGNING THE SPECTRUM

Allocation is the process whereby various parts of the spectrum are designated for use. This is in contrast to assignment, which is the process in which allocated bands are dispensed to an individual or organization.

Traditionally, the objective of spectrum management has been to allocate spectrum so that the amount of spectrum allocated reflects the value of the service for which it is to be used [Ref. 13: p. 8]. Unfortunately, this often does not take into account changing needs and the priorities of established and potential users. The second aspect of spectrum management, assignment, while sometimes using the criteria of social needs, all too often actually employs the precept of first come, first served. Yet regardless of the mechanism of distribution, under the current system the rapid pace of technological advancement in spectral equipment is not adequately recognized or utilized.

In contrast to FCC allocation and assignment, several other mechanisms have been proposed to serve the same function within a marketplace: charges or fees, auctions and lotteries. To a greater or lesser extent, these proposals could replace some or all of the restrictions currently imposed by the FCC: type of use, class of user, system design and spectrum loading.

But before discussing these means, the problem of what to do with current spectrum users or holders must be addressed. It has been suggested that to create a full-fledged market, it is only necessary to invest current spectrum users with the property rights discussed above. Outright ownership would create incentives to sell spectrum for profit and provide a method for acquiring more spectrum from those willing to sell. Additionally, this course of action might reduce the resistance of current holders to the instituting of a spectral market. However, this policy would most likely increase resistance to change by those who do not currently occupy the spectrum. [Refs. 13: p. 16, 15: pp. 88-89]

Arguments can be made for either position, but once again, it is more important to decide upon a course of action than to delay implementation of a market because of differences in perspective.

Compromise between both positions is a possibility, but current users would seem to have the edge since occupancy can be seen as having established some rights through usage. If the opposite viewpoint prevails, then charges, fees, auctions or lotteries could be used to allocate and assign the spectrum. Additionally, any spectrum currently not allocated or assigned would use one, or a combination of, these methods when that spectrum was opened for use.

1. Charges and Fees

The idea behind charges or fees is to establish total or partial value of the spectrum. Fees are suitable for either the allocation or assignment process, or both. However, if used only for assignment, none of the four restrictions currently administered by the FCC would necessarily be affected. Using fees for allocation would affect these restrictions. A charge placed on a specified band would be allocated to any service willing to pay the fee, with or without conditions of use regarding the four restrictions. Revenue produced by charges or fees could then be claimed by the government, and should help promote economic efficiency. [Ref. 23: p. 13]

However, it is not necessary that all charges or fees be collected by the government. At the opposite pole, all fees could be paid between competing users. Any newcomer could reimburse an incumbent for costs associated in vacating, sharing or lending spectrum for the benefit of the newcomer. This does not mean than an incumbent must automatically accommodate any and all newcomers. The incumbent would have the option to refuse use of the spectrum to newcomers. In this case the incumbent would be forced to recognize the opportunity costs of the spectrum held: the value of the spectrum to the incumbent as opposed to the value of that spectrum to the newcomer. If the value held by the newcomer is greater than that of the incumbent, then the expectation is that the incumbent would accommodate the newcomer. This is in contrast to the present system where a newcomer must choose between developing a new system in an unused band, using substitutes for radio, or attempting to administratively share, borrow, or preempt spectrum from an incumbent through hearings before the FCC.

Newcomers would now have the option to share a portion of the spectrum with an incumbent. This could have the added benefit of increasing efficient use of the spectrum. Inefficient spectrum use is fostered by a paucity of users: inexpensive spectrum substitutes for expensive equipment. With charges imposed, the opportunity cost of the spectrum will be realized and technically efficient use of the spectrum will be fostered, as long as investment in equipment is less expensive than the costs of excluding newcomers. Likewise, newcomers would choose to invest in new technology as long as it cost less than sharing or preempting spectrum of an incumbent. [Ref. 24: pp. 346-347]

Between these two extremes, any percentage of charges could be assigned to the government with the remainder paid to incumbents for renting or vacating a portion of the spectrum.

Numerous proposals have been advocated for use in determining fees, each attempting to determine the correct price for promoting economic efficiency. Establishing the "correct" price for the spectrum is seen as a major drawback in a fees systems. The determination of a formula for each industry using the spectrum, in order to establish fair fees, is the difficulty. [Ref. 11: pp. IV-17-IV-21]. This drawback suffers from using a cost based rather than a market based pricing scheme. Given the many factors necessary to establish a price based on costs, it would be practically impossible to set fair standards for all industries with competing uses. However, these defects would not appear in a market based scheme, since there is only one price. That is the price where supply equals demand, for whatever industry or use.

