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Alternative Licensing Arrangements and Spectrum Economics: The Case of Multipoint Distribution Service

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ABSTRACT

At present, the Federal Communications Commission assigns radio licenses following a determination of the public interest. Whenever mutually conflicting license applications are filed, the Commission holds a comparative hearing. This assignment mechanism has been criticized as cumbersome and unrealiable, and three alternatives have been proposed: increasing the available spectrum, and either auctions or lotteries of radio licenses.

This paper presents an analysis of the present system and these alternative arrangements for assigning rights to the frequency spectrum for the Multipoint Distribution Service (MDS). Although MDS is a relatively minor radio service, it serves as a prototype for message distribution services with a large potential for use in business communications. Moreover, the way in which the initial batch of MDS licenses was assigned provides a unique opportunity for empirical work on the economics of the licensing process.

Briefly, the analysis suggests that the present system of assignments by comparative hearing is indeed a costly way to select applicants. Increasing the spectrum allocation by an amount sufficient to eliminate hearings will create more assignments than will be demanded by MDS in many areas of the country, which is wasteful if other uses are foreclosed.

Auctions or lotteries with free resale of licenses, offer more efficient selection mechanisms. Moreover, because there is free entry into the license process, each of the alternatives has interesting distributional applications, which are brought out in the paper.

1. INTRODUCTION

When government controls a scarce resource, and licenses private individuals to use it, it must decide how to assign the license. The radio frequency spectrum is such a resource, and this paper presents an economic analysis of the method used in the United States to assign rights to the spectrum: licensing it to individuals following a comparative hearing intended to determine which of several competing license applicants will best be able to serve the "public interest."

Two alternative assignment mechanisms, currently under discussion by policymakers, also are analyzed: auctions and lotteries of licenses. A third alternative--avoiding the problems of the present system by allocating enough spectrum to eliminate competing applications--also is being considered. This paper compares these proposals to hearings, examining how all three alternatives affect (1) the use of the resource, and (2) the distribution of the benefits from its use.

A particular example, Federal Communications Commission (FCC) licensing of radio stations in the Multipoint Distribution Service (MDS) is used throughout the paper. Although MDS is a relatively minor radio service, its history provides a useful focus for the analysis. For example, data on the behavior of license applicants are easier to interpret for MDS than for other services. Also, the FCC has recently proposed the use of auctions or lotteries as an alternative to awarding MDS licenses by comparative hearing.[1/] This makes the results of the analysis particularly timely. However, the general conclusions are relevant to radio regulation generally.

The structure of the paper is as follows. Section 2 presents background on MDS, summarizes the historical development of the service, and discusses the use of comparative hearings to award radio licenses. Section 3 discusses the recently proposed alternatives to comparative hearings, Section 4 presents an economic analysis of the use of comparative hear ngs, using a model of the assignment process. The model provides efficiency and distributional outcomes of the present system. Section 5 presents a parallel analysis of auctions, lotteries, and of a possible increase in the number of channels allocated to MDS. Finally, Section 6 summarizes the policy consequences of the alternatives.

2. AN OVERVIEW OF MDS

Multipoint distribution service is a relatively new interstate common carrier service used for broadcasting of multiply-addressed material to different fixed receivers.[2/] In the top fifty television markets, MDS has been allocated two 6-MHz channels in the frequency band 2150-2162 MHz. (A 6-MHz bandwidth is the standard one for a television signal.) In other markets a single 6-MHz channel is allocated, along with a 4-MHz channel.

2.1 History

MDS did not assume its present form until 1974. Prior to 1970, it had only a 3.5-MHz allocation. The FCC apparently thought that this service would operate as a "transmitter for hire," a sort of wideband counterpart to the radio common carrier service in mobile radio (CATJ, 1977). In 1970, the FCC added 2.5-MHz to the service, making transmission of a television signal possible.

The rules for the present service were established in 1972, and in 1974 the second MDS channel, with the 6-MHz capacity needed for a television signal in the top 50 television markets, was allocated.[3/] The Commission's decision in this case fixed MDS in its present form, and initiated its growth period. This can be seen by considering the number of stations tabulated in different editions of the Television Factbook. Prior to the Factbook edition for 1974/5, there is no listing whatever for MDS. Table 1 shows the number of licenses and construction permits issued since that time. The compound annual growth rate for licenses shown in the table is about 48 percent annually.

Table 1

Growth of MDS Licenses and Permits*

Time Period	No. of Licenses	No. of Permits
1974/5	7	18
1976	13	61
1977	22	74
1978	44	100
1979	54	66

* Excludes two users of the 4-MHz Channel 2A

Source: Television Factbook, for years noted (Vol's 43 to 47)

At present, MDS is used primarily to distribute pay television programs to cable television systems, hotels, apartment complexes and the like. Consequently, the 4-MHz channel, which cannot carry a standard television signal, has been very little used. The growth shown in the table is entirely in the 6-MHz assignments. However, MDS has the capability to distribute "viewdata" or "teletex" information services to businesses and households. As the costs of MDS receiving equipment have dropped, such applications have been increasingly discussed, and, at the time of writing, it seems likely that one or more such business information systems soon will be operating on a commercial basis.

Normally, an MDS transmitter operates at a power of 10 Watts, although powers of up to 100 Watts are permitted. MDS signals propagate along the line of sight at these power levels. Typically, reception is possible up to 15 miles from the transmitter, and the signals can penetrate some structures up to 8 miles from the transmitter site. Because the two available assignments are in adjacent frequency bands, special coordination of transmitters is required to control interference if spacing between MDS stations is under 50 miles (FCC Rules, 21.902 (c)). For a further technical description of MDS, see CATJ (1977).

Immediately following the FCC's 1974 decision on MDS, a large number of license applications were filed. Because the number of licenses available was so restricted, many of these applications conflicted, in the sense that licensing one applicant necessarily prevented the Commission from licensing other applicants. Table 2 shows the multiple application situation in late 1975, about a year after the FCC's decision. The table

Table 2

Number of Applicants for MDS Licenses

(September 1975)

Number Applications For An Assignment	Frequency of Occurrence
	Applications for Each Channel
1	21
2	49
3	35
4	20
5	9
6	4
7	7
8	3

Source: Television Factbook, Vol. 45 (1976) shows the frequency with which different numbers of competing applications were filed for the same assignment. Under the present rules, discussed below, a comparative hearing is required whenever there are two or more applications. Thus, the table indicates a need for 127 hearings, 100 of which are for assignments in the top fifty television markets. That is, mutually exclusive applications were filed for every available assignment in the largest markets.

