Problems of Radio Frequency Allocation

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NOTE

This manuscript on "Problems of Radio Frequency Allocation" was originally intended to become a RAND research memorandum (RM). For various reasons, it never reached the publication stage. Even though it is now over 20 years old, the content is still of interest and copies are occasionally requested. To make the document more easily available, it is now being published as an unrestricted draft (DRU).
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I. INTRODUCTION

Under the National Aeronautics and Space Act of 1958, Congress assigned to the National Aeronautics and Space Administration responsibility for "the establishment of long-range studies of the potential benefits to be gained from, the opportunities for, and the problems involved in utilization of aeronautics and space activities for peaceful and scientific purposes."* This study has been undertaken for the National Aeronautics and Space Administration in accordance with that responsibility.

Peaceful and scientific space activities involve the use of frequency spectrum for communication links. The use of frequency spectrum for communication links. The use of frequency spectrum for telemetry, for tracking, for guidance, and for command and control has been characteristic of space endeavors almost from the very beginning. Until now the requirements for these functions have been modest and have not imposed a serious strain on frequency usage. However, much greater demands for spectrum are being forecast for future space endeavors. In particular, serious concern has been expressed regarding the provision of frequencies for operational communication satellite systems.

Short run decisions regarding frequency spectrum for space activities must necessarily be made within whatever institutional framework exists for determining how radio spectrum will be used. In the long run, however, institutions are amenable to change. For the most part, this study is directed to the long-range question of what modifications in the institutional framework are advisable. We believe, however, that an understanding of the analysis contained in the study also will be valuable to those responsible for short-run decisions concerning the use of frequency spectrum.

*42 U.S.C. 2451 (c) (4).
The Three-Dimensional Nature of Frequency Utilization

The use of frequency spectrum, i.e., the act of radiating or broadcasting, involves three dimensions. First, there is the frequency at which the emissions take place, or, more precisely, the frequency bandwidth within which emissions take place. Second, there is the time during which the emissions occur. Third, there is the space in which the emissions radiate. The third dimension itself involves two dimensions—power as a function of points in space. "Interference" occurs only when emissions from one source interact with emissions from another source in all three dimensions. Two stations which radiate frequency at the same time but within different (3-dimensional) areas will not interfere with each other. Two stations operated on non-overlapping frequency bandwidths will not interfere with each other even if they are operated at the same time and in the same area, and, of course, there will be no interference between two stations that operate at different times even though they use the same frequencies in the same area.

Sharing

Since radio operations can be adjusted in all these dimensions, a vast array of combinations of space, time, and bandwidth is possible. Generally, the term sharing is used to mean that two or more individuals are permitted to broadcast at the same frequency at different locations or at different times. That is, frequency (used in the narrow sense) is shared by isolating the areas in which radiation occurs or the time at which it occurs.

Sharing by geographical separation is made possible by two things. First, the power at any point in a radiation pattern is a decreasing function of the square of the distance from the source of radiation. Second, radio waves generally do not follow the curvature of the earth. Because of either or both of these phenomena, signal strength from a remote source can be so small that interference with reception from a nearby source at the same frequency is negligible.

There is an important exception to the second phenomenon, however. At certain frequencies radiation is reflected or refracted by the
gaseous layers that surround the earth. This makes it possible to broadcast at these frequencies over long distances, but it also makes it very difficult to share bandwidth by resorting to geographical separation.

The extent to which different parties can use the same frequency is also a function of the minimum quality of reception that is tolerated. As more and more interference is allowed by expanding the number of broadcasters using a frequency, or the area in which they broadcast, the quality of reception declines, and less and less information can be communicated per time unit in a given channel. Thus one question that must be resolved in deciding how frequency spectrum is to be used concerns the amount of interference that is tolerable.

These elementary concepts and physical relationships provide a basis for analyzing problems that arise in the use of frequency spectrum by communication satellites. Our purpose here is twofold. First, and most important, communication satellites furnish a convenient vehicle for illustrating what is involved in determining how frequency spectrum is used. Second, we are interested directly in the problem of making frequencies available for communication satellites if their promise proves to be real.

Accommodating Changes in Demand for Frequencies

Though communication satellites (and other space activities) are a product of new technology, in one important respect they represent no new problems so far as spectrum utilization is concerned. The history of spectrum utilization has been marked by a stream of inventions that have placed new demands on frequency spectrum. The microwave relays that have come to dominate overland long-distance communications are a good example of technology that places new demands on frequency spectrum. Such relays offer enormous communications capacity at very low cost, but their development introduced a new demand for frequency spectrum. Five years ago, no one foresaw the kinds of demand now being made for allocation of frequency spectrum on an international basis for space purposes. Even today the frequency bands that will
be wanted for the operation of communication satellite systems five years hence is a matter of great conjecture. Much of the recent concern over providing frequency spectrum for space services arises out of the inflexibility of existing institutional arrangements. Though technology will not have developed to the stage where space applications justify it until, say, 1970, it is argued that we must make enormous allocations to space services today in order to guarantee that frequencies will be available in the future. On the other hand, it is clearly desirable to avoid keeping large portions of the frequency spectrum idle simply to provide for future developments. In brief, from the standpoint of an efficient utilization of frequency spectrum, we would like a frequency utilization system that enables us to make full use of frequencies currently, but which is not so inflexible as to make it impossible to meet changed circumstances in the future.

The Costs of Sharing

There is now a broad consensus that communication satellites will in the future be able to share frequency spectrums with other communication services. Putting the argument in terms of sharing or not sharing, however, is very misleading. A showing that it is technically possible for satellites to share frequencies with other systems is insufficient; the real question concerns the extent to which communication satellites should share frequencies with other services. Different levels of sharing involve different costs, and in deciding the question of the extent to which sharing is desirable, the costs of each arrangement must be weighed against the associated benefits.

Because of limitations on payloads that can be placed in orbit, the power available in communication satellites will be relatively limited, at least for the near future. As a result, signal strength from the satellite to earth will be so weak that it will not appreciably affect reception in other terrestrial communication services operating at the same frequencies. Thus the problem of interference in the near term is limited to interference between the earth terminals of
the satellite systems and other communication services at the surface of the earth.*

A description of some of the steps that might be taken to reduce interference between satellite ground terminals and terrestrial communication systems will illustrate how sharing is a matter of degree and how it imposes costs.

In the case of communication satellites there is no doubt that the possibilities for keeping interference to a minimum by carefully selecting the location of terminals has been the most important factor leading to agreement that it is technically possible for satellite systems to share frequencies with other services. The choice of the geographical location of ground terminals obviously has an important effect on the space in which radiation occurs.

At the frequencies being contemplated for communication satellites, radiation generally will not follow the curvature of the earth but will travel in a straight line. Moreover, as pointed out above, the power at any point in a radiation pattern is a decreasing function of the square of the distance from the source of radiation. Thus, by choosing remote areas as sites for ground terminals for communication satellite systems the amount of interference, either from satellite terminals into other communication systems, or vice-versa, can be substantially reduced.

Terrain factors are also important in the choice of terminal locations, because radiation patterns are affected by terrain. Thus, a communication satellite ground terminal located in an area surrounded by mountains would cause less interference to other ground services, and would be interfered with less by other ground services, than would a terminal located in a perfectly flat area.

Locating ground terminals in isolated and/or protected areas, however, may impose costs that would not exist if a less isolated location were chosen. A West Coast ground terminal, for example,

*This limitation, however, will not apply in the long run, and the long run may be fairly soon for the USSR.
located in the Mojave Desert would require the construction of communication channels of some sort, probably microwave relay, from the ground terminal site into some central exchange area. The more remote the site, the higher the costs are likely to be for these interconnecting channels. Thus we must weigh the additional costs associated with remote location against the (interference) costs that would be imposed on other communication systems if the ground terminal were to be located in a more populated region.

Choice of the ground terminal location is by no means the only parameter in the design of a satellite system that will affect the amount of interference. The directivity of antennas will also affect the level of interference. Steps can be taken to minimize the amount of energy emitted by antennas in various directions. Moreover, the antennas can be shielded to get the same effect as choice of terrain. The power tubes that are used can be designed more or less carefully to control radiation at frequencies other than those at which the tube is intended to be operated, etc., however, none of these steps is free; each imposes a cost.

It is important to note that such design measures are applicable not only to the ground terminals of the satellite systems, but also to all terrestrial communication equipment that might interfere with satellite reception. The design of surface microwave systems, for example, can be varied to regulate the interference caused to communication satellite terminals. Microwave terminal sites can be selected in areas removed from communication satellite terminals. Microwave antenna directivity can be controlled, shielding can be used, etc.

Again, however, all of these measures impose costs on the particular system involved, and raise the question of whether the design precautions are worth the benefit obtained in the form of reduced interference with other systems.

Frequency Bandwidth "Requirements" for Communication Satellites

The economic potential of communication satellites appears to be found in their use as high-capacity long-distance transoceanic links, e.g., from London to New York, or Hawaii to San Francisco.
The capacity of a given communication satellite system is a function of a number of design parameters, all of which are more or less substitutable in providing any given capacity. Some of the important parameters are: power in the satellite, orientation of the satellite, sensitivity of ground terminal receivers, and size of receiving antennas. Also one of the important parameters is the amount of frequency bandwidth available for use in transmission. It is the latter fact that has prompted requests for very large sectors of frequencies to be allocated to communication satellite systems. Bandwidth on which to transmit can be substituted for other means of attaining high capacity—means which are quite expensive. It will be no simple matter to develop a communication satellite system that has a sufficiently high capacity, the utilization of which will yield revenues sufficient to make it pay. And, of course, those who undertake this development will want a large frequency assignment in order to avoid the cost of achieving capacity by other means. On the other hand, providing large blocks of frequency for communication satellites will impose costs on other existing or potential radio communication systems. Again this raises the question of whether the benefits are worth the costs involved.

Frequency Spectrum as One of the Costs of Communication Satellite Systems

Even the question of whether any communication satellite system is economic and, if so, the type of system that is most economic, depends on the value of the spectrum used by the satellite system. Different satellite systems have different characteristics so far as frequency spectrum usage is concerned. Passive systems require ground radiation at very high powers, because there is no amplification in the satellite itself. Radiation at these powers requires much greater isolation for the ground terminals of a passive system than would be required for active systems because the ground radiation power required for an active system is considerably smaller than that required for a passive system.
Low altitude systems, active or passive, require the use of antennas with 180 degree coverage—they must be capable of sweeping from horizon to horizon at almost any angle. Twenty-four hour equatorial satellites will, however, be able to operate with antennas that are essentially fixed. Thus, the size of the geographic area surrounding the ground terminals that will have to be protected for low altitude satellites will be somewhat greater than for 24-hour equatorial satellites. In comparing alternative satellite systems, one of the costs which should be added to each of the systems is the cost of the frequency spectrum required for equivalent operations. Moreover, since submarine cables take no frequency spectrum, the total value of frequencies used by communication satellite systems should be added to their costs in comparing satellite system costs to cable costs.

Resumé of Recent Activities

The first serious consideration of frequency allocations for space purposes was generated by preparations for the 1959 Administrative Radio Conference of the International Telecommunications Union at Geneva. The role of the International Telecommunications Union is discussed in some detail in Chapter V of this report. In practice its primary function has been to limit authorizations to use frequencies through international agreement, and thereby to contain interference. Today the ITU has a membership of 101 nations including all major powers, geographical and political subdivisions, with the exception of Communist China and East Germany. Agreements among ITU members have the force of treaties. Periodically, the members meet for the purpose of revising existing regulations, including the table of frequency allocations. This was the purpose of the 1959 Conference.

Recommendations by the U.S. delegation to such conferences are typically the product of two years or so of study and consultation by interested parties. Primary responsibility for advising the State Department is divided between (1) the Federal Communications Commission which handles U.S. allocations and assignments to private
individuals, firms, and state and local government agencies; and (2) the Interdepartment Radio Advisory Committee which handles allocations and assignments for all departments of the federal government. Each of these in turn consults directly with current and prospective spectrum users over whom they have cognizance.