2. Auctions

Related to the use of fees is the establishment of an auction. An auction could be used to allocate a band to a specific service. As an assignment process, it would be used to choose between competing claimants. The advantage of an auction would be to eliminate the need for administrative hearings designed to determine use of the spectrum among numerous mutually exclusive yet similar applicants. The basis for an auction being that the user valuing the spectrum most will bid the most. Thus, determination of the price of a channel within the spectrum allocated would be determined by the market, which in turn would be influenced by the amount of spectrum allocated for assignment. Like fees, auctions could possibly eliminate some or all of the FCC restrictions, depending upon employment, and could produce government revenue. [Ref. 23: pp. 11-13]

The determination of whether to use an auction or a fee, or some combination, for allocation and assignment must be made only after deciding what the desired final state should be. Each system possesses different properties which will produce different outcomes regarding the structure of a spectrum market, such as the length of time over which spectral property rights may be exercised, willingness to introduce technical innovations and the ability of the government instead of private enterprise to generate revenues. It is not necessary that all services utilize the same system, but once a decision is reached, it must be a long term commitment if benefits are to be realized.

3. Lotteries

Lotteries are not an unexplored method for assigning spectrum. When the FCC has been swamped by spectrum requests initiated by emerging technologies (cellular phone being one example), it has used a lottery system because of inadequate administrative resources. Lotteries reduce administrative costs by consciously refusing to discriminate between applicants.

This is not to imply that the mechanism of the lottery is a particularly suitable method for assigning the spectrum. Indeed, abuses invited by this system have led to its virtual demise as an assignment tool. Lotteries tend to degenerate into a gamble for anyone who can furnish the necessary documentation. For a small investment, a winner gains control of a portion of a very valuable resource which can then be subsequently disposed of at an enormous profit. Lotteries provide an incentive to increase the number of applicants, thus exacerbating the original problem they were meant to solve. The true significance of the lottery is that it is an admission that some assignment mechanism, other than the current FCC administrative process, is necessary, at least in some cases.

D. MARKET IMPLICATIONS

An overriding characteristic of a market is the expression of individual preferences. This is not evident in any other system. A market provides information about accumulated private preferences based on demand. This is in contrast to an expression of "need." Need does not take into account relative alternatives, whereas demand does. While there may be a relationship between need and demand, in a market system the subjective concept of need is always subordinate to the more objective concept of demand. A market is only concerned with those who are willing to forego alternatives based upon a price system. [Ref. 10: pp. 47-50]

The establishment of any market is influenced by two fundamental philosophies: competitive and monopolistic ideologies. Spectrum markets are no exception. The monopolistic view of spectrum use stresses that strict control leads to optimum utilization. Duplication of equipment is eliminated, thus ensuring demand does not exceed supply. Likewise, frequency coordination is more easily achieved within a single organization. Alternatively, in the case of radio frequencies, the competitive position is represented by regulated competition. Administration of the spectrum is handled by a governmental body which seeks to attain the same ends as a monopolistic enterprise would: allocation, assignment and engineering standards. Neither system can be said to be superior to the other in every respect, each having benefits in unique situations. Therefore, the main difference is not in how the spectrum is utilized by an individual, but rather the number of individuals who are allowed to utilize the spectrum. Competition will tend to favor utilization of the spectrum by more users, leading to diverse allocation based on popular demand. Monopolization allows fewer users but a potentially more economic use. [Ref. 1: pp. 190-193]

1. Monopolies

It is feasible that the establishment of a market system could create a spectral monopoly once rights are transferable. If the cost of spectrum service provides an incentive for the establishment of a natural monopoly because of economies of scale, then it would definitely be in the economic interest of some company to monopolize a band in order to reap a greater profit through lower costs. After all, monopolies are established for the sake of profit, not for the sake of establishing a monopoly. As indicated above, this could be the most efficient method of providing a service. However, if this should be the case, then that firm should face regulation just as with any other natural monopoly. [Ref. 13: p. 18]

2. Free Market

The essence of spectrum management in a free market is that an individual has complete control over the uses to which the airwaves are put, within confines of the law. The reason for this is the belief that individual producers and consumers will make decisions more capably than a bureaucratic process regarding efficient use of the spectrum.

Decisions on type of use, class of user, system design and spectrum loading which are currently made by the FCC would now rest with individual users, after frequency rights were defined. While it could be argued that this would result in a chaotic situation, if property rights have been adequately defined, interference should not occur or would be of short duration and settled by litigation.

Users seeking access to bands outside those assigned would be free to enter into discussions with holders of desired bands, or similarly, seek to change coverage area within the same band. This could well mean that some users would find it more profitable to sell their rights to other users rather than use the airwaves for the purpose originally intended. Eventually, an equilibrium should be reached wherein all users are satisfied with the spectral distribution. However, this does not imply that this system would initially provide a quicker or less costly method of allocation and assignment than through an administrative process. The question of the length of time it would take the market to reach an equilibrium and whether transaction costs would be prohibitive still remain. [Ref. 23: pp. 7-8]

3. Hybrid Markets

A hybrid market attempts to combine elements of a free market with current administrative methods. There are several approaches to a hybrid market. Some proposals are based on fee and auction mechanisms. Others take different tacks. [Ref. 23: pp. 9-10]

A simple hybrid approach is frequency coordination. In this system, potential new users must determine whether their entrance into the spectrum will cause interference with any established user's system. If interference is proven, then the new user must bear the cost of modifying his or the incumbent's equipment. If the new user cannot mitigate interference to established systems, then permission to use the spectrum is denied. However, since it is the new user who must bear all costs of admission, even to the point of upgrading an incumbent's equipment, permission to operate is generally not seen as a problem. A newcomer will cease attempting entry when the cost of admission exceeds the economic return expected from use of the spectrum.