As can be seen, the frequency distribution is highly skewed. The mode and the median are both three, but only one-sixth of all assignments had more than four applications.

According to the FCC (Docket 80-116, p. 4), the multiple application situation was stable between 1976 and 1978--settlements among contending applicants roughly equal new conflicting applications so that the backlog of unresolved conflicts was constant. Beginning in June, 1978, a large number of new conflicting applications for channel 1 assignments were filed.

Most cases involving a conflict are settled without a full hearing. The contending applicants generally consolidate their ventures, resulting in one amended application. Robinson (1978) reported that of 147 applications filed by 1975, 73 remained to be settled in 1978. Only 4 applications had been settled by a hearing, while 25 had been settled prior to designation for a hearing, and another 45 had been settled before the hearing actually took place. The FCC is said to have encouraged such pre-hearing settlements by proceeding slowly with the hearing process, but acting quickly as soon as a settlement resulted in a single application.

By mid-1980, there were 127 licenses for channel 1, with an additional 225 applications pending. Only 2 licenses had been authorized for channel 2, with 185 applications pending. All of the channel 2 applications were mutually exclusive, as were 131 of the channel 1 applications.[4/]

2.2 Legal Background on Assignment by Comparative Hearing

One solution to the problem of multiple applications is to increase the number of assignments by increasing the spectrum allocation. This, in fact, is under consideration by the FCC at the time of writing. But, such increases are not always easy to make, since they take place at the expense of other actual or potential uses of spectrum. Moreover, because there is no formal market in the radio spectrum, there are no price signals to help indicate how much of an increase is desirable. Thus, in the case of MDS as in many other cases, the FCC must ration the available assignments among the applicants. Under its procedures, this rationing requires comparative hearings among all competing applicants.

The background behind the decision to use hearings is as follows. Section 309(a) of the Communications Act of 1934 requires the Commission to award a license if it determines that the public interest, convenience and necessity will be served by so-doing. Section 309(e) of the Act states that if the Commission cannot make such a finding the applicant is entitled to a hearing.

In 1945 the Supreme Court decided a case involving mutually exclusive applications for a broadcast license. In Ashbacker Radio Co. v. FCC, 326 U.S. 327 (1945), the court held that when there are mutually exclusive applications, granting one without hearings on both deprives the losing applicant of its opportunity for a hearing. The Court ruled that it was not sufficient to set a hearing on the losing applicant's application after awarding the license, because this would place on the loser the additional burden of showing that the competitor's license should be denied, as well as showing that it is in the public interest to grant his own application (326 U.S. 331).

The Commission's reaction to Ashbacker has been to hold a simultaneous hearing on all competing applications whenever they are mutually exclusive.[5/] In the case of MDS, the initial case (Peabody Answering Telephone Service, 55 FCC 2d 626 (1975)) established five factors on which evidence was to be taken:

1. Efficient frequency use.
2. The nature of the services and facilities proposed and their relationship to the service requirements in the licensee's service area.
3. Quality and reliability of service.
4. The proposed tariff for the service, and the tariff's relation to costs.
5. Managerial, promotional and entrepreneurial abilities of the applicants.

In the early cases (reviewed in Docket 80-116), the applicants were awarded "preferences" based on evidence on each of these points, with the overall award being made on the basis of these preferences.

While no general conclusions are possible from the few cases which have been decided, it appears that in a number of instances no difference between the applicants is found. For instance, technical factors seemed often to be similar for each applicant. Moreover, there is at least one instance in which the hearing process apparently induced applicants to make their applications similar (Docket 80-116, pp. 7-10): in several early cases, the winning applicant was awarded preference for quality and reliability of service because it proposed to offer a "hot standby" transmitter. This decision apparently induced a flurry of amendments to pending applications adding a hot standby transmitter.

While the evidence is sparce, it seems likely that in many comparative hearing situations the Commission probably could make a public interest finding in favor of more than one of the competing applicants if there were no competition. That is, in many cases many applicants are technically and financially capable of providing the service, and can demonstrate to the Commission providing the service would promote the public interest, convenience or necessity. However, because the radio frequency spectrum used to provide the service is scarce, so that its use by one individual denies it to others, the uses proposed by the competing applicants are mutually incompatible. Spectrum scarcity is the root cause of the "problem" of comparative hearings.

3. ALTERNATIVES TO COMPARATIVE HEARINGS

In 1980 the FCC began to consider significant changes to the rules governing MDS, opening three dockets on various questions, two of which are relevant to the hearing problem. General Docket 80-112 proposes a reallocation of spectrum which would combine the existing MDS allocation with the allocations for the Private Operational Fixed (Microwave) Service (POFS) and the Instructional Television Fixed Service (ITFS). The reallocation would create a total of 33 television bandwidth channels for the three services. MDS would have a total of twelve channels as its "primary" allocation (i.e., MDS applications would have priority in these channels). IFTS and POFS would have primary allocations of eleven and ten channels respectively. In addition, if all primary channels in a given service area are occupied but one of the other 21 channels is available, an MDS station could be licensed to use one of the latter channels. If adopted, this proposal will provide at least six times as many channels to MDS as now are available. Moreover, multiple application cases could be settled by assigning additional unused channels in the primary allocations of either ITFS or POFS.

The second proceeding is Common Carrier Docket 80-116, a notice of inquiry and proposed rulemaking into methods for awarding licenses. This proceeding makes certain changes in the Peabody rules listed above (essentially, only evidence on points 1, 3 and 4 is now required), and requests comment on the use of several mechanisms intended to expedite the assignment process. One such mechanism is termed the "paper record" hearing. As the name suggests, this mechanism relies on written presentations by applicants rather than oral argument. However, the Commission, noting that "our recent experience reveals a trend toward fewer and fewer differences ... [between applicants]," and that in the near future, we may find ourselves in a position where no differences exist at all or where such differences cannot be rationally measured against a public interest standard ..."[6/] goes on to propose the use of two other mechanisms--a lottery or an auction--to select a licensee.