In anticipation of the 1959 Conference various groups (for example, the American Rocket Society and the U.S. Army Signal Corps) presented studies and testimony to IRAC and the FCC regarding frequency requirements for space activities. As a result, the United States delegation went to the conference with a formal proposal for the allocation of specific frequencies to space services. Initially, the U.S. proposed the allocation of eight channels for space services. They were:

\[
\begin{align*}
25.60 & \quad 25.65 \text{ [mc/s]} \\
135.0 & \quad 136.0 \\
1,700 & \quad 1,725 \\
1,825 & \quad 1,850 \\
2,275 & \quad 2,300 \\
8,300 & \quad 8,400 \\
15,150 & \quad 15,250 \\
31,500 & \quad 31,800
\end{align*}
\]

The band 400.0 - 401.00 Mc/s was added to this list while the conference was in session. Though the United States proposal contemplated sharing these frequencies with other services, first priority was to be given to space services.

The International Radio Consultative Committee (designated CCIR) of the ITU also undertook studies of frequency requirements for space in preparing for the 1959 administrative Radio Conference. The CCIR is an advisory committee established by the ITU to advise it on technical radio questions. The CCIR studies, as well as the recommendations that it had adopted at its Plenary Assembly meeting in Los Angeles, April 1959, were transmitted to the ITU for consideration at the 1959 Administrative Radio Conference.

Similarly, the Committee on Space Research (COSPAR), established in 1958 by the International Council of Scientific Unions, made
recommendations to the ITU for frequency allocations to space services. A letter forwarded to the ITU by Professor H. D. Van de Hulst, President of COSPAR, contained the following:

"Cospac recommends that at least 12 Mc/s of bandwidth be reserved by international agreement for the purpose of space research, spread approximately as follows:

1 Mc/s in the lower part of the 100 - 300 Mc/s region
1 Mc/s at the lower end of the 300 - 1000 Mc/s region
10 Mc/s at the upper end of the 300 - 1000 Mc/s region
or at the lower end of the 1000 - 3000 Mc/s region.

Frequency bands for telecommunications between points on different parts of the earth by means of passive or active use of artificial satellites are not included in the estimates made above."

Largely as a result of the endeavors of these groups, the 1959 Administrative Radio Conference made certain provisions for space services. However, final action fell considerably short of the recommendations of the U.S. delegation. International Telecommunications Union Resolution No. 34 adopted at Geneva states:

"The following frequency bands have been allocated on a worldwide basis for research purposes in connection with space and earth-space services:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
</tr>
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<tr>
<td>136</td>
<td>Mc/s</td>
</tr>
<tr>
<td>400</td>
<td>Mc/s</td>
</tr>
<tr>
<td>1427</td>
<td>Mc/s</td>
</tr>
<tr>
<td>1700</td>
<td>Mc/s</td>
</tr>
<tr>
<td>2250</td>
<td>Mc/s</td>
</tr>
<tr>
<td>5250</td>
<td>Mc/s</td>
</tr>
<tr>
<td>8400</td>
<td>Mc/s</td>
</tr>
<tr>
<td>15.15</td>
<td>Gc/s</td>
</tr>
<tr>
<td>31.5</td>
<td>Gc/s</td>
</tr>
</tbody>
</table>

(Gc/s is an abbreviation of "Cygacycles" = 1,000 Mc/s.)

In addition, the following frequency bands have been allocated for the same purposes on a secondary basis:

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 003</td>
<td>kc/s</td>
</tr>
<tr>
<td>19 999</td>
<td>kc/s</td>
</tr>
<tr>
<td>39 985</td>
<td>kc/s</td>
</tr>
</tbody>
</table>

Furthermore, the frequency 183.6 Mc/s + 0.5 Mc/s can also be used on a noninterference basis."

*Ibid., p. 48.*
All of these frequencies share with fixed and mobile services, i.e., none are exclusive; and only in the bands 136-137 Mc/s, 1427-1429 Mc/s, 15.15 - 15.25 Ge/s, and 31.5 - 31.8 Ge/s is space or service designated as primary. In all other bands the allocation to space is on a secondary basis. Finally, all of the allocations are restricted to research purposes so that no spectrum is allocated to regularly operated systems such as communication satellites.

In addition, the Administrative Radio Conference adopted a resolution calling for an Extraordinary Administrative Radio Conference to be held in 1963 for the express purpose of allocating frequency bands for space and radio communication purposes.

Through 1959, space frequency deliberations centered about the modifications that should be made in international agreements in order to provide for space activities. Beginning in 1960, however, the question of what frequency provisions would be made domestically for such activities came to the fore. In August 1959, the Federal Communications Commission issued a Report and Order in Docket #11866. That Docket, under consideration since November 1956, was concerned with FCC policies regarding frequencies above 890 megacycles. In its Report and Order of August 1959, the Commission announced that it had decided to make a significant part of the microwave spectrum (above 890 Mc/s) available to private firms and individuals for the purpose of establishing private microwave communication systems.

Not unexpectedly, the communications common carriers, led by the American Telephone and Telegraph Company, took exception to this decision, and petitioned the FCC for reconsideration. Largely because it believed that important developments in space communications had occurred subsequent to its earlier proceedings, the Commission agreed in May of 1960 to reopen the Docket and to bring it up to date as regards frequency requirements for space communications.

In the proceedings that followed, the demand for frequency spectrum that would be generated by operating communication satellite systems was the key issue. In their testimony, American Telephone and Telegraph Company representatives argued: (a) that communication satellites would require the use of very large amounts of frequency spectrum,
e.g., 2000 megacycles, and (b) it would be impractical for satellite systems to share frequencies with ground microwave systems. On the other hand, the Electronic Industries Association, representing manufacturers of privately used microwave equipment concluded that such sharing was feasible if reasonable engineering care was exercised by all concerned.

After hearing both sides, the FCC upheld its previous finding in favor of liberalized licensing of private microwave users in the spectrum above 890 megacycles. In statements supporting its decision, the FCC essentially agreed with the contention of the Electronics Industries Association that communication satellites could share with other services in the use of frequency spectrum.

At the same time that it reopened Docket #11866, the Federal Communications Commission released a separate Notice of Inquiry (Docket #13522) directed to the question of frequency needs for space communications on a longer range basis. A deadline of March 1, 1961, was fixed by the Commission for reports to be submitted by interested parties to Docket #13522. The commission requested that parties to the proceedings, in their statements and data, respond to a series of nine questions,* and the Commission set a deadline of March 1, 1961, for reports to be submitted.

Statements were filed by a number of communications common carriers, electronic equipment firms, private microwave users, and various associations whose members had an interest in the outcome. From the statements that were filed, the question of uppermost concern was the one around which controversy had centered in the reopening of Docket #11866, namely, the sharing of frequency bands among space and other radio services. In the statements prepared for Docket #13522, however, there was very little attention devoted to the question of whether sharing was possible per se—generally, the physical possibility of sharing was conceded. Instead, the emphasis was on what design conditions would have to be imposed on systems to ensure high quality transmission.

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*For the full text of the questions, see Appendix A.
The Joint Technical Advisory Committee of the Institute of Radio Engineers and the Electronic Industry Association appointed an Ad Hoc Subcommittee 60.2 to examine the problems of frequency allocations for space communications. The services of the Boulder Laboratories of the National Bureau of Standards and Stanford Research Institute were engaged to assist the Subcommittee. The JTAC report was released in March of 1961. On the subject of sharing the report stated:

"Subject to important restrictions, sharing of spectrum space between fixed microwave point-to-point systems and satellite systems is possible. Among the restrictions that may be required are the following:

a) Separation between terminal locations of satellite systems and of surface microwave systems—distances from 100 to 150 miles should suffice and, under ideal conditions, distances less than 100 miles may give adequate protection.

b) Control of antenna radiation patterns—side- and back-lobe suppression may be necessary for both surface and satellite systems.

c) Avoidance of terminal locations inadequately protected by terrain features.

d) Limitations on effective radiated power, including harmonics, of both satellite and surface systems.

It seems certain that frequency bands allocated to satellite communication systems must be different, and adequately separated from, those used by high-power ground radars, tropospheric scatter, and mobile communication services."*

On May 19, 1961, the Federal Communications Commission released its Second Notice of Inquiry in Docket #13522. Attached to the Second Notice of Inquiry was a draft entitled Preliminary Views of the United States of America Frequency Allocations for Space and Radio Communications. The purpose of this draft was "to serve as a vehicle by which the ideas and reactions of other countries can be obtained and taken

into account. Following study of the comments received in response to this second notice, the Commission, in consultation with the OCDM, expects to make such modifications in the attached statement in the light of comments received as appeared to be appropriate and practicable. The resultant statement then is expected to be transmitted to the Department of State with a recommendation that it be used by the United States Representative as a basis of discussion with other countries."* Section 7.5 states "On the basis of information currently available, there is little doubt that it is feasible for a communication satellite space service to share frequency bands with fixed and mobile services to which these bands are now allocated, provided reasonable engineering care is exercised by each of the sharing services."** For communication satellites the draft recommends a total allocation on a shared basis of 2,875 megacycles. In addition, it recommends an allocation of 100 megacycles on an exclusive basis. The sharing would be with fixed and mobile services. The exclusive allocations are intended to fulfill requirements for mobile earth terminals that are used with a communication satellite system.

In addition to the recommendations for allocations to communication satellites, the draft also makes a number of recommendations for allocations to other space services--meteorological, telemetry, and space research.

Appendix B to this chapter briefly indicates for the non-technical reader some fundamental attributes of radio emissions.

APPENDIX A

The Appendix to the Notice of Inquiry in Docket #13522 stated:

"Statements and data submitted by parties to this proceeding should be responsive to the matters set forth below:

1. The nature and extent of experiments which have been conducted or are now in progress involving utilization of frequencies for space communications of various kinds.

2. What segments of the radio spectrum are required for the various space communications functions to be performed, e.g., earth-space-earth, space-space, telemetry, tracking, guidance, command, etc.? How much spectrum space is required for each such function? At what point in time will access to these bands be required for each such function? Does each function require the same degree of protection from interference?

3. Under what conditions can frequency bands for space communications be shared with other services:

   a. in the case of passive relays?
   b. in the case of active relays?
   c. in the case of other space systems and functions?

Replies to this question should recognize that the emissions of the sharing services may be incompatible and should specify (1) the type of sharing service, i.e., fixed, mobile, radio navigation, etc., (2) transmitter powers, (3) antenna gains and orientations, (4) geographical separations, (5) the minimum angle above the horizon to which the earth terminal antennas will be oriented, (6) orbital characteristics of the satellite system being considered, i.e., altitude control, with or without stationkeeping, etc., (7) the area to be served by the space system, if other than worldwide, and (8) any other pertinent information.

4. Do non-Government entities plan to launch either active or passive communication satellites?

5. If non-Government entities have no plans for launching active communication satellites, by what means would access to active relay satellites be achieved for non-Government communications?

6. Should there be separate or shared frequency allocations for Government and non-Government space communications?

7. Will the receiving sites for space communications systems be generally distributed throughout the United States or limited to specific areas?
8. The purposes to be served by space communications which are not met by other communications systems.

9. Assuming, at least initially, (1) that existing surface communications must continue to function, and (2) that geographical separation is the key to successful sharing of frequency bands; it appears that earth terminals should be located in sparsely settled areas, away from concentrations of communication installations. Therefore, should the Commission, on the basis of criteria developed pursuant to the new issue three, give consideration to amending its Rules at an early date to establish protected geographical areas to be held in reserve for the installation of future earth terminals for civil communication systems via space relays? If such a concept were adopted it might be advisable to prohibit, for example, the use of certain frequency bands between 1,215 Mc and 10,000 Mc within "x" miles of a given site for all uses other than space communication. Comments are requested on geographical areas which might be appropriate for such a protected reserve status and the frequency limits between which it would be applied."