Another hybrid approach is represented by band assignment. In this mechanism, an allocated band, such as mobile radio, is divided into sub-bands which are then assigned to individuals or groups. The difference is no in-band technical requirements would be imposed. The users would have the freedom to define modulation techniques, signal strength, channelization and antenna characteristics. However, the user would be required to adhere to interference standards established by property rights. Initial assignment could be made to current holders, or a lottery or auction used. Several different versions of this technique exist utilizing various proportions of free market and administrative processes.

E. CONCLUSIONS

Although the establishment of a spectrum marketplace would be initially difficult and entail considerable confusion, there are no overriding social, political, or economic reasons preventing implementation. Negative externalities and problems posed by undefined property rights do have solutions, albeit imperfect. However, there is no perfect solution in the foreseeable future. Therefore, if a market is to be established, one of the systems proposed to mitigate externalities and define property rights must be adopted. Depending upon the desired objective of a spectral market, numerous mechanisms exist to allocate and assign bands and channels. Likewise, the type of market desired may influence allocation and assignment, and will determine the extent of administrative influence found in the market.

No one method can be said to be best, nor is it necessary that the same system be used across the entire spectrum.

V. LAND MOBILE RADIO

A. INTRODUCTION

Land mobile radio denotes a conglomeration of various communications services. These services include police and fire use; dispatching gas, telephone and public utility crews; dispatching taxis, buses, trucks and the like; railroad operation; remote control of machines and industrial processes; and alerting individuals through the use of pagers. [Ref. 25: p. 49]

Land mobile is divided into several service categories based upon message characteristics, number of common channels, and the nature and purpose of the system. These categories include public and private land mobile systems. Public services, as the name implies, are open to the general public, such as paging systems and cellular phone. Private land mobile is restricted to users who regularly interact via radio communications, such as taxi companies. [Ref. 9: p. 284]

The benefits accruing from the use of mobile radio are incalculable in terms of safety provided to life and limb. In more easily quantifiable areas, such as speedier business service, lower manufacturing costs, and improved manufacturing and transportation operations, the cost savings are enormous. It is for this reason that land mobile has become an essential part of U.S. economic vitality. It is as important to economic growth as roads, rails, waterways, and other components of the U.S. infrastructure. Given the dynamic pace of our economy, mobile radio is an excellent method to provide the rapid, reliable and close control and supervision required in a modern industrial society.

B. HISTORY OF THE LAND MOBILE RADIO SERVICE

Regulation of land mobile by the FCC is a particularly interesting history for a number of reasons. Land mobile services have evolved through a series of difficult allocation decisions involving a scarce resource desired by numerous users. These decisions have had extended consequences relating to the service. FCC actions have also influenced the communications industry structure. Lastly, the expense and delays in introducing new land mobile radio technology has often been cited as evidence that the FCC, as currently organized, is not the optimum mechanism for dealing with the spectrum. [Ref. 3: p. 106]

The history of the Land Mobile Radio Service can be found in several texts, offering general agreement and diverging only in the extent of particulars [Refs. 9: pp. 291-292, 3: pp. 107-110, 10: B 1-B 51]

General agreement starts the story of land mobile with the Detroit Police Department. If not the first, it was certainly among the first users of land mobile radio with the establishment of an experimental one-way (base-to-car) system in the early 1920's. The advantages gained by that department led other police departments to install similar systems. By 1930, police radio stations were operating in 29 other cities. In the early 1930's, the Federal Radio Commission (predecessor to the FCC), allocated frequencies above the broadcast band for police use.

In 1932, two-way communications became a reality when transmitters were licensed for installation in vehicles, at least on an experimental basis. The late 1930's and early 1940's saw the first Very High Frequency (VHF) band in use, and Frequency Modulation (FM) was introduced. Continued research and development for military applications during the Second World War, coupled with the FM and VHF advances, significantly improved the performance of earlier systems. This stimulated demand for mobile services.

If the industry grew fast prior to World War II, it was explosive in the post-war era. Not only did private services expand, but common carrier services were licensed. Demand for airwaves to support these new systems reached such a point in the mid-1940's that the FCC, in Docket 6651, added several new services to the already established Emergency Radio and Miscellaneous Radio Services. Additionally, the FCC addressed the question of frequency allocations for land mobile radio by establishing a rulemaking proceeding, the General Mobile Radio Proceeding (Docket 8658), in 1949.

In the decision arising from Docket 8658, several subcategories of service were recognized, such as Police Radio and Automobile Emergency. By 1950, radio frequencies had been allocated for public land mobile radio services, private land mobile, mobile telephone services (on an experimental basis), and public paging services, among others. Of special interest was the 1949 establishment of special industrial radio, and other services which allowed the use of mobile radio to support commercial and industrial applications. Other subcategories of industrial use followed.