If the lottery is used, a random drawing would take place among all "qualified" applicants--that is, applicants meeting some prespecified criteria. The present rules for MDS essentially require qualification on financial, technical and legal grounds. A determination of technical and legal qualifications can be made by a staff evaluation of the applicants' proposals; but the financial requirement is more difficult to enforce. The financial qualifications of an applicant basically require the ability to construct and operate the proposed station. However, the notice of inquiry (p. 42) points out that a station must be constructed within eight months of the time a construction permit is awarded. Consequently a failure to have adequate financial backing is likely to be revealed quickly, and, the construction permit having expired, the assignment would again become available to other users. The lottery proposal analyzed in this paper therefore assumes that financial requirements are dispensed with. Put somewhat differently, a qualified applicant in a multiple application situation would be anyone whose application would have been granted in the absense of a mutually conflicting application.

The auction proposal is an outgrowth of a plan suggested by Robinson (1978). The plan discussed by the Commission would auction off assignments to applicants, subject to minimal qualification standards. These standards would be no higher than those for the lottery, and could be set considerably lower because the auction itself is to be relied upon as a selection tool. (For instance, financial qualifications are unnecessary in the auction, since a participant in an auction must be prepared to make a substantial payment.)

The actual auction could be conducted in several ways. From the viewpoint of economic efficiency, the so-called "English" or philatelists' auction has much to recommend it. Under the sealed bid version of this scheme the highest bidder wins, but pays the second highest price bid. Vickery (1961) and others[7/] have analyzed this arrangement, and have shown that it has several valuable properties. For example, it causes every bidder to state his estimate of the true value of the object of the auction. (Stated formally, bidding the true estimate is a Nash equilibrium strategy for each participant in the auction.) As a consequence, the English auction should award the object to the bidder who values it the most. Also, it is relatively easy to determine one's bidding strategy, so that the costs of deciding how to bid are minimized. The analysis in Section 5 of this paper assumes that the auction is English.

Licenses would be issued to the auction's winner on the same operating and technical grounds currently specified in the FCC's rules, eliminating the need to develop mechanisms to resolve interference. The license could run for the statutory five-year term, and would be re-auctioned at its expiration.[8] (To facilitate re-allocation of spectrum, all licenses in a given region would expire together.) The license's price would be a lump sum paid to the FCC. Transfer of the license would be allowed to any other party meeting the qualifications of a license holder.

4. A MODEL OF THE APPLICATION DECISION AND COMPARATIVE HEARINGS

In Table 2 we saw that the FCC's 1974 decision on MDS caused a large number of license applications to be filed. Multiple applications were received for all 100 assignments in the top 50 television markets, and for many of the single assignments available elsewhere. Because these applications were filed more or less simultaneously, it is possible to use data on the applicants to address the economic consequences of the present system. It would be much more difficult to do this for larger and older radio services, such as television broadcasting, because of the time that has passed since licenses were first awarded. On the other hand, licenses in these services are bought and sold after they are issued. Levin (1964, 1971), Crandall (1977), Noll, Peck and McGowan (1972), and others have used this data to analyze the economic behavior of these license markets.

There are two crucial points about the present system of assignment. First, the license awarded to the winning applicant provides a limited, legal monopoly. The value of any monopoly rents connected with the license depend on several factors, including:

1. The amount of competition from substitute services,
2. The competition from other MDS licensees with overlapping assignments,
3. Characteristics of the area being served, such as household size or income, and CATV or MATV subscribership, or the inherent desirability of the services being offered.

The second point is that the hearing is a competitive process with an uncertain outcome for which there are participation costs. Not surprisingly, an inspection of the pattern of license applicants suggest a kind of competitive equilibrium. For example, in those markets in 1975 where both MDS channels were available, applicants tended to divide evenly. Table 3 shows the joint distribution of applications for the two channels. In 13 out of 16 cases, the number of applications divides evenly between the two assignments.[9/]

In other to assess the economic effects of the different assignment mechanisms, one needs to know the value of a license, and how this value is related to the factors listed above. Ideally, one would build a model to explain the value of an MDS license as a function of the characteristics of the community where the station is located, the number of competing applicants, the number and characteristics of competing services, and the costs of obtaining a license. Sadly, most of the data needed for cuh a model are unobservable. In particular, we lack direct observations on the costs of obtaining a license.

However, we can use the data on applications to say qualitatively how the license's value varies. The next subsection presents a simple model that is consistent with the available data, and which suggests that the competition for licenses is a substitute for the sort of price competition that one would see if licenses were sold in a market.

Table 3

Number of License Applications in Markets with Two Available Assignments

		Number of Applications for Channel One				
		2	3	4	5	Total
Number of Applications for a Channel Two	2	5				5
	3	1	2		1	4
	4		3	2		5
	5		1			1
	6	1				1
	Total	7	6	2	1	16

4.1 Model Structure

Consider a particular MDS market, and let the index i run over all possible assignments and markets. In any particular market, let V_i be the value of the assignment. V_i can be thought of as the certain equivalent of the present value of the future stream of profits derived by exploiting the assignment. (As such, V_i includes any risk premium for the uncertainty associated with operating the assignment.)

In practice, different applicants may value an assignment differently. There are several possible reasons for this, including different perceptions of risks, or different estimates of revenues or costs by applicants. (For example, some MDS operations are part of a chain of systems, while others are locally owned and operated.) However, we will take V_i to be the same for all applicants.

V_i will also vary from assignment to assignment. In particular, the availability of competing assignments in the i^{th} market will affect V_i, because they offer a substitute service. In MDS, the total number of competing assignments N_i, and hence the number of competing systems, is fixed by regulation, and can be taken to be an exogenous variable.

The second factor affecting the decision to apply for a license is the cost of applying and participating in the hearing process. If a hearing is required, the cost of participation may be quite high. It will, in general, depend on the identities of the other participants. For example, the cost to a locally owned and operated system may be different from the costs for one of the "multiple station operators" because the applicant will be called on to demonstrate different things at the hearing.