*From FCC Notice of Inquiry Docket #13522, as released May 20, 1960; revised and amended by Supplement to Notice of Inquiry Docket #13522, released December 28, 1960.
APPENDIX B

THE FUNDAMENTAL NATURE OF RADIO EMISSIONS

Radio waves are electromagnetic radiations that travel at the speed of light. They differ from other forms of radiation in the manner in which they are generated and detected, and in the range of frequencies through which they are emitted. They consist of traveling electric and magnetic fields of equal energy, forming a right angle in a plane perpendicular to the direction of travel. If the electric field is parallel to the earth the wave is said to be horizontally polarized. If it is perpendicular to the earth the wave is said to be vertically polarized.

Upon emission, a radio wave spreads out through a three-dimensional area (volume of space) and may be thought of as consisting of three wave-paths -- the ionospheric wave, the ground wave, and the

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1The relationship between wave length, frequency and velocity of a radio wave is expressed by \( \lambda = c/f \), where \( \lambda \) is the wave length, \( c \) velocity, and \( f \) the frequency at which the wave is emitted.

The 1947 convention of the International Telecommunications Union arbitrarily divided the radio spectrum into the following frequency ranges:

<table>
<thead>
<tr>
<th>Name</th>
<th>Symbol</th>
<th>Range</th>
<th>Wavelength (in air)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Low</td>
<td>VLF</td>
<td>10 - 30 kc</td>
<td>10,000 - 50,000 m</td>
</tr>
<tr>
<td>Low</td>
<td>LF</td>
<td>30 - 300 kc</td>
<td>1,000 - 10,000 m</td>
</tr>
<tr>
<td>Medium</td>
<td>MF</td>
<td>300 - 3,000 kc</td>
<td>100 - 1,000 m</td>
</tr>
<tr>
<td>High</td>
<td>HF</td>
<td>3 - 30 mc</td>
<td>10 - 100 m</td>
</tr>
<tr>
<td>Very High</td>
<td>VHFM</td>
<td>30 - 300 mc</td>
<td>1 - 10 m</td>
</tr>
<tr>
<td>Ultra High</td>
<td>UHF</td>
<td>300 - 3,000 mc</td>
<td>10 - 100 cm</td>
</tr>
<tr>
<td>Super High</td>
<td>SHF</td>
<td>3,000 - 30,000 mc</td>
<td>1 - 10 cm</td>
</tr>
<tr>
<td>Extremely High</td>
<td>EHF</td>
<td>30 - 300 gc</td>
<td>1 - 10 mm</td>
</tr>
</tbody>
</table>

Frequencies are expressed in cycles per second (kc is equal to 1,000 cycles, mc is equal to 1,000,000 cycles, gc is equal to 1,000,000,000 cycles). Wavelengths are expressed in millimeters (mm), centimeters (cm), and meters (m).

Since the velocity of light in air is constant, either wavelength or frequency is readily obtainable if one is known.
tropospheric wave. The ionospheric wave is that part of the transmitted energy that is radiated in an upward direction and returned to earth from the ionosphere at some distance from the point of transmission. The ground wave component of the transmitted energy travels the surface of the earth. The tropospheric wave is that portion of the energy that is returned to earth from regions in the troposphere.

As with other forms of radiation, radio waves are reflected from discontinuities encountered in the medium through which they are traveling; they are refracted upon entering a medium of travel in which the velocity of propagation differs from that of the preceding medium, with the direction of refraction being toward the medium with the lesser velocity of propagation; finally, radio waves are diffracted when they pass the edge of an obstruction in their medium of travel -- the direction of part of their energy is altered with the result that it can be received at some distance behind the obstacle.

Insofar as it relates to the definition of property rights, the essential characteristic of radio transmission is that a signal, once emitted, does not simply proceed to some (distant) point and cease, but continues on throughout the entire volume of space. As with a light signal, however, the strength of a radio signal attenuates as it proceeds through space so that at distances remote from the source of its generation it becomes undetectable. In principle, the extent to which a radio signal attenuates depends on two factors -- the spatial spreading-out of the wave, and the method used to propagate the wave.

ATTENUATION AND DISTANCE TRAVELED

In principle the radiation of energy involves the distribution of a given level of power at the source of transmission throughout a three-dimensional area (volume of space). If a non-directive antenna is used to transmit the signal the resulting pattern of radiation is spherical -- the signal spreads through space in all directions. Since the transmitted power is distributed evenly in all directions, the portion of the transmitted power passing through (received at) any point (a unit area on the surface of a sphere whose radius is the distance from the
point of transmission to the point of reception) is equal to the transmitted power divided by the surface of the relevant sphere. As the distance to the point of reception increases, the surface area of the relevant sphere increases and the (same) unit area of the point of reception becomes a smaller fraction of the total surface over which the signal is radiated. Consequently, the total power passing through the unit area of reception has decreased. As a result of this characteristic of attenuation, the power received from a transmission varies inversely with the square of the distance of the point of reception from the point of transmission.

Through the use of directive transmitting antennas the pattern of radiation can be altered to concentrate the transmitted energy in one direction. As a consequence, the power passing through a point (in the direction of concentration) is increased over what it would be if a spherical radiation pattern is used. Thus, effective radiated power on a particular frequency (in a given direction) is a function of the transmitted power and the directivity of the transmitting antenna. The power received at a point expressed as a ratio of the power level that would obtain at that point if a spherical radiation pattern were used is called the "gain" of the antenna.\(^2\)

METHOD OF PROPAGATION

Different methods of radio wave propagation -- ionospheric, ground wave, or tropospheric -- have differing abilities to transmit energy through space.

Ionospheric Propagation

Transmission of radio waves for distances of more than (about) 100 miles is accomplished by reflecting skywaves from the various layers of ionization found in the ionosphere. The ionosphere begins about 25 miles above the surface of the earth and extends to altitudes of 250

\(^2\)Several factors determine the antenna gain in the practical case -- transmission line losses, filtering devices designed to reduce spurious emissions, distortion of the radiation pattern as a result of nearby structures, etc.
miles or more. It consists of that part of the earth's atmosphere that has been ionized by ultraviolet rays and charged particles from the sun. The extent of ionization depends on the density of the atmosphere and the intensity of the ultraviolet rays. As the ray penetrates the atmosphere, air density increases and the ray's energy is decreased by absorption. Thus, a given frequency of ultraviolet radiation will cause a layer of ionization in the atmosphere. Since there are different ultraviolet wave frequencies, several different layers of ionization are formed:

1. **The D Layer**. This layer is present only during daylight, offers very little reflection, and results in pronounced absorption of frequencies below 2 megacycles.

2. **The E Layer**. This layer is used for shortwave daytime transmission of about 100 miles. (The "Sporadic E" Layer occurs at the same altitude as the E Layer, but at irregular times and locations, both during day and night hours. It occasionally prevents radio frequencies that would normally penetrate the E Layer from doing so and also occasionally results in long distance transmissions at very high frequencies.)

3. **The F Layers**. The F₁ Layer is present only during daylight hours and merges with the higher F₂ Layer at sunset. It is occasionally used for shortwave transmission and also causes the absorption of some waves that would normally penetrate to the higher F₂ Layer.

The F₂ Layer exists both day and night and is used for shortwave long distance transmissions. It is more effective at night than during daylight hours because of the absence of the lower F₁ Layer and the reduced absorption of the E Layer during the night.

The nature of these layers of ionization and their effect on radio transmissions is such that the effectiveness of their use for long distance transmission varies with the time of day, sunspot activity, the frequency of the transmission, and the angle at which the emitted energy strikes the layer being used. As a general rule, this method of transmission is most effective for transmissions of relatively long wavelengths (low frequencies).
Ground Wave Propagation

The ground wave is that part of the radiated energy of a transmission that is propagated at a low angle from the transmitting antenna. It, in turn, consists of two components -- a surface wave and a space wave.

Surface Wave

This component of the ground wave travels the surface of the earth and is not subject to seasonal, irregular, or day-night variations since such variations are due primarily to changes in atmospheric conditions. The rapidity of its attenuation depends primarily on absorption caused by the conditions of the terrain over which it passes. Its rate of attenuation increases as the transmitting frequency increases and because of this, this type of propagation is seldom used for long distance transmissions at frequencies above the broadcast band.\(^3\)

Space Wave

The space wave component of the ground wave is the result of the elevation of the transmitting antenna. It travels through two regions -- the line-of-sight region and the diffraction region.

The line-of-sight is a straight line from the transmitting antenna to the earth's horizon. The radio horizon is beyond the actual horizon because the wave is refracted by the earth's atmosphere to points beyond the actual horizon.

As the radio horizon is reached, the signal does not halt but is diffracted as it passes over the earth's surface. This results in a diffraction field beyond the radio horizon in which the field intensity decreases rapidly as the wave penetrates deeper into this area, and as the transmitting frequency is increased.\(^4\)

\(^3\)Absorption of this wave is least over bodies of water and greatest over jungle terrain.

\(^4\)A third field, 20 to 30 miles beyond the horizon, results from the effects of tropospheric scatter. This field is not as sensitive to frequency changes as is the diffraction field.
Because the space wave is basically line-of-sight transmission, its effective distance over the surface is a function of the height of the transmitting antenna and the curvature of the earth. It attenuates very little from causes other than the normal attenuation associated with the spreading out of radiation.

Tropospheric Scatter Propagation

The troposphere is the region of the atmosphere extending from the surface of the earth to an altitude of about six miles. Temperature and pressure decrease with altitude in this region and the majority of the earth's weather phenomena take place in it. It is also characterized by negligible ionization.

Tropospheric scatter propagation is used for point-to-point transmission beyond the line-of-sight region. It is accomplished, basically, by the transmitting antenna "illuminating" a certain volume of the troposphere which scatters the energy so that it may be picked up by a receiver whose antenna is aimed at this illuminated volume. This "scatter volume" can be thought of as a relay station located above the horizon, receiving radiated energy and re-radiating it to a receiver at some point beyond the horizon. Attenuation of the signal is affected by the height of the scatter volume, and by atmospheric turbulence encountered by the radiation. Much of the transmitted energy is lost in this method of propagation and attenuation is pronounced.

THE FUNDAMENTAL NATURE OF RADIO -- SUMMARY

Insofar as they affect the feasibility of defining property rights in radiation, two important conclusions may be drawn from an examination of the nature of radio wave transmission:

1. Once emitted, a radio wave continues on and on throughout the entire volume of space. The nature of these emissions, however, is such that the strength of the wave diminishes rapidly as the distance from the transmitting source increases. Consequently, at distances remote from its source of transmission the wave is undetectable.
Thus, while in principle a radio signal is not "confinable", it is, as a practical matter of fact, meaningfully confined to an area (a volume of space) whose dimensions are determined by the fundamental characteristic of attenuation, the strength of the emitted signal, and the directivity of the transmitting antenna.

2. There are various combinations of resources -- transmission power, antenna height and directivity, frequency of transmission, method of propagation, etc. -- that can be utilized to achieve a given level of (received) power at a point distant from the point of transmission. The range of alternative combinations is determined by technology -- the state of the arts -- and is an engineering problem. The "proper" combination actually to use to achieve a given goal is, however, an economic problem and is not (properly soluble solely in terms of engineering data.
II. THE PRESENT SYSTEM OF ALLOCATION

AN HISTORICAL REVIEW

The allocation* of radio frequencies in the United States is carried out through two administrative bodies: The Interdepartment Radio Advisory Committee, which allocates frequencies to departments and agencies of the Federal government and the Federal Communications Commission, which allocates frequencies to all other users, including State and local governments.