Between 1955 and 1958, land mobile spectrum allocation continued to require a significant portions of the FCC's time as they struggled to find spectrum for land mobile radio. This occurred at a time when narrow-band standards were established and Citizens Radio Service rules were revised.

Docket 11991 of 1958 was the next major regulatory action dealing with land mobile radio. Under this proceeding, business radio service was established. This provided for a substantially greater number of eligible licenses.

By the mid-to-late-1960's, rapid growth in land mobile had again reached a point where congestion was significantly degrading services, especially in large urban areas. This prompted the FCC to establish a Spectrum Management Task Force to design a more efficient system to manage existing land mobile frequencies. Steps were also taken to investigate various spectrum reallocation proposals in Dockets 18261 and 18262.

In 1968, under Docket 18261, the FCC proposed that the lower seven UHF television channels (14-20) in large urban areas be reallocated to land mobile radio. This was designed to provide immediate relief for mobile radio. The designated channels were adjacent to an existing land mobile radio allocation, facilitating equipment availability. The broadcast industry immediately, but unsuccessfully, rose in protest. Two years later the FCC granted approval for vacant UHF-TV channels in the ten largest mobile radio markets to be assigned to land mobile. A total of six years had passed from the initial proposal to a resolution.

Docket 18262 was a related proceeding to decide if spectrum near the 900 MHz band should be allocated to land mobile. The primary competing service for this band was the television industry. Also involved with this allocation was the eventual reallocation of UHF-TV channels 70-83 for a total of 84 MHz of spectrum.

The FCC deliberated for seven years before deciding that the public was best served by use of this band for land mobile rather than broadcasting. This reallocation practically quadrupled the spectrum available for land mobile radio.

Though the television industry vigorously protested both dockets, the sharing of UHF-TV channels has presented no interference problems. [Ref. 10 : p. B 42]

From the beginning, growth of mobile radio was rapid. In the space of approximately sixty years, the industry has grown from one system connected with a few Detroit police cars to over 3,500 mobile common carriers and just under three million private land mobile systems [Ref. 9 : pp. 285-287] While the early systems were intended only for emergency operations, land mobile is now a part of millions of Americans daily lives. As uses for land mobile have expanded, the governing factor in its development has been the search, by both the industry and the FCC, for sufficient spectrum to satisfy this rapid growth. This is not likely to change in the near future, even though mobile radio has consistently been in the forefront of technological innovation to reduce spectrum requirements.

C. LAND MOBILE RADIO TECHNOLOGY

Radio frequencies most suitable for land mobile radio are to be found in the approximately 865 MHz spectrum range between 25 and 890 MHz. Lower frequencies in this range are best for long-range communication, but suffer from occasional noise and skip problems. Higher frequencies excel for short-range communication. Over the entire 865 MHz spectrum range, more than half of the frequencies not allocated to the federal government are allocated to the broadcasting industry. [Refs. 15: p. 30, 25: p. 48]

Services and service categories previously mentioned can be placed in one of three basic types of land mobile radio: paging or one-way signaling, dispatch and mobile telephone. [Refs. 3: pp. 106-107, 9: pp. 283-284]

Paging provides a one-way signal to a device which alerts the user to take some action. Simple systems use a tone or vibration, after which the user takes a predetermined action. More sophisticated devices provide the user with an alphanumeric or voice message which determines subsequent action.

Dispatch communications utilize a two-way (send and receive) radio link between mobile units and a base station, or simply between mobile units. Communication is accomplished without access to public telephone networks. Normally, dispatch communication is used to coordinate a fleet of vehicles, such as taxis or police cars.

The primary difference between dispatch and mobile telephone services is the ability of the mobile phone user to receive or place calls through a telephone exchange. The service is equivalent to regular phone service. Indeed, in some areas and countries this is exactly how it is used, except that the phone is carried in a vehicle or on a person's body. The most familiar application is cellular phones.

Any of these services can be provided by a private or common carrier, on a shared or exclusive basis. A private system allows the user to be independently licensed, and equipment (leased or owned) is used on an exclusive basis. A shared system, as the name implies, allows several users to share the use and cost of a system. Service provided by a common carrier (such as AT&T) means that the base station, repeaters and other facilities, are owned by the carrier. Service is leased to users. The carrier may also rent mobile units or they may be owned by the subscriber.

While the spectral implications of FCC Docket 18262 to the 900 MHz band have been discussed, it also has consequences for the technological use of this band. From competing proposals, three system classes emerged: conventional, trunked and cellular. [Refs. 3: pp. 115-118, 9: p. 287]

The conventional mobile radio system is the most common type of service. The simplest example of a conventional system would be a private, single-channel dispatch service. More complicated conventional systems can include multiple channels. The entire system would consist of a base station, including the transmitter-receiver (transceiver) and antenna, and the individual mobile transceivers. The base station could be located either at the business site or remotely, for better coverage (such as on a tall building or mountain). The channel used might be shared with other businesses using a similar system. If a larger area of coverage is required, then the system might incorporate repeaters located at high elevations away from the base station. A repeater would receive a signal on one frequency, from either the base station or mobile transceiver, and retransmit it using a second frequency. A repeater can normally receive and transmit over a large area. This enables low-powered mobiles to communicate with each other through the repeater, as long as both are within line-of-sight of the repeater. Without a repeater, these mobiles might not be able to communicate directly with each other, even if only a few miles apart.