We can now characterize the equilibrium that results after potential applicants have decided separately whether or not to apply. This equilibrium is defined by the standard free entry condition: after all applicants have observed each other's behavior, only those for whom the expected value of the assignment, exceeds the expected cost of obtaining it will participate in the hearing. If (1) potential applicants have the same V_i, (2) the same costs of participation, and (3) the same probability assessments of their chance of winning, the equilibrium number of applicants n_i will equate expected value to expected costs, as follows:

$$V_i/n_i = C(n_i) \qquad (4.1)$$

where $C(n_i)$ is the cost of participating in the hearing using a linear approximation to the cost function given. For a single applicant, and n_i has been treated as if it were a real number.[10/]

Using a Taylors' series expansion gives:

$$\begin{aligned} C(n_i) &= C(\bar{n}) + C'(\bar{n})(n_i - \bar{n}) \\ &= C_o - C_1 n_i \end{aligned} \qquad (4.2)$$

where $\bar{n}$ is the expected value of n_i. Substituting the equation (4.2) into equation (4.1) and solving for the number of applicants gives:

$$n_i \ (\sqrt{C_o^2 + 4C_1V_i} - C_o)/(2\ C_1) \qquad (4.3)$$

Linearizing this equation gives the following approximate relationship:

$$n_i \approx V_i/C_o \qquad (4.4)$$

This approximation will be reasonable provided $C_1V_i \ll C_o^2/4$.

This equation says that the expected number of applicants is roughly proportional to the value of the assignment, where the consent of proportionality is the "fixed" cost of application.

4.2 Data Used to Estimate the Model

This ratio depends on other variables, such as the characteristics of the market, of the applicants, and competing licenses, and we can obtain some data on these quantities. In particular, the Television Factbook tabulates MDS license, construction permits and application activities since 1975. The Factbook also contains the following data for each city where at least one application was on file at the time of publication:

- whether a license or permit had been granted,
- the identity of the applicants, and
- the channel they were filing for.

This information was used to find the number of applicants n_i and the number of available assignments N_i. In addition, it seems reasonable that the success or award of a license for one MDS operation in a market would convey information to the applicants for the second license about their prospects. This suggests that for channel 2 applications, one of the independent variables affecting V_i would be whether or not a channel 1 application had already been awarded, or whether it was still to be awarded. This variable was also derived from the Factbook.

In addition to this data, some measure of the size of the MDS market was obviously important. The activity variable chosen for this study is the Arbitron figure for ADI (area of dominant influence) television households for the television market that contains the application. This variable has several unsatisfactory features. First, it is available only for large markets. Consequently, the regression reported below may not hold for small markets. Second, ADI households measures the potential audience in a larger geographic area than an MDS station can serve. Data on a more detailed geographic basis could not be obtained. However, there are several ways to correct for this problem: one can allocate portions of the ADI figure in markets served by more than one MDS station. (The most important cases where this could be done are New York, Los Angeles, and the San Francisco Bay Area.) Alternatively, one could exclude observations on such shared markets. The results reported below do not include either of these adjustments because when they were used in regressions not reported here (but available from the author) they had no material effect on the results.

Another factor that might affect n_i is due to the circumstances of particular applications. In particular, several large multiple system operations (MSO's) participated in certain hearings but not others. It might be argued that if one or more of these systems participated, other applicants would be inhibited from entry. (This would be a form of the "deep pocket" argument often made about the advantages of small and large companies.) However, the inclusion of variables accounting for the participation of these systems on the right hand side of a regression equation explaining n_i introduces a simultaneity problem, because these variables reflect the decision of some of the applicants.

Ideally, the solution to this simultaneity problem would be the specification of additional equations for each decision. This would suggest appropriate instrument variables. No such instruments are obvious present, nor does the data allow us much liberty in this regard. Thus, when we use these variables in some regressions, the possibility of simultaneous equations bias must be kept in mind.

There are a number of other econometric points raised by the model specified above, most of which are too complicated to deal with given the available data. In particular, it should be pointed out that there are two forms of truncation error involved with the data obtained in the Factbook. First, the model deals with n_i as if it were a real number, whereas in practice it is an integer. Second, the Factbook never contains information on towns where there are no applications, so that a form of selection bias inevitably is present. Both these problems could, in principle, be addressed by additional modeling of the selection factors, coupled with the use of maximum likelihood estimation in place of ordinary lease squares.11/

4.3 Regression Results

Table 4 shows the results of several ordinary least squares estimates of the equilibrium relation equation (4.4). Overall, they support the equilibrium model developed in Section 4.1 above. The left-most equation is estimated for the 106 cases in which there were at least two applications. The specification is the same form as that used by Levin (1964, 1971), in which the value of an assignment was known from market data. As can be seen, the market size variable (log of ADI households) and the presence of an already licensed channel 1 are both highly significant.

Table 4

ESTIMATED COEFFICIENTS

Variable	(Dependent Variable is APPLICATIONS)		
Intercept	-3.911 (0.997)	-3.650 (0.954)	-3.404 (0.931)
Ln (ADI households)	1.322 (0.208)	1.270 (0.198)	1.223 (0.193)
Number of Assignments Available	-0.588 (0.329)	-0.560 (0.311)	-0.658 (0.355)
Channel 1 already licensed?	1.279 (0.285)	1.313 (0.275)	1.171 (0.273)
Single Application?		-1.432 (0.385)	-1.322 (0.379)
Largest MSO was an Applicant?			-0.0264 (0.363)
Other three top MSO's were applicants?			0.675 (0.317)
Standard error of estimate	1.091	1.061	1.027
$\bar{R}^2$	0.560	0.620	0.644
Number of Cases	106	115	115

The number of assignment variables has the expected sign, but has a T-value of only -1.8. Since this variable takes on only two values (one or two) there is probably not enough variation to give a significant result.

The two right-hand columns show the effect of introducing additional variables, with the nine single-applicant stations included. The middle column shows results when a dummy variable for single applicant cases was introduced. This variable was significant, but the other regression coefficients were little changed. The right-most equation also contains two dummy variables (which are, to repeat, endogenous) for the presence of the largest MSO, or the second through fourth largest MSO, in a hearing. (Two variables were included because the largest MSO, according to industry sources, planned to operate a business communications network. Consequently, its actions in applying for licenses in different markets might have been motivated by networking considerations.) As can be seen, one of the two coefficients is significant but positive while the other is not significantly different from zero. The hypothesis that both coefficients are zero cannot be rejected at the 5% level ($F_{2,107} = 1.97$). None of the other coefficients are changed very much. The incorrect sign and the lack of significance, coupled with the fact that these variables are endogenous, has lead us to use the center equation in Table 4 for the work described in the next section.

4.4 The Value of an MDS License

If we had external observations on the cost of hearings (C_o), we could use one of the regression relationships to estimate the value of the license. Unfortunately, only anecdotal evidence is available. Robinson (1976) estimated the costs of presenting an MDS at 15,000 to 35,000 dollars per participant, based on "rather sparse" information. Discussions with industry sources indicate that this value is still approximately correct, when inflation is adjusted for. Thus, we can take these values as a rough interval estimate of $C(\bar{n})$.

