A COMPARISON OF SPECTRUM MANAGEMENT BY GOVERNMENT VS MARKET

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Summary

The radio spectrum is a scarce resource, and society's concerns in managing it are, in principle, no different than in managing other scarce resources. These basic concerns are (1) rationing, (2) conservation and (3) control of external effects, such as interference. There are two decision-making institutions which society can use in managing the spectrum: government and market. Spectrum management by government, the present approach, delegates decision-making to a small group of appointed officials and addresses the three basic issues through regulation and administrative processes, such as block allocation, technical standards and comparative hearings. Spectrum management by market would delegate decision making to a large number of individual rights holders; price would become the principal rationing force and would create incentives for voluntary conservation; and interference would be controlled by enforcement of property rights.

The necessary and sufficient condition for the establishment of a market in spectrum is a system of transferable property rights. A simple system of property rights could be instituted by allowing for the free transfer of spectrum assignments as defined under existing licenses. A more flexible and efficient property right could be created by transforming existing frequency assignments, which are defined by restrictions on system inputs, to a set of output rights which stipulate permissible levels of radiation across frequency and geographical boundaries. Other steps which could be taken to improve the functioning of a spectrum market include reducing or eliminating block allocation distinction between services and permitting re-negotiation of rights packages among assignees.

Introduction

A number of proposals have been given increased attention recently for changing the traditional way that we have allocated and managed the radio spectrum for nearly 50 years. Such proposals, variously called spectrum economics, spectrum deregulation or spectrum markets, all have one thing in common: a shift of decision making authority over the use of the spectrum from Government to private individuals. Stated another way, these new proposals, such as band assignment, auctions, transferable licenses, etc., would, if adopted, move to substitute the marketplace for the Government as the basic decisionmaking institution in determining how and by whom the spectrum resource is used in this country.

While these ideas seem consistent with the way we manage other scarce resources and with the current mood of the country to diminish Government presence in our private lives, there is a great uneasiness in the radio industry as to how these new approaches to spectrum management may affect their business. It is human nature to resist major changes in long established social institutions, but the concerns and fears over these proposals seem unusually intense. Some of this concern may stem from a lack of understanding of how a spectrum market would function, how it would deal with the issues, and how it would replace the volumes of spectrum-related rules which have been painstakingly developed over the years. But all of these rules, our block allocation plan, equipment technical standards, interference criteria, frequency coordination procedures, channel loading standards and others, were developed in response to specific regulatory concerns. This paper attempts to define more clearly what these basic concerns are in spectrum management and to compare how those concerns are addressed under the present regulatory system versus how they might be addressed by a spectrum market. It also suggests a potentially feasible approach to defining enforceable property rights in spectrum based on calculated rather than measured radiation levels, and sets forth a possible transition scenario for the orderly evolution of spectrum markets as a replacement for Federal regulation.

The Basic Issues in Spectrum Management

In its broadest sense spectrum management is the management by society of one of its scarce resources: the radio spectrum. The spectrum is a resource consumed in the production of telecommunication services. It is consumed in the sense that each and every radio system, to operate, requires exclusive access to some finite quantity of the spectrum. While we are continuously developing techniques to reduce the amount of spectrum consumed by radio systems, so far we have not been able to operate two radio systems on exactly coincident frequencies, at the same instants of time and with electromagnetic fields oriented precisely within the same geographical space.

The spectrum is, as indicated, not only a resource but also scarce. That is, absent any constraints on its use, there would not be enough of it to satisfy all demands. In other words, if the spectrum were free and there were no rules which restricted who could use it, how much they could use and for what purposes, some potential users could not be satisfied. This is more true,

* The views expressed are those of the author and do not necessarily reflect the views of the Commission.

of course, in certain bands, geographical areas and periods of time than others, which is only to say that spectrum is not uniformly scarce. But it certainly seems intuitively obvious that in at least the major cities, the most useful portions of the spectrum can be considered scarce, according to any reasonable definition of that term.

If it is true that the spectrum is a scarce resource, then there are certain ways society can organize its use of it to increase the benefit it derives from the spectrum. The first thing society can do is to prioritize its use of the spectrum and ensure that those uses of greatest value are met. In other words the spectrum, being scarce, can be rationed to obtain increased value. Secondly, since those uses which must be excluded presumably have some potential value to society, efforts should be taken to reduce the amount of spectrum consumed by each use which is satisfied so that additional uses can be accommodated. In other words the spectrum should be conserved.