A multi-channel trunked system uses a group of channels (usually five or more channel pairs) pooled together. Users have access to all channels. In a multi-channel trunked system, switching between channels is handled by a computer. In contrast, multi-channel conventional systems use manual rather than computer-controlled channel selection. The advantage of computer-controlled channel switching is better service for users, or a greater volume of traffic for the same level of service.

The computer provides a channel for the duration of a user's message. If there are no unused channels, the computer places the user in a queue for the next available channel. The efficiency of trunking over conventional systems can be visualized by considering a collection of conventional systems. At any one time, some of these channels will be heavily used, while others are lightly loaded. Trunking provides the opportunity to distribute the message load equitably over an entire group of channels. While it is obvious that trunking is more spectrally efficient than conventional systems, trunking is used only in the 900 MHz band due to assignment regulations and a lack of sufficient channels in other bands to support trunking.

The third system class to emerge from the FCC proceeding was cellular. The 900 MHz band was particularly suitable for cellular because of its short propagation characteristics.

Cellular derives its name from a concept first advocated by AT&T. Geographic areas are divided into hexagonal cells. This cell shape was chosen because it roughly approximates a circle surrounding a base station. Furthermore, a hex, unlike a circle, can be joined with other hexes to completely define coverage of an area. A transmitter and receiver are located in each cell. They are connected by wirelines to a central switching computer. The central computer is then connected to the regular telephone network by other wirelines.

The cell receivers and transmitters are designed to provide coverage for that cell only. However, signals must be strong enough to cover the entire cell, so there is naturally some frequency bleed-over into adjacent cells. This precludes the use of the same frequency in adjacent cells but not in cells further away.

In a low density market, or initial installation of a cell, the cell area can be quite large. As demand for cellular service increases , the cell can be subdivided into smaller cells. With a large cell, a channel will be used only once. As the large cell is subdivided into smaller cells, that same channel may be used numerous times in the same area where it was previously used only once. This depends, of course, on the separation of the cells in which this frequency is being reused. Whereas a conventional system may preclude the reuse of a channel over an entire metropolitan area, cellular allows reuse of that channel within the same area.

The advantage is spectral efficiency. As more users demand service, they are accommodated without an increase in frequencies required. Trunking can further increase spectral efficiency. Future economies of the spectrum are currently envisioned by coupling a cellular system with digital processes or spread spectrum techniques.

While services traditionally have been provided by equipment mounted in vehicles, advances in sold-state electronics have now produced devices small enough to be carried by a person.

D. ALLOCATION AND ASSIGNMENT MECHANISMS

Land mobile radio did not exist when the Radio Act of 1927 was enacted. Therefore, spectrum allocation for this service has been subject only to the criteria of public need. Unfortunately, that portion of the spectrum best suited for land mobile is also well suited for other uses, especially broadcasting. Thus, land mobile must compete with these other uses in the arena of public interest. The rapid and continuing growth of land mobile has placed demands upon the FCC for allocation. In all probability, this will continue. More than any other service, land mobile has consistently demanded increased spectrum. As bands have been allocated, channels have been loaded to capacity as fast as the Commission has assigned them. [Ref. 10: pp. 53-54]

1. Historical

Until the mid-1930's, land mobile allocation was made only on an experimental basis; assignment was restricted to police departments. The mid-1930's saw the first non-experimental allocation of land mobile as other uses for the service were realized. In the late 1930's, the frequencies allocated to land mobile, and services which would become land mobile, were extended as equipment technology progressed. [Ref. 10 : pp. B 7-B 9]

The first coherent apportionment of the spectrum usable by land mobile began in 1944. By 1949, the Commission had established the allocation policy for land mobile that more or less exists today. This decision was based on estimates of what existing services would need for future growth. Approximately 60 percent of the 25-890 MHz band was reserved for broadcasting uses, 34 percent was retained by the government (exclusive and shared use), and the remaining six to seven percent of the spectrum was to be divided among aviation, maritime, amateur, citizens, and land mobile services. Of this six to seven percent, land mobile received about four point seven percent. Failure to predict the phenomenal growth which has occurred in land mobile accounted for this relative imbalance in allocation. [Ref. 25: pp. 48-49]

2. Current

Admission into many land mobile services has historically been practically uninhibited for eligible applicants. Operators in services such as business and land transport radio were allowed to enter their respective bands knowing full well that their entry would very likely cause interference for others on various frequencies. [Ref. 15: p. 30]