These organizations are not recent creations. The Federal Communications Commission** was brought into existence by the Communication Act of 1934, but insofar as the allocation of radio frequencies was concerned, it merely took over the powers which had hitherto been exercised by the previously existing Federal Radio Commission. This Commission has been established in 1927. Up to that time, although the Secretary of Commerce possessed certain regulatory powers, it is substantially true to say that no organ of the Federal Government existed for the allocation of radio frequencies to private users. It was the advent of broadcasting in the 1920s which led to the creation of the Federal Radio Commission. Before the 1920s, radio had been thought of in terms of point-to-point communication (mainly ship-to-ship and ship-to-shore) and such governmental regulation as there had been of a rather rudimentary kind. The first act regulating the radio industry (The Wireless Ship Act of 1910) was intended to promote safety at sea by requiring that large ocean-going passenger ships (later this act was

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* The world allocation is commonly used in the radio industry to mean the reserving of bands of frequencies for use for particular purposes and the word assignment to mean the provision of a frequency or frequencies within the band to a particular user. In this paper the word allocation will be used to cover both of these purposes.

amended to include large cargo ships) should employ skilled operators
and should install and maintain radio equipment capable of trans-
mitting and receiving messages over a distance of at least 100 miles.
A later act, (The Radio Act of 1912) required that anyone operating
a radio station should have a license issued by the Secretary of
Commerce. This license had to specify the ownership and location
of the station, the wavelength or wavelengths authorized for use,
the hours for which the station was licensed to operate and so on.
Regulations were included in the act governing the conduct of those
operating radio stations and these required, among other things,
that the station operator designate a normal wavelength, which had
to be less than 600 or more than 1600 meters, but the station could
use other wavelengths provided they did not fall in this prohibited
range. The wavelengths between 600 and 1600 meters were to be used
by government radio stations.

Experience soon showed that, using the powers given to him in
the 1912 Act, the Secretary of Commerce was not able to prevent
interference between the signals transmitted by different stations.
In consequence, bills were introduced in Congress which aimed to
bring about stricter governmental regulation of the radio industry.
The Navy Department, which was particularly anxious to extend govern-
ment control, at one time (in 1918) even proposed that all radio
communication should be made a government monopoly in the charge
of the Navy. It was, of course, usual in these early days to think of
radio as being primarily useful for communication with ships. Thus,
a high naval officer, testifying before a House Committee said:
"Generally speaking.... The department believes that wireless
communication should be limited as far as possible, to its legitimate
field; that is, communication between the shore and vessels at sea."

But all this was changed with the coming of broadcasting. This
led, of course, to much more interference and thus increased the

*See Davis, Laws of Radio Communication (1927), p. 34
pressure for more stringent government regulation. But at the same time, it became impossible to think of the radio industry as largely the concern of the Navy. To ventilate the problems, Mr. Hoover, who was the Secretary of Commerce, called a series of Radio Conferences (in 1922, 1923, 1924, and 1925) to which he invited representatives of government departments and the radio industry. He also attempted to deal with the problems arising out of the increase in the number of broadcasting stations by inserting detailed conditions in their licenses. But the effectiveness of this procedure was completely nullified by court decisions. In 1923, in a case involving the operations of a radio station which had caused interference, it was held that the Secretary had no power to refuse a license.* And in 1926, in a case which arose out of the failure of a radio station operator to abide by the conditions which the Secretary of Commerce had inserted in the license (the Zenith Radio Corporation had been assigned the wavelength of 332.4 meters, with hours of operation limited from 10:00 to 12:00 p.m. on Thursday provided the General Electric Company did not wish to broadcast at this time from their Denver station), it was held that the Secretary was required to issue a license only to the regulations which were in the Act.**

The upshot of these decisions was that anyone was free to erect and operate a radio station in any location, using whatever wavelength he wished (provided that it was outside the prohibited range set out in the 1912 Act). This hobbling of the Secretary's authority led to the establishment of many more broadcasting stations and this brought about an increase in the amount of interference. The experience of this period, which has commonly been described as one of "chaos in broadcasting," or more recently, by the Federal Communications Commission, as "bedlam on the air,"

had the immediate effect of inducing Congress to pass legislation establishing strict governmental control of the radio industry (which had been recommended by the Radio Conferences and had been under consideration by Congress for some years) and had the long-run effect of producing a public opinion favorable to the continuance of such regulation, the wisdom of which seemed to be firmly founded on the practical experience of what had happened without it.

The act to create the Federal Radio Commission was passed in 1927. The Commission was given the authority to classify radio stations, prescribe the nature of the service to be rendered by each class of stations and each station within a class, allocate bands of frequencies to individual stations, determine the kind of apparatus used and to make such other regulations as the Commission might consider necessary to prevent interference and to carry out the provisions of the Act. Anyone operating a radio station had to obtain a license from the Commission. The Commission was thus armed with massive powers to control the use of radio frequencies. In 1934, as a result of the passage of the Communications Act, the Federal Radio Commission was abolished and its functions were taken over by the newly created Federal Communications Commissions, which, in addition, was also made responsible for the regulation of the telephone and telegraph industries. This reorganization of the regulatory machinery did not alter the character of the control exercised over the radio industry. The powers granted to the Federal Communications Commission for the regulation of radio were almost exactly the same as those possessed by its predecessor. Nor has any substantial change been made in the years which elapsed since 1934. Such amendments as have been made to the Communications Act have related almost exclusively to procedural matters. The authority of the Federal Communications Commissions (which in the future will be referred to as the FCC) has not been diminished.

There is, however, one area of radio communication which has always been outside the authority of the FCC. Section 305 of the Communications Act makes it clear that the FCC has no authority to control the activities of radio stations belonging to and operated
by the United States. "All such government stations shall use such
frequencies as shall be assigned to each or to each class by the
President." Although it was provided that these stations would
have to observe such regulations as the FCC might make when the trans-
missions of the stations did not relate to government business, it is
ture to say that, for all practical purposes, radio stations owned
and operated by the Federal Government are not subject to control by
the Commission. The powers possessed by the President to coordinate
the use of radio frequencies by the departments of the Federal Govern-
ment are in fact exercised through the Interdepartment Radio Advisory
Committee, a body which already existed before the creation of the

It will be remembered that the coming of broadcasting led to a
serious increase in the amount of interference, as a result of which
Mr. Hoover, then Secretary of Commerce, called a series of Radio
Conferences to which representatives of government departments, as
well as private users of radio frequencies, were invited. After the
holding of the first Radio Conference (in 1922), the Chairman of the
Conference suggested to the Secretary of Commerce that interested
government departments should form a committee to examine the use of
radio frequencies for government broadcasting. At that time govern-
ment broadcasting stations were operated by the U.S. Navy and by the
Post Office, mainly for broadcasting crop and market news. This led
to the formation of the "Interdepartment Advisory Committee on
Governmental Radio Broadcasting." Its first meeting was held on
June 1, 1922. It was agreed that the committee would be purely
advisory to the Secretary of Commerce. It was soon decided to widen
the scope of the committee's interest. This led to a change in the
committee's name (in March, 1923) to the "Interdepartment Radio
Advisory Committee,"* a name which it has retained to the present

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time, although it is commonly referred to as IRAC. At first, the Committee took a broad interest in radio problems but it soon became involved in the assigning of radio frequencies to government stations and this came to be its main function.

It is possible to discover the character of the Committee in these early days from a "Statement of Government Domestic Radio Policy" adopted by the Committee, May 8, 1925.* The functions of the Committee are described in the following terms: "Measures to prevent interference; the assignment of frequencies within the allotted wave bands; determination of the character of broadcast material; and other radio matters of common interest to all departments, not having an international aspect, shall be determined through the permanent interdepartmental organization. Departments which operate radio stations shall give priority to calls of distress and to other messages concerning safety of human life or marine or aerial navigation, but shall otherwise determine priority of service and other features involving the details of traffic."

In its Statement of Policy, the Committee made a parade of its desire not to intrude. It pointed out that when two agencies only are concerned with any matter, "such question or questions can be best settled through direct conference." It emphasized the autonomy of the departments: "Subject to the limitations stated herein and to such instruction as may be issued by the President each of the Executive Departments shall be the sole and final judge as to its own policy in respect to radio matters; shall determine its own mission; and decide upon the steps toward executing such mission. Such decisions shall include the questions of location of stations, power output, apparatus to be installed, service to be rendered, the

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*This will be found reproduced in Donald R. MacQuivey, Frequency Assignment Administrative Control (May 1956, The American University, Washington, D.C.), Appendix 3, pp. 305-309.
capital investment and operating details." It was, of course, desirable that one department, in making its decisions, should take into consideration the effect of its actions on others: "Before deciding upon any changes in location or services rendered, each department shall ascertain through the existing interdepartmental coordinating organization how such proposed changes will affect the interests of any other department, and shall in its decisions, give the suggestions from other departments careful consideration, in order that the final results will produce a government radio system designed to meet the need of the Federal Government as a whole in war as well as in peace." The Statement of Policy made clear the advisory character of the Committee and stressed the undesirability of it playing a more positive role: "Cooperation and coordination supervision as prescribed...is, under existing circumstances, the only practicable means of realizing the highest degree of efficiency in the utilization of government radio facilities. The coordination at present exercised through the Interdepartment Radio Advisory Committee is advisory. It provides an effective means of investigation and presentation of pertinent facts for consideration by the President of the merits of any case which required his action." The Committee opposed centralization of control. Under the heading "Centralized supervision of government radio facilities" in the Statement of Policy, it was said: "Centralized control of Government Radio Communications, by means of consolidation or otherwise, is not at present either practicable or desirable."

A Committee which could make such a realistic assessment of its own objective was clearly destined to enjoy a long and successful life. It is hardly surprising, therefore, to find that when the Federal Radio Commission was formed in 1927, it was the IRAC which came to exercise the powers reserved to the President of assigning radio frequencies to Federal Government departments. The Federal Radio Commission in 1928, asked for, and was granted, membership on the IRAC and its place on that committee was quite naturally assumed by the FCC in 1934.
A major change in the administrative structure was made in the years 1951 to 1953. In 1951, President Truman created the position of Telecommunications Advisor to the President. The Telecommunications Advisor was to "assist and advise the President" on such matters as "coordinating the development of telecommunications policies and standards" and "assuring high standards of telecommunications management" in the executive branch of government but also with respect to "assigning radio frequencies to Government agencies under the provisions of Section 303 of the Communications Act of 1934...and establishing policies and procedures governing such assignments and their continued use" and "developing U.S. Government frequency requirements." It was also provided that the Telecommunications Advisor should "to the maximum extent feasible, perform his function with the aid, or through the facilities, of appropriate departments and agencies of the government." The relationship of the new Telecommunications Advisor to the IRAC was described as follows: "The Interdepartment Radio Advisory Committee shall report to and assist the telecommunications advisor in the performance of his functions as he may request." The Telecommunications Advisor was to "cooperate with the Federal Communications Commission on problems of mutual concern," but he had no authority over it. "Nothing in this order shall be deemed to impair any existing authority or jurisdiction of the Federal Communications Commission." As part of the reorganization, the Telecommunications Advisor appointed the Chairman of the IRAC while the FCC withdrew as a regular member of the Committee and appointed a liaison representative to work with it. Meanwhile the Committee was assigned the "additional responsibility to formulate and recommend policies, plans and actions in connection with the management and usage of radio frequencies by the U.S. Government radio communication activities." In 1953, a further change was made when the position of Telecommunications Advisor to the President was abolished and the functions which he had hitherto performed were transferred to the Director of Defense Mobilization. In 1958, as a result of the merger of the Office of Defense Mobilization with the
Federal Civil Defense Administration, the IRAC had to "report to and advise" the Director of Civil and Defense Mobilization (renamed, in September 1961, the Director of the Office of Emergency Planning).

A further reorganization in February, 1962, brought about the present administrative structure. Executive Order 10995 established the position of Director of Telecommunications Management within the Office of Emergency Planning. The authority to assign radio frequencies to Government agencies, vested in the President by the Communications Act, including all functions heretofore vested in IRAC, was delegated to the Director of the Office of Emergency Planning. He was authorized to redelegate his powers to the Director of Telecommunications Management and this in fact he did. IRAC was not abolished; but the effect of the reorganization was to make its legal position that of an advisory body. In fact, IRAC has continued to assign radio frequencies to Government departments, although its decisions are subject to the approval of the Director of Telecommunications Management.