Finally, as in other resources, the way one user chooses to use the spectrum can effect other users in either desirable or undesirable ways. These are generally referred to as external effects. Interference is an example of a familiar negative external effect of spectrum use. On the other hand, a positive external effect can result, for example, from economies of scale if many individual spectrum users select a common equipment design. Also, in some applications the selection of common frequencies by individual users can increase value to others by providing a greater number of potential communication points. Thus, society can increase the benefits it derives from the spectrum by devising ways to reduce negative external effects and increase positive effects.

This, then, defines the three basic issues which any spectrum management institution must address: (1) rationing, (2) conservation and (3) control of externalities. Now let's look at the way these issues are resolved under the present system in which Government is the basic decision-making institution and compare that with how they might be addressed by a spectrum market.

Spectrum Management by Government

Under the present system of spectrum management, practically all decisions regarding civilian spectrum use are made by the Federal Government, namely the FCC. The basic decision-making vehicle is the public rulemaking proceeding, which provides the opportunity for interested parties to express their views to the regulatory agency before any final rules are adopted. Decisions are made by a majority vote of seven politically appointed Commissioners guided by the public interest mandate of the Communications Act.

These regulatory decisions governing the spectrum are reflected in the Commission's Rules and Regulations. While they fill many volumes, these rules can be grouped into six basic

categories: (1) ITU regulations which allocate the spectrum by bands to broad categories of use (e.g., mobile, broadcasting, fixed, etc.); (2) FCC/NTIA agreements which divide the spectrum between Government and non-Government users; (3) FCC band allocations to more narrowly define categories of use (e.g., land mobile, paging, mobile telephone, dispatch, etc.); (4) FCC band allocations to groups of non-Government users (e.g., common carrier, educational institutions, public safety agencies, amateurs, citizens, businesses, etc.); (5) FCC standards on equipment and systems design (e.g., power, antenna height, modulation type, trunking, frequency tolerance, occupied bandwidth, spurious emission, etc.) and (6) FCC rules for loading the spectrum (e.g., co-channel distance separations, authorized bandwidth, number of mobiles per channel, number of bits per second per Hertz of authorized bandwidth, etc.).

These six categories of regulations constitute a hierarchy of regulatory decisions ending ultimately in the assignment of a small piece of spectrum (called a channel) to an individual licensee. Since each such regulatory decision has the effect of reducing uncertainty about the potential use of a band, one way to display the current spectrum regulatory structure is shown in the following figure.

Each tier in this regulatory structure deals with one or more of the three basic issues of spectrum management. Rationing, for example, is accomplished by the several layers of so-called block allocation in which each band is set aside for specific types of use and groups of users. If there are still competing applicants for a given channel, the final rationing decision is made by a hearing before a judge to select the most qualified applicant. Spectrum conservation is addressed through the rules on equipment and system design and by channel loading criteria which, together, determine fairly precisely how much spectrum will be consumed by a given use, e.g., 25 kHz for one voice channel, 6 MHz for one video channel, etc.). Interference (negative external effect) is controlled also by imposing equipment standards, coupled with rules which prescribe how close together (in time, frequency and space) users must operate within the spectrum. Other, positive external effects, such as economies of scale and interoperability, are achieved both through national and international

band allocations (e.g., worldwide maritime bands) and through system technical standards (e.g., compatible mobile units for cellular service).

Spectrum Management by Market

While not often thought of as such, a market is as much a formal, decision-making institution as is Government. We need only look at markets in other scarce resources, such as land, to see that they are, in fact, highly organized, efficient decision-making institutions.

The underlying basis of any resource market is a system of clearly defined, transferable property rights. This is fundamental. Without use rights which can be bought and sold, markets in spectrum or any resource cannot exist. The buying and selling of such property rights by individuals in the marketplace creates a price structure for the resource which, in turn, becomes a substitute for Government regulation.

For example, as a result of the creation of price, the spectrum resource would automatically be rationed to those users who value it the most. Spectrum price would also produce voluntary conservation of the resource, similar to what we see happening in other resources (e.g., gasoline). Interference in a spectrum market would be controlled by enforcement of property rights. Since interference would be the violation by one user of another user's property right it could be remedied in the courts (or by some other arbiter) in much the same fashion as are infringements of land use rights. Positive externalities such as economies of scale or interoperability of equipment could be provided through voluntary coordination, in which existing organizations such as user groups, industry associations or even individual manufacturers could play an important role. A Government agency could also perform such a coordination function, particularly when interaction with other countries is involved.