By Equation (4.1) above, this estimate of hearing expenses implies that the typical comparative hearing in 1975, with 3.5 applicants, involved a license valued at between \$50,000 and \$125,000 ($3.5 \times 15,000 = 52,500$, and $3.5 \times 35,000 = 122,500$). This estimate of the implied value of an MDS license in 1975 obviously are only approximate, and therefore we will take a "typical" station to be worth about \$100,000. However, it is interesting that they suggest that the value of the television channel provided by MDS was strikingly less than the value of a commercial television broadcasting license.[12/] The probable reason for this disparity is that MDS, in 1975, was far from a mature business, and there must have been considerable discounting present for uncertainty.

5. ECONOMIC ANALYSIS OF ALTERNATIVE POLICIES

The model estimated in the preceding section, along with some other information introduced below, can be used to address the economic effects of alternative policies for assigning spectrum. There are four alternatives of interest:

1. The status quo policy of continuing to make the assignments by comparative hearing whenever there are more than two applicants.
2. Allocate enough additional spectrum to the service so that there is usually only one applicant for an assignment. This eliminates the hearings without requiring any change in the law.
3. Conduct a lottery for the assignment among all qualified applicants.
4. Auction the assignments to the applicants, using, for example, the "English" second price auction.

The economic implications of these policies are explored in the rest of this section.

5.1 The Costs of the Present System

As indicated in the preceding section, a typical MDS license (with a value of roughly \$100,000) might attract two to four applicants, each of whom expected to pay between \$15,000 and \$35,000 for the right to compete in a hearing. The private costs of obtaining a license if a hearing was required could thus run from \$30,000 to \$140,000--i.e., to more than the license's value. It is therefore not surprising that (as noted above) more than half of the cases that might have involved hearings were settled without one. In fact, the value of the license itself (V_1) is probably a rough upper bound on the total private costs, because if the sum of expenditures on hearings by all parties were to significantly exceed the value of the license, a negotiated settlement in which all but one of the parties dropped out of the case in return for some form of compensation, would be in everyone's interest.

In view of this, it seems reasonable to take the typical private costs of obtaining a license in 1975 at a hearing to be in the range $30,000 to $100,000 for a "typical" assignment with three competing applications. In one sense, this cost is a transfer, because it is paid by potential licensees to their lawyers, consultants and other experts on matters of interest to the FCC. However, we will treat private costs as real costs to society, and, as we will see, they can be significantly altered under the other alternatives.

In addition to these private costs there are two additional categories of cost, one of which is a true welfare loss:

1. The administrative costs of the hearing to the spectrum manager (e.g., the FCC), and
2. The opportunity cost of the spectrum, incurred because the delay in the hearing process leaves the allocation lying idle or underused.

Robinson (1978) presents an estimate of the administrative costs. He estimated that at least two months of staff time would be required, plus $1,900 in recording costs at the hearing itself. Using $60,000 at the cost of a year of staff time in 1975, including an allowance for overhead, this estimate implies a cost of about $12,000 per hearing.

As noted above, however, many of the potential hearings are not held. If we assume that a month of staff time is needed in any case, and use the data given above, we find that the average administrative cost is about $5,400 (the average of four cases requiring a hearing and 70 others that do not).

The opportunity cost of an idle assignment depends on the value of the assignment, the value of the spectrum in its next best use, the delay needed to make the assignment, and the discount rate used. Robinson reports that the typical time required to resolve a set of mutually conflicting applications by a hearing is 3 years. The opportunity cost is therefore 3 years of the rental value of the license. Using a 10 percent interest rate as the social rate of discount, 3 years of lost use of the assignment amounts to about 25 percent of the value of the license.[13/] Since many cases are settled short of a full hearing, this fraction overstates the loss. In the event of a settlement prior to a hearing, we will take the administrative delay to be one year, resulting in a loss of 9 percent in the license's value. The average fraction of value which is lost is therefore 10 percent ((0.09 x 70 + 0.25 x 4)/74).

Finally, one needs some estimate of the value of the spectrum in an alternative use. In the case of MDS in 1975, it is arguable that this value is zero because no other service was authorized to use the same frequency band.[14/] With these figures in mind, we can construct Table 5, which shows the costs of the present system of assignment for the typical system.

Table 5

Average Costs of Assigning a "Typical" MDS License

Administrative Cost to FCC	$5,400
Private Cost of Representation	$30,000 - $100,000
Opportunity Cost of Idle Assignment	$10,000
Total	$45,400 - $115,400

As can be seen from the table, the administrative costs (as Robinson suspected), are relatively unimportant. The opportunity cost of the unassigned licenses, and the costs of participation, dominate. And, the overall costs almost equal the assignment's value.

5.2 Distributional Consequences of Hearings

Accepting the estimates in Table 4 as roughly correct, it is interesting to examine how the costs and benefits are distributed among the parties to the selection process. Five groups can be identified as potential gainers or losers:

1. The government,
2. The winning applicant,
3. The losing applicants,
4. The professional intermediaries (lawyers, consultants, and so forth) who represent the competing applicants, and
5. The general public.

For the typical case with the costs summarized in Table 5, it can be seen that the government is a loser in the game, since it costs $12,000 to award the license if a hearing has to be held, and $5,000 otherwise. Naturally, these costs are passed along through the tax system to the other four groups. (Practically speaking, this means our fifth group, the general public.)

The winning applicant receives a license typically worth $100,000, but pays representation costs of $15-35,000, so the winner's net gain is $65,000 to $85,000. On the other hand, the losing applicants receive no license but nevertheless must pay whoever represented them. Our fourth group, the intermediaries, are economic gainers, in the amount of $30,000 to $100,000. The general public bear the opportunity costs.

5.3 Implications of an Increased Spectrum Allocation

The first alternative policy to be considered is one that increases the spectrum available. If one wishes to eliminate the delays and costs associated with hearings, one possibility would be to increase the allocation until there are enough assignments available to accommodate all applicants without hearings. This, in effect, is what the proposed expansion of the allocation for MDS, coupled with sharing between MDS, ITFS, and operational fixed services, might allow.