Block assignment compounds the problem of uninhibited admission. Used since the early days of land mobile, blocks of frequencies are allocated for the various services. Requirements are then set for entry into the band. Because of the large number of services desiring use of the spectrum, blocks allocated to each service are small. Assignment must be on a shared basis for licensees within each allocated block. In contrast to broadcast service, where exclusive use of a particular channel is granted to one licensee, land mobile services do not limit the number of licensees permitted to operate on each channel. If the number of frequencies is greater than the number of users, this system works well. However, this is rarely the case. Therefore, a system of licensing and frequency selection has emerged. [Ref. 25: p. 50]

While the FCC actually issues licenses for all land mobile services, voluntary industry advisory committees, commonly known as frequency coordinators, play a significant role in the assignment process. These coordinators recommend assignments and sharing arrangements for users in virtually all mobile radio services. They also resolve interference complaints. Reliance on frequency coordinators is designed to reduce delays in processing applications, encourage sharing and ease the introduction of new technologies. [Ref. 9: pp. 287-288, 15 : p. 31]

E. ESTABLISHING A MARKET IN LAND MOBILE RADIO

While mechanisms exist to ensure an efficient utilization of land mobile radio, the questions must be asked: would the establishment of a marketplace for these services not achieve the same or even more advantageous benefits? What would such a market look like and how would it operate? Lastly, to what extent could this system be extended to other uses of the spectrum?

A simple, yet practical trial market could be established in order to test these concepts and derive at least partial answers. Utilizing the present FCC allocation scheme or an auction system, a channel or group of channels could be designated from the reserve spectrum. If reserve spectrum is used, it would not affect any bands currently in use. If this is not the case, the current FCC allocation scheme would be used so as not to conflict with other bands.

Assignment would be by a sealed bid auction. All participants in the auction would still be required to show the currently required financial, technical and social documentation for access to a band. That is, bidders must meet standards of current licenses. The highest bidder would gain control of the band. No right of renewal is anticipated, since as long as the band is being utilized by the initial owner, he retains control. If the owner does not use the band, then it becomes open for auction again. However, before allowing the band to go unused, and thereby losing the initial investment, the owner is more likely to attempt to lease or sell the band.

Economic efficiency will come from the current owner's ability to transfer spectral rights to other persons or organizations, subject to meeting license standards. No other restrictions concerning transfers should be imposed. The incumbent would be free to sell or lease all or portions of the assigned band. The current owner would likely transfer rights when it is more economically efficient than retaining the band for his own use. That is, a new user who values the band more highly will be willing to pay the incumbent user more than what the incumbent could reap from his own use of the band. Likewise, spectral efficiency would be enhanced if the cost of new spectrum saving equipment is less than what could be earned by selling or leasing the spectrum thus saved. These benefits would accrue because a price would now be associated with the spectrum.

Problems associated with "free spectrum" would disappear in bands where a monetary cost is established.

The only service restriction imposed by the FCC would be that the band could be used only for mobile radio. No technical standards would be imposed. the owner would be free to utilize any system deemed to best utilize the spectrum assigned. The user would be responsible for choosing technical standards which do not cause interference to other systems. That is, the incumbent's property rights must not infringe upon the property rights of others. If interference occurs, it will be the financial responsibility of the offender to remove the source of interference by reconfiguring either his own system or the system which is being interfered with. For simplicity, the last user to begin utilizing the spectrum could be considered the cause of interference.

The government's role, other than initial allocation and assignment by auction, would be to enforce property rights in cases involving interference. All other duties normally performed by the FCC, such as technical standards and reassignment, would be handled by the owners working within the marketplace.

Although the spectrum would now have owners, at least in those bands opened for market exploitation, it would not be lost to the people as a national asset. In fact, ownership would ensure that the national asset is used more efficiently. Ownership ensures that the highest valued users have access to the resource. Any time a portion of the spectrum is no longer used, it would automatically return to the government to be held in trust or reauctioned as appropriate. The government would also retain the right to purchase the spectrum, under eminent domain, if necessary for national security or emergency measures.

Lastly, to what extent should a spectrum market extend? Should all portions of the usable spectrum be included, or only portions currently used or planned for use by designated services, such as Land Mobile Radio Services? Arguments have been made for both positions. The answer depends upon the advocate's belief in the efficacy of economic solutions. However, in the interest of practicality, such as reducing resistance to change, only portions of the spectrum used by services like land mobile radio would initially be open to a market. At least at first, the FCC would continue to exercise the controls now established for industries such as broadcasting. This is particularly important in view of the social implications associated with such businesses. Like so many other issues, the extent of the market should be the result of extensive discussion and compromise, perhaps based on the results of a marketplace trial.

F. CONCLUSIONS

The development of the Land Mobile Radio Services has been significantly influenced by the FCC and the users themselves. Many issues have not been resolved. Problems of congestion and allocation are a recurrent theme in land mobile. Several means have been used to resolve these problems: technological advances, spectrum reallocation and sharing frequencies.Technologically, land mobile has decreased the amount of spectrum needed to carry an intelligible signal and developed equipment which allows use of the spectrum at higher and higher frequencies. Users have also sought to wrest spectrum allocated to other services, both occupied and unoccupied. Barring total reallocation, they have attempted to share those frequencies which are currently underutilized.