Defining Property Rights in the Spectrum

Since, as indicated, the creation of property rights is fundamental to a market approach to spectrum management, let's spend a few minutes delving a bit deeper into this subject.

Any spectrum rights package would, of necessity, include some delineation of the quantity and location of the spectrum resource being assigned. It is this aspect of spectrum property rights that seems to cause the greatest concern for technical people. Some¹, who have studied and written on this question, seem to have concluded that the problem is unsolvable, i.e., that we can never quantify a package of spectrum use rights which offers the holder any significant degree of freedom without incurring prohibitive enforcement costs.

The difficulty is not in defining boundaries in the spectrum. Certainly we can draw lines on maps which precisely define geographical areas, and we draw lines on frequency charts which precisely define a band, and we can block out and

assign specific periods of time. The problem is that radio waves, as everyone knows, cannot be easily confined within geographical areas or frequency bands. Thus, any definition of a piece of spectrum property would also have to specify levels of energy from outside sources which the property holder would legally have to tolerate within its assigned property boundaries.

While specifying such energy levels also seems relatively straight-forward, the real difficulty comes when the rights holder tries to enforce its right against encroachment. How can it prove that the suspected intruder is producing energy levels within his property, either across his frequency or geographical boundaries, in excess of the legally permissible level? There would seem to be two methods: measurement or calculation.

A single measurement of electromagnetic energy in the open environment is nearly always subject to ambiguous interpretation because of propagation vagaries. Such ambiguity can be reduced by taking many measurements at different locations and times and averaging. But the high cost of making numerous measurements could prohibit prosecution of any except the most troublesome interference cases. A high enforcement cost would reduce the value of the property right and lead to inefficient use of the resource.

Suppose, however, the property rights package defined an infringement based on calculated rather than measured values. To prove a violation, all one would need to do is enter the parameters of a suspected offending station into a standard mathematical model² and the number produced by the calculation would determine whether there was a legal violation or not. Conversely, each rights holder would have a simple, uniform means of determining how its own system is constrained by its obligation to protect the rights of adjacent property holders.

Under such a system, determining infringements could be simple and unambiguous with almost nothing left to litigation. The calculation model would be specified in advance and agreed to by the rights holder as a condition of grant. The grantee could also be made to agree to publicize system information which would be needed in the calculation model to determine whether it is violating someone else's property rights. About the only litigation possible in such a system of rights would be over the validity of the information supplied. However, verification should be relatively straightforward by on-site inspection of facilities, if required.

Some may argue that this approach would result in inefficiencies due to limitations on the precision of the model or models used for calculations. While it would be desirable to have a model which corresponded perfectly to the real world environment, there will always be some degree of error in any model. This imprecision translates into an uncertainty for the rights holder, i.e., the electromagnetic energy falling within a given property from other users may be

more or less than that predicted by the model. While this would not result in litigation, since the calculated figure would be binding, it would create a degree of interference risk which would have to be taken into account in the design of systems. But this is no different than the interference risk that exists under the present system of assignment which is also based on calculation. The main difference is in who manages this risk, Government or private parties.

Transition from Government to Market Spectrum Management

Another potential area of concern about the creation of spectrum markets lies in how the transition process might be managed. How might a system of spectrum property rights be instituted without massive displacements of existing users? Of course, there are many possible ways to proceed to implement spectrum markets. However, possibly the only feasible approach would be one which preserves the present equities in the spectrum. This could be done by converting existing spectrum assignments into transferable property rights.

The simplest way to create a property right from a present assignment would be to eliminate rules which restrict free transfer, i.e., repeal antitrafficking rules. This would allow an existing licensee who may be making only marginal use of his assignment to sell it. It would also allow someone who may believe he can do a better job of using that channel to try out his ideas in the marketplace, whereas now his entry may be totally blocked because all channels are assigned. Both the seller and the buyer benefit, or else the sale would not take place, and chances are society would benefit from a higher valued use of that piece of spectrum. While the public may have given up one service of marginal value, it will quite likely have gained a new service of greater value. Also, since the new entrepreneur will have paid for his right to that channel, he will have a strong incentive to use it efficiently.

It should be noted that, during this initial transition to a spectrum market, the spectrum rights package need not be changed from that as defined today under FCC licenses. The only necessary regulatory change would be the legalization of transfer. The assignment could remain subject to the same restrictions as at present including that it be used only for the type of services presently permitted. While this would create a market of sorts, it would be a rather rudimentary one. To increase the efficiency of the market, regulations on the use of the spectrum might be removed or made less restrictive.