The regression model estimated in the preceding section can be used to address this possibility in several ways. First, one can look at the number of assignments that would have to be made available to eliminate multiple hearings. To do this, set the left hand side of the regression equation (n_i) equal to 1 (i.e., set the expected number of applicants to 1), and solve for the number of assignments N_i. Evaluating the number of assignments at the mean of ℓn(ADI households), and with the two dummy variables equal to 1 (this is consistent with having $n_i = 1$ and $N_i > 1$), we find that an estimate 5.13 assignments are required. For comparison, the sample mean number of applicants in 1975 is 3.5.

This estimate is biased, however, because the coefficient on N_i is random. Using the method of Tin (1965) for estimating the ratio of two random variables gives an approximate estimate of the mean and its standard error, namely 6.67 ± 3.83. Thus, in 1975 something like 7 assignment would have been necessary to satisfy demand without resorting to hearings.

The same calculation can also be made for individual cities. Table 6 (columns 2 and 3) shows the estimated mean and standard deviation of the number of required assignments for 44 of the fifty largest television markets.[15/] As can be seen from the table, the largest markets apparently could have accommodated as many as 16 ± 9 MDS stations in the long run.

Another way of analyzing the effect of an increased allocation is to calculate the probability of having two or more applications if there are N_i^* assignments available. To do this requires an assumption about the distribution of the error term. In view of the many approximations made up to now there is no clear choice. If we assume the errors are normal, for example, we can calculate the appropriate probability in each market.

The results of such calculations are shown in Table 6, columns 4 and 5, for two different assumptions about the number of assignments that would be allocated to MDS. In the first case, it has been assumed that each television market had a total of twelve assignments available (ten of them newly allocated, plus the two originally available). In the second case, a tabulation of "unencumbered" channels in FCC Docket 80-112 has been used to give the total number of available channels.

TABLE 6 — MODEL PREDICTIONS FOR LARGE MDS MARKETS

	Total Available Channels[1]	Estimated Number of channels needed to give 1 application per assignment		Probability that more than 12 Channels are needed to give 1 application per assignment	Probability that more than the total available channels are needed
		Mean	Standard Deviation		
Atlanta, GA	22	9.24	5.04	11.89	6.69
Albany, NY	28	6.97	3.82	8.21	4.9
Baltimore, MD	18	8.86	4.84	11.2	7.45
Birmingham, AL	2	6.67	3.66	7.81	72.97
Boston, MA	4	11.77	6.46	17.54	86.33
Buffalo, NY	22	8.01	4.37	9.76	5.96
Chicago, IL	3	13.56	7.48	22.64	98.62
Cincinnati, OH	26	8.3	4.53	10.23	5.6
Cleveland, OH	2	10.81	5.92	15.18	97.16
Columbus, OH	13	7.54	4.12	9.04	8.34
Dallas, TX	5	10.11	5.53	13.63	56.91
Dayton, OH	27	6.98	3.82	8.22	4.97
Denver, CO	21	8.11	4.43	9.92	6.18
Detroit, MI	14	11.4	6.25	16.58	13.31
Ft. Worth, TX	16	10.11	5.53	13.63	9.62
Hartford, CN	33	8.36	4.56	10.32	5.08
Houston, TX	11	9.41	5.14	12.21	13.73
Indianapolis, IN	19	8.79	4.8	11.08	7.09
Kansas City, MO	32	8.3	4.53	10.23	5.07
Los Angeles, CA	2	14.43	7.98	25.49	99.84
Louisville, KY	7	7.24	3.96	8.6	17.61
Memphis, TN	33	7.55	4.12	9.04	4.83
Miami, FL	3	9.33	5.09	12.06	82.05
Milwaukee, WI	5	8.26	4.51	10.16	39.59
Minneapolis, MN	18	9.47	5.17	12.34	7.98
New Orleans, LA	32	7.32	4.	8.72	4.81
New York, NY	5	16.4	9.11	32.78	96.36
Norfolk, VA	13	6.61	3.63	7.74	7.21
Okla City, OK	5	7.18	3.93	8.52	30.61
Philadelphia, PA	13	12.8	7.05	20.36	17.92
Phoenix, AZ	33	7.47	4.08	8.93	4.81
Pittsburgh, PA	33	10.19	5.57	13.79	5.7
Portland, OR	31	8.19	4.47	10.04	5.15
Providence, RI	12	8.	4.37	9.74	9.74
Rochester, NY	27	5.74	3.19	6.68	4.52
San Antonio, TX	25	6.67	3.66	7.82	4.99
San Diego, CA	9	7.62	4.16	9.15	13.05
San Francisco, CA	5	11.69	6.42	17.33	85.81
Seattle, WA	33	9.02	4.92	11.48	5.3
St. Louis, MO	33	9.64	5.27	12.67	5.51
Syracuse, NY	33	6.41	3.53	7.49	4.5
Tampa/St.Peter, FL	29	9.2	5.02	11.83	5.69
Toledo, OH	33	6.61	3.63	7.73	4.55
Washington, DC	25	10.83	5.93	15.23	7.03

1. Includes 2 channels at 2140-2152, plus channels listed as "unencumbered" in FCC Docket 80-112, Appendix B.

(This figure is shown in column 1 of Table 6, with the two original channels included.)

As can be seen from this table, there are only four cities where the probability that more than twelve assignments is needed exceed 0.20. Even in New York, there is calculated to be about only a one third chance that more than twelve assignments are needed. However, in 14 out of the 44 cities, there are already fewer than 12 channels available; not coincidentally, these tend to be the largest cities where the demand for MDS assignments, and for spectrum for use by other radio services, already is high.

These results tell us something about the likely effect of the changes proposed in Docket 80-112. On the one hand, in all but the largest markets the proposed allocation of additional spectrum will probably eliminate the need for comparative hearings because the demand for assignments will be less than the supply. On the other hand, hearings will still be needed in the largest markets, for the most valuable assignments.

More generally, the results in Table 6 illustrate a point about so-called "spectrum scarcity." This phrase is usually used to describe a situation where there the demand for spectrum (at a zero price, under the present system) exceeds the supply. The results in the table show that there is substantial variation in the value attached to the spectrum. Hence, a system that allocates spectrum nationwide almost inevitably causes spectrum to be idle or underused in some areas, while keeping it "scarce" in other places.