THE INTERNATIONAL SETTING

The fact that signals transmitted in one country may interfere with the reception of signals in another country has led to the making of international agreements on the allocation of radio frequencies. Consequently, the American authorities concerned with the allocation of radio frequencies, the FCC and the IRAC, must take into account those international agreements to which the United States is a party and which control the use to which radio frequencies may be put. The organization responsible for arranging for and supervising international agreements of this kind is the International Telecommunication Union. One of its purposes is to "effect allocation of radio frequency assignments in order to avoid harmful interference between radio stations of different countries...."

*Article 4, Section 2(a), International Telecommunication Convention, Geneva, 1959.*
The last general conference held by the International Telecommunication Union to draw up an international table of radio frequency allocations met in Geneva, Switzerland, in 1959. The International Telecommunication Union also holds extraordinary conferences from time to time and one such conference, to deal with the allocation of radio frequencies for space and space-earth communications, is scheduled to meet in October 1969. On matters which are the concern of a restricted number of countries (for example, when the interference from signals in one country is likely to be experienced in a limited number of other countries), conferences restricted to particular groups of countries are held and these result in regional, multi-lateral or bilateral agreements (for example, those which the United States has made with Canada or Mexico). In the current International Telecommunication Convention it is stated (Article 43):

Members and Associate Members reserve for themselves, for the private operating agencies recognized by them and for other agencies duly authorized to do so, the right to make special agreements on telecommunication matters which do not concern Members and Associate Members in general. Such agreements, however, shall not be in conflict with the terms of this Convention or of the Regulations annexed thereto, so far as concerns the harmful interference which their operation might be likely to cause to the radio services of other countries.

The sovereign right of every nation to regulate its own telecommunications is recognized* and no nation can be bound by these international agreements except to the extent that the nation itself accedes to them. In fact the Convention setting forth the agreement reach in Geneva in 1959 contains many reservations to the general agreement which have been inserted by various countries.

As is evident from the description in the previous section of the administrative machinery to allocate radio frequencies in the United States, the character of these international agreements, although denying the use of certain frequencies or their use in

certain ways to individual countries, is nonetheless such as to leave a wide area of choice to the authorities as to how radio frequencies shall be used. First of all, when frequencies are available to a particular country for a particular use, say, broadcasting, there is still the question to be decided as to who shall be allowed to use them and in what ways: whether the use of a particular frequency is to be shared, and how, the location of the transmitter (or transmitters), the power of the signals, the design of the antenna (or antennas) comprise some of the questions which have to be decided. And in any case portions of the radio frequency spectrum are often allocated to such broad groups of uses, for example, a band of frequencies may be allocated for fixed and mobile services, as to leave the individual countries with considerable freedom of choice concerning how the frequencies shall be employed.

Furthermore it must not be forgotten that the purpose of the International agreements is to avoid "harmful interference": "All stations, whatever their purpose, must be established and operated in such a manner as not to result in harmful interference to the radio services or communications of other Members or Associate Members or of recognized private operating agencies, or of other duly authorized operating agencies which carry on radio service, and which operate in accordance with the provisions of the Radio Regulations."* It is further provided: "The Members and Associate Members are bound to abide by the provisions of this convention and the Regulations annexed thereto in all telecommunication offices and stations established or operated by them which engage in international services or which are capable of causing harmful interference to radio services of other countries...."** What this means, although it is not so stated explicitly, is that a country is allowed to use a frequency in derogation of the agreement

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* Article 47, Section 1, International Telecommunication Convention, Geneva, 1959.

** Article 21, Section 1, International Telecommunication Convention, Geneva, 1959.
provided that this does not cause harmful interference to stations in other countries which are conforming to the table of allocations in the agreement. This provision in the Convention very much increases the range of choice open to the authorities in particular countries since there will be many cases in which they will be able to use a frequency for purposes other than that described in the allocation table without causing harmful interference to anyone else.

A final point is that the agreements do not restrict military use of radio frequencies: "Members and Associate Members retain their entire freedom with regard to military radio installations of their army, naval and air forces."* The great bulk of the radio frequencies which are assigned by the IRAC are for the use of the military services. In making these assignments, the IRAC is therefore not bound by international agreements although it endeavors to conform to the international table of allocations and other pertinent provisions: When determining what frequencies should be used by the military IRAC invariably takes into account the purpose for which the frequencies were allocated and also how they are in fact being used by foreign countries.

THE WORK OF THE FEDERAL COMMUNICATIONS COMMISSION

The FCC consists of seven Commissioners, of whom not more than four may belong to the same political party. The Commissioners are appointed by the President, subject to confirmation by the Senate. Each Commissioner is appointed for a seven-year term, except when his appointment is to fill the unexpired term of a former Commissioner. The Chairman of the Commission, who is also its chief executive officer, is designated by the President. The Commission makes its decisions regarding policy and the general direction of its work as a unit. It sits as a body to receive testimony in major proceedings. Responsibility for particular areas is delegated to individual

*Article 50, Section 1, International Telecommunication Convention, Geneva, 1959.
Commissioners or to a Committee. Controversial matters may be dealt with by a hearing examiner or by the Commission as a whole. The FCC has the task of regulating the telephone and telegraph industry but this account of the Commission's work will be confined to their administration of the radio frequency spectrum. In performing this task it allocates bands of frequencies for use for particular purposes, it assigns frequencies to individual users and regulates in detail the way in which the frequency can be used and the purposes which it can serve. As we have seen, its authority does not extend to the use of radio frequencies by the Federal Government.

To perform its role, the FCC has been given massive legal powers. But the job which the FCC has been asked to undertake is awesome in its range and complexity. By 1960, the FCC had authorized the operation of nearly 7000,000 radio stations and this involved the use of over 2 million transmitters. It is usual to think of the FCC as the body which controls the operations of broadcasting stations (both sound and television) and it is certainly true that the bulk of the time and thought of the FCC is taken up with broadcasting problems. But the vast majority of the radio stations in the United States are not used for broadcasting. They are used by telephone and telegraph companies, by police, fire and highway departments, by forestry services, by shipping companies and airlines, by railroads, streetcar systems, taxicabs, buses and trucks, by pipeline companies, mining and construction companies, by oil companies and motion picture companies, and many more besides. Indeed there can hardly be a business or industry in the United States which does not add to the demand for radio frequencies. In their Annual Report for 1955, the FCC gave a list of miscellaneous examples to illustrate the diversity of the uses of radio frequencies at the present time:

To control city and highway traffic systems.
To direct movement of crews cleaning city streets, water mains, etc.
To expedite delivery of food, fuel, building material, etc.
To speed repair of home and business office fixtures and other refuse.
To route rural school buses.
To aid beach and other recreation area patrols.
To contact workers on isolated ranches, etc.
To direct the movement of machinery on large farms.
To look for oil on land and under offshore waters.
To spot schools of fish from moving planes and radio their locations to fishing boats.
To control car placements in a parking lot.
To direct motion picture crews on location.
To aid bank and business protective patrol systems.
To relay news between reporters on assignment and their newspaper offices.
To control model airplanes, etc.
To send fingerprints and other information from one police department to another.
To control traffic lights from ambulances, fire apparatus, and police cars on emergency calls.
To communicate between the engine and caboose of long freight trains; between moving trains and wayside stations; and in yard operations.
To control railroad track switches by the engineer on a moving train.
To pick up and deliver telegrams by auto.
To relay telephone and telegraph messages, also TV programs.
To bridge gaps in disrupted wire lines.
To transmit pictures and facsimile.
To control crowds at large regattas, horse shows, golf matches and other big outdoor events.
To page doctors and other persons.
To direct firefighters at the scene of a blaze.
To enable garage and automobile associations to provide emergency road service.
To send weather and market reports.
To supervise and control valves, pressures and fluid levels along pipe lines.
To record sunspot cycles, measure radio propagation, and study planetary reflection.

And to provide emergency communication in time of local, regional or national disaster.*

This list is not be be regarded as giving more than an indication of the range of uses of radio frequencies, a range which is constantly expanding. Nor are radio frequencies used only for communications purposes. Some restaurants use electronic radiation to cook food more quickly. The food is heated from the inside out, which, as the FCC tells us, "is the reverse of the usual method."**

These cooking stoves are also used in the home. Ultrasonic equipment 'developed in the last few years, generates radio frequency energy which is applied to a special kind of crystal or to a rod of magnetic material which is thereby caused to vibrate at ultrasonic frequencies, and is used largely for cleaning and flaw detection in industry and for medical purposes."*** Many industrial devices make use of radio frequencies. These "include a wide variety of electronic heaters running the gamut of the radio frequency spectrum from below 10 kilocycles, used for heat treating large gears and automobile crankshafts, through the VHF spectrum used for 'sewing' plastics and making plywood and furniture, etc., to the microwave region now being explored for use in processing the newer plastics such as 'teflon.' Other devices include radio frequency generators for removing superfluous hairs (depilatories), radio frequency stabilized arc welders...linear accelerators used to sterilize medical products and to preserve food, and accelerators for atomic research and production."**** Radio frequencies are also used by individuals for such purposes as radio-controlled garage-doors. And, of course, an important new demand for radio frequencies is emerging with the development of the space program. Without radio communications, the placing of vehicles in

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***Ibid., 1955, p. 151

****Ibid., 1958, pp. 172-173.
outer space would be extremely difficult and largely valueless. Radio signals are used to control the launching, flight and working of the vehicle, to locate the vehicle and to transmit to earth information on conditions in outer space. In the case of the communications satellite, radio signals are also required to transmit, and retransmit, messages between earth and the satellite and between the satellite and earth.

The examples in the preceding paragraphs, taken mainly from FCC reports, illustrate the many uses of radio frequencies. How does the FCC come to know of these uses which radio frequencies may serve and how does it decide in which way the radio frequencies are to be used? The first part of this question is easier to answer than the second. If a Government agency was presented with a warehouse full of steel and was handed the task of giving it away, it would soon come to learn that there were people who want steel, and who they were, and why they wanted it. In the same way, the FCC comes to know of demands for radio frequencies because businessmen as well as industry associations apply to the FCC and ask it to assign particular radio frequencies for use for particular purposes. The difficult problem is not to learn the character of the demand for radio frequencies but to decide, in cases in which the various demands for use of the radio frequency spectrum exceeds the total available spectrum, which demands are to be met. The agency with the warehouse full of steel might well be puzzled as to the criterion which it should use in deciding to whom to give the steel. The FCC faces a similar problem. It is easy to describe the procedure followed by the FCC. In cases in which there are conflicting claims for the same frequency or bank of frequencies, hearings are normally held by the FCC in which the various claimants give reasons why the frequency or bank of frequencies should be awarded to them and denied to others. But what is a good reason and what is a bad reason? And how is the FCC to weigh two good, but different, reasons?