These latter two avenues have often brought land mobile into conflict with the broadcast industry. The competition between land mobile and the broadcast industry concerning the UHF band is far from over. Even with these problems, the industry has grown at an explosive rate. This is not likely to change, especially with the current interest in cellular communications. Mobile radio will become more important, not less, to the economic health of the United States.

VI. CONCLUSIONS AND RECOMMENDATIONS

The telecommunications industry is an essential component of the U.S. infrastructure; as important to economic growth as roads, rails and waterways. With this thought in mind, there are at least two reasons why our status as an economic power is in jeopardy. First, an expensive, slow and often arbitrary system of spectrum allocation is gradually causing the loss of our technological edge in electronics based communication products. Second, the scarcity of frequencies for commercial use has impeded the development and commercialization of new telecommunications products and services, and reduced the capacity and efficiency of our telecommunications systems.

There is little doubt that the availability of additional spectrum for commercial purposes would promote the emergence of new industries, create new products and services for consumers, and provide additional jobs in emerging industries and services. Additionally, an extension of the spectrum would also help improve America's international competitiveness in telecommunications markets, since nations and businesses which first commercialize new technologies tend to gain significant advantages in international markets.

However, since the radio frequency spectrum is a finite resource which can not be infinitely extended, the problem becomes obtaining the maximum use from the available spectrum. A feasible method to quickly achieve this objective would entail substantial changes from the current government regulatory method in the allocation, assignment and management of the frequency spectrum.

Under the current administrative scheme, several negative characteristics, both within and outside the system, prevent maximum occupancy of the spectrum:

- Delay.
  Generally, allocation occurs only after long delay (as occurred in Dockets 18261 and 18262) because an atmosphere of inadequate or unavailable information typifies the Commission. Given this situation, it is easy to understand these delays as an indication of the Commission's desire to avoid allocation mistakes. Delay also is a manifestation of the spectrum's free good aspect (price set to zero). Under this situation, demand almost always exceeds supply. Therefore, the Commission must decide between numerous competing claimants using a criteria of "need" for the service. The difficulty and delays encountered in this system are readily apparent.

- Inflexibility.
  Often, the Commission has been reluctant to reallocate spectrum even when it is obvious that allocated spectrum was not being used extensively or as efficiently as possible. This may be a result of the human trait of not wishing to admit

mistakes, or a belief that soon, the allocation will prove correct. Another likely reason is that spectrum incumbents exert political pressures on the Commission in order to retain current allocation decisions.

- Bias against innovation.
  The politics and bureaucracy of spectrum management also hinder technological innovation. Incumbent users tend to control technology and are loathe to introduce new technology before capital investment in previous equipment has been recovered, or until forced to do so by competitors. Free spectrum also provides little incentive for efficient use.

Whereas the Commission's original purpose was to remove pol.,y from the political realm and entrust it to the hands of experts, this concept has not been totally realized, especially as it relates to politics. Likewise, a judicial regulatory bottleneck prevents wider and more efficient use of benefits available from the spectrum.

Rapid changes in the telecommunications climate requires the reevaluation of the government's role in order to eliminate, or at least reduce, the effects of negative attributes. Yesterday's institutional arrangements have lost and will continue to lose relevance in the face of technical and commercial requirements. The imposition of a managerial system dating back to 1934 has hampered the introduction of new technology, such as occurred with cellular services.

At the time, the FCC's inception and institution was not necessarily an erroneous or bad idea. In a static world with little innovation and a clear understanding of the demands which will be placed upon the spectrum--conditions which were thought to exist in the early decades of this century--a bureaucracy is probably adequate to satisfy the desires of airwave consumers. But in a dynamic world, characterized by innovation and uncertainty regarding demand--the world which we now live in--a market would seem to offer distinct advantages in allowing consumers to utilize the spectrum to their greatest advantage.

The deficiencies of the current system are generally viewed as failings which can be rectified by legislation or other means, rather than by introducing a substantially revised system. Yet a new system incorporating elements of a market, to a greater or lesser extent, may be a better answer.

A spectral market would manage the airwaves much as the federal government now does: it would determine where, how and by whom the resource shall be used, though these determinations would be made using market prices. It would also take into account prevailing and emerging engineering factors, and social goals and priorities promoted by Congress and society at large. A major difference, however, of a market as opposed to a bureaucratic system of regulation is that the former would tend to be more responsive to the decisions of individual users. A spectrum manager attempts to distribute spectral rights like a market, but limitations of knowledge necessarily result in different patterns. The establishment of property rights associated with the spectrum in a market system would allow the user to chose his own frequency (within a band), bandwidth, and modulation technique.