One solution to this problem has been suggested by Levin (1971), namely increased use of "squatter's rights," secondary allocations which must be vacated if anyone qualified for the primary service wants to use an assignment. The analysis of how such a system of secondary and primary rights would work raises a number of interesting questions which are beyond the scope of this paper. For example, should side-payments be allowed between different classes of user, so that, for example, an MDS station using an assignment for which is primarily allocated to ITFS could pay for the continued right to use the assignment. More generally, how might allocations be made which encourage efficient inter-service sharing of assignments, without requiring comparative hearings?

Turning to the costs of this method of avoiding comparative learnings, we see that if we ignore the costs associated with allowing MDS to use spectrum, rather than some other service, the apparent costs fall dramatically. For the typical station now will have only one applicant, and a license will probably issue in six months without requiring a hearing. Moreover, if there is enough spectrum so that everyone who wants to can enter, the losses in rent will be small because competition will have reduced the rental value of a license essentially to zero.

Of course, there are alternatives to MDS, and denying them spectrum has costs. For example, the "unencumbered" channels in Table 6 are also available for instructional television (ITFS) and private microwave systems. But there is no information of their value (their licenses were not even awarded in comparative hearings), and so it is not possible to make a cost estimate for this alternative.

5.4 Implications of Auctions and Lotteries

If auctions or lotteries are used, the number of licenses available will affect the amounts bid and the behavior of lottery participants. For example, if the spectrum allocation is increased, the value of each individual assignment falls because there are competing stations. Consequently, the bids for licenses will fall to zero, and few individuals will find the prize offered in the lottery worth the costs of competition. Therefore, in this subsection we will assume that the spectrum allocation is not increased. This assumption makes some of our calculations simpler, because fewer assumptions are required. Moreover, it provides a clear contrast to the alternative discussed in the preceding subsection, where spectrum was increased but the market system was not allowed to operate.

As our calculations for the hearing suggest, the costs of an assignment policy depend on several factors:

- The number of competing applicants and the implied value of the assignment,
- The cost of participating in the selection process,
- The administrative costs of the selection process, and
- The time required to complete the selection process.

For the purposes of this illustration, Table 7 presents reasonable values for these factors for each of the three hearing methods. The reasons for choosing these values are discussed in the following paragraphs.

Table 7

Factors Used to Assess Differences
Among Alternative Assignment Mechanisms

	Comparative Hearing	Lottery	Auction
Time Needed to Assign License	3 years	6 months	6 months
Expected Cost of Assignment to FCC	$ 5,400	$5,000	$5,000
Expected Cost of Obtaining Assignment Per Competing Applicant	$25,000	$1,000	$5,000
Number of Competing Applicants	3.5	15	4

As can be seen from the table, the factors chosen for the comparative hearing are the same ones developed in the preceding section. We have chosen the typical case, in which two applicants require a hearing, and 3 years elapse before one of them is selected and begins operation. The costs shown for this alternative are the ones developed in Table 3 above, except that $25,000 mid-point value of Robinson's range of $15-35 thousand has been used for the cost of representation.

Turning next to the lottery and the auction, we have assumed that 6 months are required to complete the selection. This time estimate is longer than the three months said by one source (CATJ) to be the time required to process uncontested applications. But, additional time will undoubtedly be needed to allow applicants to prepare for the auction or lottery.

In the lottery, as in the comparative hearing, the number of applicants depends on the cost of participating in the selection process and the value of the license. As in the hearing, rational individuals will be attracted by the chance of winning a valuable prize. If an unlimited number of risk neutral individuals are qualified to operate a station, additional applications will be received until the expected excess profits are reduced to zero. For instance, if licenses are worth $50,000 and it costs $1,000 to apply for a license, there would be 50 applicants. More realistically, risk aversion or some limit on the number of truly qualified applicants may reduce the number who participate in the lottery. On the other hand, lotteries of Federal oil leases are reported to have attracted thousands of individuals, each paying a nominal fee for a small chance at a large prize (Wall Street Journal, 1980). Overall, then, the lottery could have anywhere from 10 or so up to 100 individuals in contention. It seems reasonable for our cost comparison to assume that 20 of these individuals would be found eligible. Each of these spends resources worth perhaps \$1,000, but has a chance at a prize worth \$100,000. Such a gamble probably will be attractive to many people. In our analysis below, we assume 20 applicants participate in the lottery.

Now let us consider how the auction operates. In the table, we have shown the costs of participation to be \$5,000, representing the \$1,000 that is required to prepare the application, and another \$4,000 which represents the cost of planning, and bid preparation. As in the other two assignment methods, potential bidders must weigh this cost against their expected profits. But, it can be shown that the potential profits of a bidder at an auction decline at a rate proportional to $1/n^2$ instead of $1/n$, where n is the number of participants in the auction.[16/] Consequently, if the license is worth \$100,000 and the costs of participation are about \$5,000, the number of bidders will be about $\sqrt{20} \approx 4$ (i.e., $\sqrt{100,000/5000}$). (This calculation assumes that the bidders are risk neutral. Bidders' risk aversion would probably lead to a smaller number of applicants.) In our analysis, we assume three applicants participate in the auction.

The reason the auction attracts so many fewer bidders than the lottery is not hard to discover. The auction makes bidders pay for their license. Net of this payment, if can be shown that they make "almost normal" profits. On the other hand, the lottery gives its winner all of the quasi-rent.

Table 8

Comparison of Assignment Costs
For a "Typical" MDS License

	Comparative Hearing	Lottery	Auction
Costs of Administration	$ 5,400	$ 5,000	$ 5,000
Costs to Applicants	87,500	20,000	20,000
Opportunity Costs of Idle Assignment*	10,000	5,000	5,000
Total Cost	$102,900	$30,000	$30,000

* Assumes 10% discount rate.

To complete the illustration of costs, Table 8 presents a comparison of the three methods. In it, we have used the typical value of $100,000 in calculating the opportunity costs. As shown in the table, both the lottery and the auction are less costly than the present system of comparative hearings. However, despite the fact that the cost of participating in the lottery is one-fifth the cost of participating in the auction, the total cost of all resources used by lottery participants is as large as for the auction because the lottery has many more competing applicants.

Although auctions and lotteries are shown as having equal costs, different choices of costs and the number of participants could swing the comparison in Table 8 in favor of one or the other. Indeed, it is probably true that each technique may be least costly under certain circumstances. What seems clear is that both auctions and lotteries probably are less costly than the comparative hearing. This cost saving is achieved by reducing (1) the opportunity cost of the idle assignment, and (2) the total cost of participating in the assignment process.