The answer which is usually given to such questions is to point to the provisions in the Communications Act which requires the FCC to make its decisions in the light of whether they would serve the
"public interest, convenience, or necessity." But the light cast by the phrase is dim. The FCC and the Courts have successfully resisted the temptation to define this phrase in a precise manner. The FCC has explained that "public interest, convenience, and necessity contemplate the most widespread and effective service possible."** The Courts have been more cautious. The Supreme Court said that this phrase "is as concrete as the complicated factors for judgment in such a field of delegated authority permit..."*** The Court of Appeals for the District of Columbia said: "It would be difficult, if not impossible, to formulate a precise and comprehensive definition of the term 'public interest, convenience, or necessity,' and it has been said often and properly by the courts that the facts of each case must be examined and must govern its determination."**** Furthermore, as the Court of Appeals said in another case, "the Commission's view of what is best in the public interest may change from time to time. Commissions themselves change, underlying philosophies differ, and experience often dictates change. Two diametrically opposite schools of thought in respect to the public welfare may both be rational."****

If it is difficult to obtain any clear indication of the criteria used by the Commission by referring to the Communications Act or the interpretations of the Act by the courts, it is equally difficult to discover what they are by studying the decisions of the FCC. The area in which there has been the greatest study of this question relates to the criteria used by the FCC in choosing between the various applicants for broadcasting stations. Mr. Doerfer, when he was Chairman of the FCC, described (in 1956) the criteria used by the Commission in such cases. He said: "Congress in the Communications Act of 1934 or its several amendments refrained from laying down definitive criteria to guide the Commission in selecting the best qualified applicant among several competing for a particular channel

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*See Sentinel Broadcasting Corporation 8 FCC Reports 147 (1940).
**319 U.S. 190, 213 (1943).
***153 F. 2d 623 (1946).
****230 F. 2d 204 (D.C. Cir. 1956).
channel or facility. Instead, it has left the task to the Commission to work out under the applicable standard, the public interest, convenience and necessity. A list of comparative criteria, which have been evolved and employed by the Commission in the comparative television cases, would include the following: Proposed programming and policies, local ownership, integration of ownership and management, participation in civic activities, record of past broadcast performance, broadcast experience, relative likelihood of effectuation of proposals as shown by the contacts made with local groups and similar efforts, carefulness of operational planning for television, staffing, diversification of control of the medium of mass communications.*

In commenting on this statement of the Chairman of the FCC, it was pointed out by the Network Study Staff of the FCC that this list of factors "establishes only a useful point of reference.... The enumerated factors do not constitute a final and complete list of all the criteria which may be usefully employed in making a determination.... Nor is a rigid formulation of a relative scale of importance of the various comparative criteria feasible. While a rough generalization may be made to the effect that the certain factors are either of major or of minor significance, the circumstances of the particular case always shape the weight to be given specific factors. Even proposed programming policies which have been called the essence of service to the public cannot be assigned controlling weight, but must be evaluated in the context of the facts of the specific case."**

But even a statement such as this gives an impression of the way the FCC works which is too definite. The fact of the matter is that in applying these criteria to individual cases, the FCC has acted with

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**See the Report of the Network Study Staff to the Network Study Committee, Federal Communications Committee, published as Report No. 1297, House of Representatives, 85th Congress, 2d Session, p. 62.
a degree of inconsistency which defies generalization. Mr. Murray Edelman has commented: "It may be well that the Commission's practice of preserving a maximum of discretion for itself on the assessment of public need...is fully justified by the wide variance in the facts of particular cases, but the record has sometimes reflected a lack of consistency on this point that goes beyond the bounds of justifiable reliance upon discretion."* Mr. James M. Landis, who was for a period Advisor to President Kennedy on the Regulatory Agencies was even more outspoken on this point, as we shall see later.**

Much less attention has been paid to the criteria used by the FCC in allocating radio frequencies for non-broadcast use. In part, of course, this reflects the greater public interest in broadcasting. But study of this question must have been hindered by the fact that a general investigation of FCC policies in this area would require knowledge of the special circumstances of many different industries. Furthermore, as the FCC, in dealing with non-broadcast services, commonly allocates a band of frequencies for a particular purpose together with the shared use of the frequency by all of those eligible to use it, the FCC's policies cannot be inferred by studying the way in which they have chosen between rival claimants for given facilities (as can be done in the broadcasting field) but would have to be discovered by uncovering the alternative arrangements implicitly or explicitly rejected by the FCC. This would be a formidable task. Moreover, there is no reason to suppose that such an investigation, if carried out, would be able to discover the basis for the FCC's decisions.

When the FCC allocates bands of frequencies for use for certain purposes (which is, of course, its mode of operation), it has to specify exactly what those purposes are. And the problem of defining the purpose so that an operator knows exactly what he is allowed to

* See Murray Edelman, The Licensing of Radio Services in the United States, p. 58

** See p. 42 below.
do and what he is not, may not be an easy one, as a recent FCC ruling on what subsidiary operations FM stations may engage in illustrates. Since 1955, the FCC has allowed FM stations, by the grant of Subsidiary Communications Authorizations (SCAs), to engage in limited types of subsidiary services, such as background music and store-casting on a subscription basis. In 1960, the FCC amended its rules so as to expand the scope of these permitted additional services. With the approval of the FCC, FM stations "can use their authorized multiplex sub-channels to transmit program material expressly designed and intended for business, professional, educational, religious, trade, labor, agricultural and other special groups of subscribers engaged in any lawful activity.... At the same time, the Commission rejected a suggestion that remote pickup facsimile be allowed on a multiplex basis and also declined to adopt, at this time, changes in existing engineering standards applicable to subsidiary operations. Existing provisions concerning sub-channel leasing arrangements and the ban on sub-carrier operation during the periods of main channel inactivity were continued. In approving this modest expansion of permissible subsidiary operations, the Commission weighed and rejected, as a matter of sound allocations principle, suggestions that FM broadcasters be allowed to undertake signalling, control, telemetry or communications activities basically unrelated to broadcast operation, thereby reaffirming the concept of SCA operations as an adjunct to regular FM broadcasting."* Once, of course, the definition is provided, the operator of a radio station must use the station for that purpose, must conform to the general technical requirements of the FCC and others which are special to his own operation. In some cases, the FCC allows the employment without license of equipment which produces radio emissions provided that the equipment conforms to certain standards and is not operated above a certain level of power.

The fact that the FCC specifies the purpose for which radio frequencies may be used and regulates the apparatus that may be employed,

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has meant that the FCC has had to engage in monitoring and inspection activities to make sure that operators are conforming to its regulations and, in the case of continued or willful violation, it takes action to compel the operator to conform. In 1960, the FCC maintained 31 enforcement offices, 18 monitoring stations and 2 TV mobile units. New broadcast stations are given a detailed technical inspection after construction but before issuance of a license. In other cases, inspection is on a sample basis. Much work in the Field Engineering and Monitoring Bureau of the FCC is devoted to discovering the causes of interference. One example from the Annual Report of the FCC for 1960 will suffice: "An electronic heater used for drying glue in a piano factory in Michigan was located as the source of strong interference extending over a considerable area in the Midwest and disrupting commercial airline radio operations." In investigating the causes of interference, the FCC is aided by industry and radio users cooperative committees which handle many minor complaints.*

**THE WORK OF THE INTERDEPARTMENT RADIO ADVISORY COMMITTEE**

The present work of IRAC has been described in the following words:

1. To formulate and recommend policies, plans and actions to the Director of Telecommunications Management in connection with the management and usage of radio frequencies by Government agencies; to supervise the application and execution of such policies, plans and actions pertaining to radio frequency usage as have been approved by the Director; and subject to the approval of the Director, to assign Government frequencies to Government radio stations on an interim basis.

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*For a more detailed account of the work of the Field Engineering and Monitoring Bureau, see the Annual Report of the FCC for 1960, pp. 115-133.

**The main source describing the work of the IRAC before the reorganization in 1962 is the Hearings before a Subcommittee of the Committee on Interstate and Foreign Commerce, House of Representatives, 86th Congress, 1st session, on Allocation of Radio Spectrum between Federal Government Uses and Non-Federal Government Uses, June 8 and 9, 1959, pp. 97-178. This is referred to as Hearings on Spectrum Allocation.
2. To conduct, in collaboration with representatives of the Federal Communications Commission, a joint FCC/IRAC Short- and Long-Range Planning Program for Future United States Use of the Radio Frequency Spectrum, having as its objective the production of an improved pattern of frequency allocations which could be implemented within the next 10-15 years upon approval by the Director of Telecommunications Management and the Commission.

3. To prepare and maintain current, in collaboration with representatives from the Federal Communications Commission, a comprehensive war mobilization plan for the use of the radio frequency spectrum by the United States in war or emergency for approval by the Director of Telecommunications Management.

4. To aid the Director of Telecommunications Management, in collaboration with the Federal Communications Commission, to assist and give policy advice to the Department of State in the discharge of its functions in the field of international telecommunications policies, positions and negotiations.*

No account has been published of how IRAC is functioning in the new setting. The description which follows must therefore of necessity confine itself to the working of IRAC in the period before February, 1962. It may be presumed that IRAC's procedures remain substantially what they were before the recent reorganization, particularly in view of the short period which has elapsed since this occurred. But in its details, the account which follows may not exactly describe the procedures which are used by IRAC at the present time.

In its early years the IRAC was concerned almost exclusively with the problems of assigning frequencies to the various government departments. But as time went by, its interests expanded. For example, the IRAC devoted a considerable effort in the years 1943-1946 to the preparation of the U.S. position for the Radio Conference of Atlantic City, 1947. In 1952, the IRAC was reorganized by the

*See a statement issued by Mr. William E. Plummer, Chairman of IRAC, on May 8, 1962 (CEP 48444).
formation of the Frequency Assignment Subcommittee to deal with the routine process of assigning frequencies, the intention being that the business of the main committee would then largely be devoted to questions of policy. In 1955 the Subcommittee on Frequency Allocations was created to deal with "the determination of new radio services or techniques for which provision should be made in the allocation table, the establishment of minimum standards for equipment performance and radio service protection, and in general to explore the means to insure a more effective and efficient use of the radio spectrum."*

The administrative process involved in assigning frequencies in the Frequency Assignment Subcommittee has been described as follows: "... each Federal Government agency having need for new or additional assignments of radio frequencies or for modification of outstanding authorizations which would involve a change in the use of radio frequencies, presents such requirements with nominated frequencies therefore on form 0C7M-88 in the requisite number of copies. In effecting the selection of the nominated frequencies, account has necessarily been taken of the pertinent technical factors, all known uses of frequencies in the portions of the radio spectrum involved, and such advance coordination with other users of the same or adjacent channels as appears to be warranted."** This preliminary consultation with other users before submitting a request to the Frequency Assignment Subcommittee appears to have been the normal procedure. Mr. Donald R. MacQuivey, who was for a period Chairman of the Frequency Assignment Subcommittee, has described the procedure followed by the Air Force, Army, and Navy at that time (about 1955) in the following words: "When a frequency requirement is received [in the Air Force], a check is made first to determine whether an existing assignment to the Air Force can be shared. If not, reference is then made to other frequencies assigned to the other military agencies which may be

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*See Hearings on Spectrum Allocation, p. 109

**Ibid., p. 144
useful, and, if it appears that one may be usable, a telephone call to an officer in the agency concerned will determine whether the frequency can be shared. In some instances, this requires reference to the using unit in the field. Detailed records of the coördination results are maintained on form record cards which later are temporarily attached to the Air Force representative's copy of the application sent to the IRAC, as, of course, if no existing authorization can be shared under a group authority, it is necessary to get a new assignment from the IRAC for any usage in the United States and its possessions.... The frequency selection and clearance process in the Army is substantially similar to that in the Air Force. They seek first to accommodate a new requirement on frequencies currently assigned to the Army. Failing this, they seek to share with the military and if this is not possible, other frequencies are selected and those agencies shown in the records available to have operations within interference range are contacted in an effort to clear the frequency informally before making application for a frequency assignment from the IRAC.... The process of frequency selection and clearance in the Navy is very similar to that in other military services."

At the meeting of the Frequency Assignment Subcommittee "each agenda item is considered in turn, the subcommittee either approving, approving in part, approving as amended, disapproving or tabling it as is considered appropriate. At the more recent meetings [1959] the agendas have averaged well over 800 items."** Departments disagreeing with a decision of the subcommittee may take the matter to the full committee, to the Director of Telecommunications Management or even to the President, but such appeals from the decisions of the subcommittee are rarely undertaken.

The recital of the administrative procedures does not, of course, give us the tone of the proceedings. Mr. E. M. Webster who was the chairman of the IRAC in 1945 described the character of the

*See MacQuivey, op. cit., pp. 171-173, 177-178. Mr. MacQuivey's account is dated 1956 and may not therefore in all respects describe current procedure.