While this may be seen as forcing the obsolescence of previous systems and thus ultimately devaluing the spectrum, that situation is not likely to occur. The value of the radio frequency spectrum is dependent upon not only the ability to transmit, but also the ability to receive information. Therefore, similar systems will either advance apace or at least remain compatible. As to whether a market would, in fact, accelerate technological innovation, it is not certain. But, that innovation under government control has not proceeded as quickly as possible is a fact. One reason for this is that under government input specifications and licenses, there is a cost for new equipment but no attendant increase in the value of the rights associated with the spectrum. The user has no incentive to adopt new techniques. However, if a system is imposed whereby the increase in value of the spectrum is enjoyed by the innovator, the motivation is clear: if the value exceeds the cost, the new technology will be adopted.

Yet, in the final analysis there is no perfect method of spectrum management. Just as clearly, however, there exists a need for some form of management, if for no other reason than to prevent the airwaves from dissolving into chaos.

These two statements form the essential question: what is the least imperfect method? In economic terms, this would be the system which utilizes the scarce resource optimally. As I've attempted to explain, this is best achieved through a market mechanism. However, market-type efficiency considerations may not be enough in managing the spectrum. Maintaining safety, internal and external security, education and cultural values, and the Orwellian implications of mass communications are also important aspects which must be kept in mind. While a full-fledged market would have advantages, at least in theory, a regulated market-type system may be more practical and appropriate.

Given this situation, a combination of market incentives and bureaucratic control might be the least imperfect method of regulation. A clear separation of market and government control would certainly be the easiest system to establish and control. For example, the government could control broadcasting (to further social goals) while fixed and mobile services would be left to the marketplace. While this is the simplest method, it denies the advantages of the market to the segment of the spectrum occupied by broadcasting.

The proposal recommended here, not as easily instituted or regulated, seeks to combine the best aspects of each system. In this hybrid system, advantages of the market (innovation, efficiency, personal choice, property rights) would be combined with those of bureaucratic regulation (security, safety, social progress). For example, services promoting safety and security would be completely regulated. These would include maritime, aviation, fire, police, ambulance services and the like. These bands would retain a "free" price for allocation and assignment by the government. These services are not expected to be profitable ventures, and as such would be at a disadvantage if forced to bid for the airwaves against businesses operating for profit. Utilizing the example of a national park again, the special uses to which a park has been set aside, as opposed to other parcels of land, allow it to be retained for the enjoyment of all the public, at little or not cost. Likewise, the special uses of safety and security services for the general welfare of the public would argue for the same consideration.

Likewise, while broadcasting is a profitable business, strictly economic allocations and assignments might not achieve social and cultural aspects deemed beneficial by our society. Therefore, while control of the spectrum may be a strictly economic process, the actual occupancy of those same airwaves could be made to meet established standards. In this way, efficiency can be attained while other goals are also met. Market control over the spectrum must be granted to broadcasters, regardless of whether permission to use the airwaves for the transmission of programs is given based on social concerns. In this way, transfers of unused spectrum may be made to those desiring access or more spectrum. This leaves that segment of the radio frequency spectrum occupied by fixed and mobile services, which are not accounted for by the safety, security or broadcast services. It is here that the utility of the marketplace is evidenced. Here, government regulation should be relegated to the protection of property rights.

As proposed earlier, the FCC could attempt a limited marketplace experiment for this latter category by making a specific band available. The information gained would be valuable in determining the efficacy of an extension of the program, that is, whether the advantages of defined property rights outweigh the costs of defining and enforcing them.

In conjunction with this approach, a separate category of service should be established. In addition to fixed, mobile and broadcasting, an "emerging technology" service should be established in which spectrum is devoted entirely to new technologies being developed. This, of course, would not represent any fixed band, but would evolve as necessary. Benefits could be incalculable, based on the previous discussion of national and international benefits. In one sense, the introduction of new management techniques could also be interpreted as belonging to this experimental band. Not only could a marketplace experiment be used, but other innovative management ideas tried which might hold significant consequences.

Along with this new spectral management system, two other aspects of the current system should be discarded. First is the national allocation procedure. National allocation should give way to regional allocation, where propagation characteristics permit. This would promote the re-use of spectrum within the same band when geographic separation is sufficient. This is known as frequency sharing.

Frequency sharing also relates to the second item: sharing of government owned spectrum. Whereas this paper has been confined to non-government uses of the spectrum under U.S. control, the fact remains that approximately 40 percent of the spectrum is reserved for government use. Many of those frequencies are unused [Ref. 19]. There is, in many cases, no reason some of these frequencies can not be allocated or at least shared with commercial users. While the specter of national security is often raised at this suggestion, the implementation of appropriate technology to shared or leased bands would ensure that frequencies could be quickly reclaimed by the government as needed. In the meantime, valuable contributions from these frequencies could be obtained within the marketplace. Not only could the federal government receive revenues from this current wasteland, but in a manner, the economic use of these frequencies can be said to contribute more to our national defense when they are released to the market than while going unused, given the advantages which spectral innovation can achieve on the domestic and international scene.

In conclusion, a reevaluation of the government's role in radio frequency spectrum management must be made. Whether this reassessment recognizes the advantages of a marketplace system may or may not be crucial. Yet, given the pace of today's technological developments, our present regulatory system has and will continue to lose relevance, and indeed, is slowing the introduction of innovation.

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