The auction and lottery also differ from the present system in their distribution of gains and losses. In general, the biggest gainer in the lottery is the successful applicant. In the auction, a large share of the license's value is transferred to the government through the auction payment. The intermediaries receive less under either proposed alternative than under the present system.

6. CONCLUSION

A radio license assigns specific rights to the use of the frequency spectrum to particular groups of individuals. These rights depend on the technical inputs that the licensee is allowed to use (antenna height, power, and so forth), and on the services to be offered. If the most valuable bundle of services, the least-cost way to deliver them, and the impact of that delivery method on spectrum were known in advance, the rights specified in the license could be defined optimally, and an "optimal" assignment mode.

The present system of assigning licenses using an administrative process is, as shown above, costly and suboptimal. In the comparatively tiny MDS service, the costs of assignment were estimated above to be almost as large as the value of the license. The costs associated with economically more important services (e.g., television broadcasting or domestic satellites) may bear a comparable relationship to the much larger value of the licenses.

The traditional response to situations where the demand for spectrum exceeds its supply has been to allocate more spectrum. Although this system's costs cannot be estimated without a knowledge of the value lost when other services are displaced, our analysis has shown that this "solution" may require dramatic increases in spectrum if those areas of the country with the most intense demands are to be satisfied. Such increases (because they are carried out on a national basis), are likely to leave much of the increased allocation idle or underused elsewhere.

In contrast, auctions and lotteries of spectrum have lower costs than the administrative system. The auction system has the additional not inconsequential advantage of revealing the value of particular spectrum, through the bidding mechanism. This information can be used to make decisions about how much additional spectrum ought to be allocated to a particular service.

FOOTNOTES

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1/ FCC Common Carrier Docket 80-116, Notice of Inquiry and Notice of Proposed Rulemaking, issued March 19, 1980.

2/ The rules governing MDS are contained in Part 21, Subpart K of the FCC's Rules and Regulations (47 CFR 1), hereafter cited as FCC Rules.

3/ Report and Order, Docket 19493, 35 FCC 2nd 154 (1972) and 45 FCC 2nd 616 (1974), reconsideration denied 57 FCC 2nd 301 (1975).

4/ FCC Docket 80-112, p. 9.

5/ Prior to Ashbacker, the FCC apparently set some conflicting applications for a hearing, but issued a license without a hearing (presumably after a public interest finding) in other cases. 326 U.S. 338, n. 1.

6/ Docket 80-116, p. 28.

7/ E.g., Butters (1975). See Engelbrecht-Wiggans (1980) for a survey of this and other auction mechanisms.

8/ The Communications Act of 1934, Section 309(d) specifies a three-year term for broadcasters' licenses and a five-year term for all other radio licenses.

9/ When the total number of applications is odd, there must be one more application for one channel or the other. Thus, a situation where there are two applicants for channel one and three applicants for channel two counts as an "even" split.

10/ The implication of this equilibrium condition is that each applicant assesses the probability of winning to be $1/n_i$. Since only one out of the n_i applicants can be awarded the assignment, this assumption seems reasonable ex post. However, there is obviously no reason why individuals should necessarily view their chances in this way ex ante. Taking their ex ante probability to be $1/n_i$ is an additional assumption in this model.

11/ For examples of the techniques that could be used, see Hausman and Wise (1978) and Heckman (1977).

12/ Estimates of the value of a "typical" VHF television station, for example, based on capitalization calculations, are around $2 million (Crandall, 1978). VHF stations owned and operated by one of the three major networks, all of which are in the top television markets, may be worth almost $60 million dollars each (Webbink, 1978).

13/ This fraction is based on the amortized value of the license, and is given by $1-(1+r)^{-T}$ --where r is the discount rate and T is the length of the delay. For r = 0.10 and T = 3 this factor is 0.25.

14/ As pointed out by Kim Degnan if some of the FCC's proposals are adopted, the spectrum used may have a positive value in an alternative use because MDS will share an allocation with two other services, ITFS and POFS.

15/ These markets are those listed as among the top fifty in FCC Docket 80-112. That list includes six ADI's that are not included in the 1975 data on which the regression equation is based.

16/ See Wilson (1977).

References

1. Ashbacker Radio Co. v. FCC, 326 U.S. 327 (1945).

2. Butters, "Heterogeneity and the Economics of Auctions," U. of Chicago, Dept. of Economics, (1975).

3. Community Antenna Television Journal (CATJ), "Everything You Always Wanted to Know about the 'MDS Service' but Didn't Know Who to Ask," (April 1977).

4. Crandall, R., "Regulation of Television Broadcasting: How Costly is the Public Interest?", Regulation 2:1 (Jan/Feb 1978).

5. Engelbrecht-Wiggans, R., "Auctions and Bidding Models: A Survey," Management Science 26:2 (Feb. 1980), pp. 119-142.

6. Hausman, J. And D. A. Wise, "Social Experimentation, Truncated Distributions, and Efficient Estimation," Econometrics 45:4 (May 1977), pp. 919-939.

7. Heckman, J., "Sample Bias and Specification Error," Econometrica 47:1 (January 1979), pp. 153-162.

8. Levin, H. J., "Economic Effects of Broadcast Licensing," J. Political Economy 72 (April, 1964) pp. 151-162.

9. Levin, H. J., The Invisible Resource: Use and Regulation of the Radio Spectrum, (Baltimore; Johns-Hopkins Press, 1971).

10. Noll, R., M. Peck and J. McGowan, "Economic Aspects of Television Regulation, (Washington DC, The Brookings Institution: 1973).

11. Robinson, J. O., "Assignment of Radio Channels in the Multipoint Distribution Service by Auction," presented at Sixth Annual Telecommunications Policy Research Conference, Airlie, Va., (May 1978).

12. Television Digest, Inc., Television Factbook, (Washington DC, various years).

13. Tin, M., "Comparison of Some Ratio Estimators," J. American Statistical Association 60:309 (March 1965), pp. 294-307.

14. Vickrey, W., "Counterspeculation, Auctions and Competitive Sealed Tenders," J. of Finance 41:1 (1961), pp. 8-37.

15. Webbink, D. W., "The Value of the Frequency Spectrum Allocated to Specific Uses," IEEE Trans. on Electromagnetic Compatability, EMC-19, No. 3 (August 1977), pp. 343-351.

16. Wilson, R., "A Bidding Model of Perfect Competition," R. Econ. Stud. 44:3 (October 1977), No. 138, pp. 511-518.