**See Hearings on Spectrum Allocation, p. 145.
IRAC at that time in the following words: "The IRAC is unique among government agencies in that it came into being, not as the result of actions by either the executive or legislative branches of the government, but spontaneously through a demand of the interested government agencies. It has continued because it fills an essential need and because throughout its existence, it has been careful to confine its activities to filling that need. In the process, it has furnished a conspicuous example of voluntary self-regulation resulting from a realization of the necessity for cooperation and coordination in the common good."* Mr. MacQuivey has given us some further information about the way in which the IRAC and FAS go about their work. The FAS "has a body of procedures which have been brought together in a rather informal manner but are frequently used for reference purposes during committee discussions. These procedures have been accumulated from the minutes and records of past actions by the IRAC and FAS. These detailed procedures are not for publication, although they are not classified from a security standpoint. It is possible, therefore, to discuss them only in general terms. Of particular interest with regard to frequency management are such items as the requirements for application justification. The requirements are quite broad and detailed, but in practice when an application is being considered by the Subcommittee, the requirement is assumed to be justified unless questioned by a member of the Subcommittee. Exceptionally, the justification is questioned when the application related to a frequency use which does not fit in with established past practice. An example might be an application for an assignment to a military government agency in a band normally used only by non-military government services.** Mr. MacQuivey's discussion of the resolution of disagreements in the IRAC shows that the committee was run in 1955 with the same desire to avoid imposing its will on the individual departments and to confine its activities to filling "essential needs" as was evident in the Statement of

*See Webster, loc. cit., p. 495.
**See MacQuivery, op. cit., pp. 191-192.
Policy in 1925 of Mr. Webster's account in 1945. In this connection, it is interesting to see that Mr. MacQuivey considered that study of the working of the international arrangements for allocating radio frequencies could be worthwhile from the light it might shed on United States domestic arrangements. "As the international system involves sovereign nations which will not be told what to do, much depends upon coordination and persuasion. Within the United States the size of the government is such and its organization is such that many of the problems of coordination are markedly similar to international problems."

Mr. MacQuivey's account of how IRAC resolved disagreements was as follows: "As a voluntary coordinating committee the IRAC must depend for its effectiveness upon implementing decisions made within each agency. It was seen...how each agency goes about the process of determination of its radio-frequency proposals [the description of the procedures of the Air, Navy and Army quoted earlier was taken from this section of Mr. MacQuivey's work].

If this work is adequately done and there is no objection, the only function remaining for the FAS to perform with regard to the frequency assignment is to confirm and record such confirmation of agreement among the agencies to the use of the frequency suggested. Such action together with recording and publication of the record comprises the assignment process. It may be said that the IRAC and FAS work under the rule of no objection! The reason is a very practical one. Unless there is substantially no objection to a course of action, a voluntary committee is ineffective. It depends for its effectiveness upon cooperation among its members and, if they disagree, they simply do not take action."

The contrast between the way in which the IRAC and the FCC have worked is striking. There has been much less investigation and control of the use to which radio frequencies are put in the case of the IRAC. The assignments of the IRAC once made have been indefinite

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*See MacQuivey, *op. cit.*, p. 112.

*See MacQuivey, *op. cit.*, p. 201.*
(although it may make temporary or trial assignments) while those made by the FCC have been for limited periods and automatically come up for review. The procedures of the IRAC have put much greater reliance on the statements of the individual agencies than has the FCC on those of claimants for the use of radio frequencies. The proceedings of the IRAC have been essentially much more informal in character. The IRAC has worked on the principle of unanimity and has drawn its power from the consent of the governed.

It remains to see what effect the appointment of the Director of Telecommunications Management will have on the working and authority of IRAC. It may however be remarked that, over the years, IRAC has shown considerable resilience.


The FCC allocates radio frequencies to private users; the IRAC allocates radio frequencies to Federal Government departments. The radio frequency spectrum from which each makes its allocations is the same. How do these two independent bodies make sure that the same radio frequencies are not allocated both to a private and a government user? And if this is avoided, how is it decided whether a particular radio frequency is to be allocated to a private user or a government department?

We may start by surveying the relationship which has existed between these two bodies in the past. The IRAC antedated the formation of the Federal Radio Commission and was therefore assigning radio frequencies to the various Government departments before any agency existed to perform the same function for non-governmental users (if we exclude the ill-fated attempt of the Secretary of Commerce to perform this task). When discussions were proceeding in Congress which were to lead to the establishment of the Federal Radio Commission, the War and Navy Departments both expressed apprehension that a new Commission, if it had the task of allocating frequencies to all users (government as well as private) might give
insufficient weight to military needs.* In the event, the problem
was solved by reserving to the President authority to allocate fre-
quencies to government departments and delegating the exercise of
this authority to the IRAC.

From the earliest days, the Chairman of the IRAC was a representa-
tive of the Department of Commerce and it was through the Secretary
of Commerce that the IRAC reported to the President. The Secretary
of Commerce does not appear to have used his position to control in
any way the actions of the Committee. Mr. T. A. M. Craven said that
the Secretary of Commerce acted "as a messenger boy, and also, he
explained to the Executive only if an explanation was required."**
In 1928, a year after the formation of the Federal Radio Commission,
it became a member of IRAC. In the 1930's, there were some disputes
over the allocation of frequencies between private users and the
military services. In 1930, for example, "the Navy blocked a Federal
Radio Commission proposal that a frequency used by government agen-
cies be made available instead to AT and T for transatlantic communi-
cation. The State Department vigorously supported the Commission,
its representative asserting that the frequency in question was the
most effective for the proposed radiotelephone service and only the
Navy was blocking it. But the Navy was upheld after its representa-
tive had delivered himself of an eloquent peroration on the importance
of maintaining established practices and habits, including frequencies
in the Navy.***

In 1933, the representative of the Federal Radio Commission be-
came Chairman of IRAC and this arrangement continued when the FCC

* See Congressional Record 12497 (July 1, 1926) and 12631 (July 2,
  1926) and Hearings before the House Committee on Merchant Marine and
  Fisheries on H.R. 5589, 69th Congress, 1st session (January 6 to 15,
  1926) p. 90.

** See Hearings before the Select Committee to Investigate the
  Federal Communications Commission, House of Representatives, 76th
  Congress, 1st Session, Part 2, p. 1824.

*** See Edelman, op. cit., p. 212, Mr. Edelman gives no authority
  for this account.
took over the functions of the Federal Radio Commission. This assumption of the Chairmanship by the representative of the Commission was no doubt made easier by the fact that the Department of Commerce representative (who had therefore been Chairman) had joined the Federal Radio Commission in 1932 when the Radio Division of the Department of Commerce was transferred to the Federal Radio Commission. Consequently, this change in arrangements did not mean an immediate change in the Chairman. Then, in 1935, the President directed that the reports and recommendations of the IRAC should no longer be transmitted to him through the Secretary of Commerce but should in future come to him through the Chairman of the FCC. This new arrangement seems to have been resented by some of the Government departments. I have quoted Mr. Craven's statement at a Congressional hearing about the passive role of the Secretary of Commerce in transmitting information from IRAC to the President. The examination continued as follows:

Mr. Garvey (General Counsel): Under the Federal Communications Commission, however, that practice changed, did it not?
Mr. Craven: I would say so, yes, in the minds of the government departments.
Mr. Garvey: IRAC felt the FCC was using this practice to its advantage and to the disadvantage of IRAC?
Mr. Craven: The government departments felt that the Federal Communications Commission had a pre-dominant voice in the matter.
Mr. Garvey: They felt that the FCC was using this situation to its advantage and to the disadvantage of the IRAC?
Mr. Craven: I think so; yes.*

The government departments thought of the FCC as the representative of private users and therefore unsuited to the role of spokesman for the IRAC in transmitting its reports and recommendations to the

*See Hearings before the Select Committee to Investigate the Federal Communications Commission, House of Representatives, 78th Congress, 1st Session, Part 2, pp. 1824-1825.
President, particularly as the questions to be referred to the President would very likely be concerned with disputes over whether government or non-government users should be allocated certain frequencies. This hostility was to show itself again when the Chairman of the FCC was made Chairman of the Board of War Communications in World War II.* However, in the meantime, the problem of the Chairmanship of IRAC had been solved by an agreement (made in 1941) under which the Chairmanship would rotate and be filled each year by the representative of a different department. This system continued until 1952, when it was provided that the Chairman should be appointed by the Telecommunications Advisor to the President and later, by the Director of Civil and Defense Mobilization. As part of the 1952 reorganization the FCC ceased to be a member of the IRAC and a liaison representative was appointed in his place.

An agreement was made between the FCC and IRAC in 1940 and this is still in force:

1. The Interdepartment Radio Advisory Committee will cooperate with the Federal Communications Committee in giving notice of all proposed actions which would tend to cause interference to non-Government station operation, and the Federal Communications Commission will cooperate with the Interdepartment Radio Advisory Committee in giving notice of all proposed actions which would tend to cause interference to Government station operation. Such notification will be given in time for the other agency to comment prior to final action. Final action by either agency will not, however, require approval by the other agency.

The two agencies will maintain up-to-date lists of their respective authorized transmitting frequency assignments.

2. Frequencies appearing in Executive orders assigning frequencies are understood to be exclusively Government frequencies unless they bear the symbol "g," "j," or "n" or a note specifically indicating otherwise and conversely,

frequencies in lists of frequencies currently assigned to stations by the Federal Communications Commission are understood to be exclusively non-Government frequencies unless they bear the symbol "g", "j", or "k", or a note specifically indicating otherwise.

Requests for assignments submitted to the FCC are referred to the Frequency Assignment Subcommittee of the IRAC for comment whenever the FCC "considers such assignments might have a technical impact upon one or more assignments to stations of the Federal Government. These referrals are processed within the IRAC in a manner similar to that for applications by Government entities."** Proposals for Government assignments which might have an adverse effect on the use of radio frequencies by private users are brought to the attention of the FCC by the attendance of the FCC's liaison representative at the monthly meeting of the Frequency Assignment Subcommittee of the IRAC and he can presumably attempt to persuade the IRAC to change its proposals when he considers that this is warranted by the harm which would be caused to private users. Of course, a good deal of this mutual notification is carried out informally in advance of the regular meetings.***

In addition to such consultation with regard to assignments the FCC and the Office of Civil and Defense Mobilization agreed in 1959 to cooperate in the preparation of a long-range frequency allocation plan. "The initial objective is to produce an improved pattern of frequency allocations which could be implemented within the next 10 to 15 years. Thereafter, the spectrum will be kept under continuing review and additional recommendations will be made by the joint study

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**Ibid., p. 145.

***See the Annual Report of the FCC for 1960, p. 152.
group as it may from time to time consider to be appropriate." The technical level study group "will prepare a list of all existing and foreseeable types of classification of frequency usage for which spectrum space should be allocated. This list should be prepared in terms of the functions involved rather than the user group or groups involved, although probable user should be indicated for information." For each listed entry, the groups will prepare "a statement of the frequency range or ranges needed to satisfy the usage category involved. The approximate optimum and the approximate maximum and minimum usable frequencies are to be indicated" with appropriate comment. "This assumes the collection, analysis, and evaluation of currently valid information on propagational qualities of the various parts of the radio spectrum, operational and manufacturing techniques, manufacturing capabilities, and other aspects of the state of the art, and additionally, the analysis and evaluation of the radio spectrum and requirements to determine the types of service which various parts of the radio spectrum can best support." Next the group "will prepare its best estimate of the amount of spectrum space needed to satisfy each usage category in each required frequency range." This estimate will cover both present and future requirements. In general, "estimates of future requirements shall be based on the time bracket 10 to 15 years hence." This work completed, the technical group will prepare a draft-table of frequency allocations and "submit it to the policy level group (FCC-OCRM liaison officials), together with recommendations on how to overcome the problems involved in the transition from the existing table to the recommended table." The technical and policy groups will consult on individual questions arising during the course of the study. "In general, the technical level study group should confine itself to consideration of technical and economic matters, and to such national security considerations as may be appropriate, with political and sociological considerations being reserved to the policy level study group. Each group will take into account existing commitments at both national and international levels."*

*See Hearings on Spectrum Allocation, pp. 170-171.
There is lacking in this account of the procedure to be followed by the joint FCC-IRAC study groups any statement of the way in which conflicts between the requirements for and availability of radio frequencies are to be resolved and of how, if the total requirements of Government departments and private users taken together are greater than the available frequencies, it is to be decided which of the requirements are to remain unsatisfied. Accounts of the assignment process similarly fail to throw any light on this point. We learn of the process by which the FCC and the IRAC come to be aware of possible conflicts but not of how these conflicts are actually resolved.