Perhaps the next step in that direction might be a redefinition of the property right from one based on input restrictions, as are present assignments, to one based on output effects, as discussed in the preceding section. Present rights packages are defined in terms of restriction on equipment and system design and operation. Thus, we have rules on power output, antenna height and design, modulation, emission

roll-off within band, etc. All of these rules are based on some usually implicit criteria for what constitutes an acceptable level of radiation outside the authorized bandwidth and area of operation. But while the present rules specify a particular set of input parameters which will comply with the implicit interference goals, there are many other combinations which will produce the same output effects. Redefining the rights package in terms of output effects thus provides more freedom for individual assignees to design their radio systems to meet their particular needs. An output rights package could be defined based on the calculated methods discussed in the preceding section, which would give essentially equivalent interference protection as exists under the present assignment, but has the advantage of giving the user more system design flexibility. This added flexibility would open up additional possibilities for spectrum saving technologies and would permit the market to operate in a generally more efficient manner.

The next step which could be taken to improve the operation of a fledgling spectrum market would be to permit a greater range of services within each of the presently defined block allocations. Once a pricing system evolves, we need be less concerned about rationing the spectrum, especially as between services which are all basically commercial in nature. Thus a band now limited to commercial use A could be opened to commercial uses A, B, C, etc. A rights holder could exercise a wider range of choices in the kinds of service he provides depending on his perception of local market needs. The rights package having already been converted to output rather than input restrictions, as discussed earlier, would accommodate the wider range of system designs required to provide the wider range of services.

The next, and perhaps final, step in the process of instituting a spectrum market might be to allow rights holders to negotiate different rights packages among themselves. Government would no doubt draw the initial property boundaries and define what constitutes infringements. But suppose someone wished to try a new service or system which required a much larger (or smaller) piece of the spectrum than that initially assigned (e.g., a spread spectrum land mobile system) or suppose the system or service required a "cleaner" territory in the spectrum (e.g., a radio astronomy observatory). This person could obtain exactly the "correct" rights package for the proposed system or service by negotiating bi-lateral or multi-lateral agreements with his neighboring rights holders. These agreements would, in effect, be partial transfers of property and would require new definitions of rights packages among the persons involved. Since such negotiations could lead to an almost infinite variety of rights packages subject to contracts between individual rights holders, the possibility of disputes also increases. To counterbalance this somewhat, the cost of dispute arbitration could be internalized to the market. In other words, government could discontinue to provide free or subsidized arbitration services. Having to bear the full cost of enforcement, the market participants would

exercise more care in how they re-defined their rights packages.

At this point in the transition process the spectrum market would be functioning at very near its maximum efficiency and the role of Government would have been reduced to a minimum. Government would most likely still be involved in negotiating spectrum use agreements with other countries, in managing the Federal Government's own share of the resource, in coordinating worldwide or nationwide common frequencies or standards for special uses requiring such commonality, and in collecting and disseminating information to assist the operation of the market. But it would no longer be the principal institution for managing the spectrum. That function would have been transferred almost entirely to the market. Decision-making authority over the spectrum would no longer be vested in seven Commissioners but rather be distributed among the multitude of spectrum property holders.

Conclusions

The author's conclusions from this limited analysis, which do not necessarily reflect the views of his employer, are (1) that a market could be an effective, disciplined social institution for managing the radio spectrum, in much the same way it manages other scarce resources; (2) that the creation of a system of flexible spectrum property rights which can be enforced at reasonable cost appears to be a solvable problem; and (3) that transition from the present system of spectrum management to a spectrum market could be accomplished in an orderly, equitable manner without major displacement of existing users or disruption of services.

This paper addresses only the feasibility of a spectrum market and not its desirability. Whether a market in spectrum should or should not be established is a matter for the American public to decide, based hopefully on an objective evaluation of the relative efficiencies of those two institutions in accomplishing society's goals. The purpose of this paper is simply to show that there is a choice to be made.

Footnotes

1. See, for example, President's Task Force on Communications Policy, Final Report, Ch. 8, p. 31 (1968); also J. O. Robinson, "An Investigation of Economic Factors in FCC Spectrum Management," FCC/OCE SAS 76-01, p. 14 (1976).
2. An example of such a model, developed empirically and in use by the FCC for some time, is its technical Report R6602 which can predict the strength of fields produced by certain kinds of stations in certain bands, given transmitter location, ERP and antenna height. Predictions take into account the effects of terrain roughness as well as the probabilistic variation of fields as a function of time and location.