Mr. Fred C. Alexander, then Deputy Assistant Director for Communications, Office of Civil and Defense Mobilization, described the position at a recent Congressional hearing:

...as I understand the law, the President and the FCC have equal power to assign an identical frequency if necessary - they don't do that because as thinking people they get together and try to coordinate this process so that there is not an element of interference, at least, not normally. Sometimes you do have accidents, sometimes particular technical things happen that must be corrected. But knowingly, the coordinative process has been highly developed.*

It is easy to see how this procedure would work when the FCC and the IRAC are in agreement as to what should be done. But suppose that they disagree; whose will is to prevail? There can be little doubt that at the present time (and it may be that this has always been true), though the FCC and IRAC have "equal power," the IRAC is more equal than the FCC. The main Federal Government users of radio frequencies are of course the military departments, and it would be difficult, if not impossible, at least at the present time, for the FCC to oppose successfully an appeal for frequencies based on the needs of national security. The nature of the relationship can be illustrated by the following extract from the Congressional hearings on Spectrum Allocation in 1959. Mr. Hoegh was Director of the Office

*Ibid., p. 28.
of Civil and Defense Mobilization, Mr. Doerfer was then Chairman of the FCC. Mr. Moss was a member of the House Subcommittee of the Committee on Interstate and Foreign Commerce, the Chairman of which was Mr. Oren Harris:

Mr. Moss: ...what we have, in effect, are two Federal Communications Commissions -- one in the Government, for Government, and the other for non-governmental uses?
Mr. Hoegh: That is right, sir.
Mr. Moss: But between the two, when they disagree, as the Chairman of the Commission, Mr. Doerfer, indicated, the executive department would win out in the disagreement.
Mr. Hoegh: No, no; I do not think so. Generally, it is by agreement.
Mr. Moss: You have disagreements?
Mr. Doerfer: I was answering that question, that in the event that there would be an irreconcilable decision on the part of the organization, then the President would have to decide that. *
Mr. Moss: Has it ever occurred?
Mr. Doerfer: I do not know of any.
Mr. Hoegh: It has never reached that stage.
Mr. Moss: That makes me want to ask why.
The Chairman: Just a minute. Will you yield?
Mr. Moss: Yes.
The Chairman: Is it not a fact that right now OCDM has asked the Federal Communications Commission to give up aviation channels, 8500 megacycles, for Government use, and the Commission had done so, solely on your statement. Is that true?
Mr. Doerfer: That is correct.
The Chairman: And also it is (sic) not a fact that on that action there is litigation pending at the moment??

*This refers to an exchange between another member of the Subcommittee, Mr. Flynt and Mr. Doerfer which had occurred earlier in the hearing. "Mr. Flynt: ...I think that in this it is not a question of negotiation at all; that if the executive branch disagrees with what the Federal Communications Commission wants to do in allocating this or that frequency, that the executive can preempt it, regardless of the wishes of the Federal Communications Commission. Mr. Doerfer: I think as an abstract proposition that is probably true." Hearings on Spectrum Allocation, p. 54.

**This is a reference to Bendix Aviation Corp. v FCC and Aeronautical Radio Inc. v United States, Court of Appeals, D.C., 1959,
Mr. Doerfer: That is right.
The Chairman: There is an example, Mr. Moss.
Mr. Doerfer: There is no litigation between the Federal Communications Commission and the Office of Civil Defense.
Mr. Moss: And the Federal Communications Commission, having great confidence in the OCDM accommodated them?
Mr. Doerfer: On the basis that the OCDM was responsible for the national security to a much closer and greater extent that (sic) we are, and we were in a position to do that with respect to that. So that, when they indicated that they wanted that, we could not find any specific authority in the act whereby we could say no. We did the other thing.
Mr. Moss: Is there any specific authority in the act that makes that possible for them?
Mr. Doerfer: No; other than when you say "they," I have in mind the President. OCDM is asking for the President.
Mr. Moss: I think this gets to another important question, Mr. Chairman: That you give something to another Government agency, just on the mere representation that you should do it. You have not had a hearing which would enable you to determine whether the request is a proper one or not; whether, in fact, the security of the Nation is involved....There is no one here on behalf of the communications agencies to say, or to determine whether or not the government agency is making a valid case, whether there is a compelling Government requirement for the channels it has requested.
Mr. Doerfer: I think that is a correct statement. I want to indicate that is the cause [because] of the act. Actually, if the President of the United States, through this agency, wanted to appropriate all of it without even declaring a war emergency, I do not know what we can do to stop it."

272 Federal Report 2nd Series 533. In this case, the FCC terminated, without a hearing, use of a radio frequency band previously allocated for radio navigation and made it available for exclusive use by the government for radio positioning. It was held that the FCC had authority to do this. The basis for this decision would seem to be well described in the following comment: "...in reality, it appears that the Commission's ruling was upheld by the Court in this case, not so much because it was a proper exercise of the Commission's powers, but because the Commission had no power to regulate channels of radio communications appropriated by the government for defense purposes." See Federal Communications Commission -- Power of Commission to Deny Application for Use of Frequencies Without Hearing, New York Law Forum, July 1960, pp. 337-342.

*See Hearings on Spectrum Allocation, pp. 87-88.
The conclusion I draw from this whole interchange is that, until recently, in the case of a serious disagreement between the FCC and the IRAC, it was highly probable that it would be the will of the IRAC that would prevail. How the appointment of the new Director of Telecommunications Management will affect the balance of power has yet to be disclosed.

PROPOSALS FOR REFORM

The fact that the administrative machinery for the allocation of radio frequencies in the United States has remained unchanged, in its main features, for 35 years might be taken as indicating general approval of its performance. But this would be wrong. If we study Congressional hearings or read the public press, there is evident a widespread feeling of dissatisfaction with the way the present arrangements are working.

In 1950, Representative Sadowski introduced a bill, amending the Communications Act, which would have established a Frequency Control Board, an independent agency in the executive branch. The Board was to formulate policies and plans for the utilization of the radio frequency spectrum and, in particular, was to have the power to apportion frequencies as between governmental and non-governmental use. To carry out its functions, the Board would have been authorized to "(1) allocate frequencies and bands of frequencies and cancel or modify any such allocation; (2) assign frequencies to government stations and cancel or modify any such assignments; and (3) prescribe regulations to govern the assignment, by the Commission of frequencies to non-Government stations." Furthermore, the Board would have had authority to disapprove any assignments made by the Commission if they would cause harmful interference to any government use of radio or would infringe any regulations the Board had made. In addition, a Military Liaison Committee was to be formed with representatives from the Military Establishment appointed by the Secretary of Defense. The Board was to advise and consult with the Committee on the allocation of radio frequencies for the purposes of national defense. If
the Committee concluded that any of the Board's actions or proposals would be harmful to national security, the Committee was authorized to refer the matter to the Secretary of Defense and if he concurred, he was to refer the matter to the President, whose decision would be final.* These provisions were interpreted by the Office of Civil and Defense Mobilization to mean that "the Committee, in a matter of national defense, would have virtual veto power over the Board."**

This bill was not passed into law, apparently due both to strong opposition and to the appointment by the President (Mr. Truman) of his Communications Policy Board.*** This Board was to make a study of telecommunications in the United States and to present recommendations to the President concerning, among other things, "policies for the most effective use of radio frequencies by governmental and non-governmental users and alternative administrative arrangements in the Federal Government for the sound effectuation of such policies...." The report of the President's Communications Policy Board, "Telecommunications: A Program for Progress," was published in March 1951. The chief recommendation was that there should be established in the Executive Office of the President a three-man Telecommunications Board, which would be responsible for assigning frequencies to the Federal Government departments. The IRAC would continue in existence but would be responsible to the Board, which would determine its policies. The new Board would cooperate with the FCC which would continue to operate as before, although with more funds and a stronger staff.****

In 1951, Senator Edwin C. Johnson, Chairman of the Senate Committee on Interstate and Foreign Commerce, introduced a bill which would have provided for the FCC to assign frequencies to

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* Ibid., pp. 4-6.
** Ibid., p. 133.
*** Ibid.
Government stations. This bill was not enacted.* In 1952, there was, as we have seen, a reorganization of the administrative structure for assigning frequencies to Government departments and also, by an Act of Congress, certain changes were made in the procedures and organization of the FCC. But these were not radical changes in the form or organization and did not remove the pressures for more far-reaching reforms. In 1957, the Electronic Industries Association proposed a government-industry study of the use of the radio spectrum and a reorganization of the administrative structure to provide unified control over the use of the radio frequency spectrum.** In 1958, the Office of Civil and Defense Mobilization created a Special Advisory Committee on Telecommunications. This Committee (the Cooley Committee) does not appear to have found its task very difficult. It confined itself to "a review of past studies in light of the current situation" and was able to draw up its recommendations within a short time. It felt that the appointment in 1952 of a Telecommunications Advisor to the President with a small staff had created "a mechanism...on a minimal basis" and that the subsequent reorganization had "resulted in a downgrading of the office." The Cooley Committee recommended that a National Telecommunications Board, reporting directly to the President, should be established. The IRAC would "report to and assist" the Board. The Board would "assist and advise" the President. It would also formulate telecommunications policies, assign frequencies to Government departments (presumably using the IRAC), review the national table of allocations, make a study of the administrative structure and much more besides.*** Meanwhile Congress had been considering various proposals for the creation of a Commission to study the telecommunications problem and particularly the management of the radio frequency spectrum.**** In

*See Hearings on Spectrum Allocation, p. 135.

**Ibid., pp. 140-141.

***Ibid., pp. 40-49.

****Ibid., pp. 7-16.
1959, the President recommended to Congress that a Commission should be established "to conduct a thorough and comprehensive study of (1) the role of the Federal Government in the management of the U.S. telecommunication resource; (2) the administrative organization for discharging the Government's responsibilities with particular reference to the division of responsibility under the Communications Act; (3) the existing method and procedures for allocating radio frequencies and bands of frequencies as between Federal Government and non-Federal Government users; and (4) the existing national table of radio frequency allocation with respect to the apportionment of the various parts of the radio frequency spectrum as between Government and non-Government users."* No such Commission to examine the present system of administration has, as yet, been appointed.** But on June 8 and 9, 1959, a Subcommittee of the House Committee on Interstate and Foreign Commerce held hearings on the problem of the allocation of the radio spectrum between Federal Government users and non-Federal Government users. The hearings were instructive both as to why people are unhappy about the present situation and why it is so difficult to do anything about it. Nonetheless, the ardor of those who wished to change the existing organization was not damped. Representative Oren Harris introduced in January 1961 a bill to set up a three-man Frequency Allocation Board in the executive branch to study, plan and allocate radio frequencies between federal and non-federal users and also to set up (again within the executive branch) a Government Frequency Administrator to study and allocate frequencies among federal departments and agencies. It will be observed that, although no Frequency Allocation Board has yet been established, the proposal for a Government Frequency Administrator was, in part at least, fulfilled by the

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*Ibid., p. 143.

**In August 1961, there was a hearing on a Senate Resolution which would have established such a Commission. See Hearings before the Communications Subcommittee of the Committee on Commerce, U. S. Senate, 87th Congress, First Session, on Space Communications and S. J. Res. 32, August 1, 23 and 24, 1961.
appointment of the Director of Telecommunications Management.

One of the chief targets of criticism has been the working of IRAC. The Report of the President's Communications Policy Board stated that the IRAC was not "an adequate means for keeping in order the large portion of the spectrum occupied by Government agencies."* Basically this was so because "IRAC is a group of users. As such, it has been severely limited in its capacities as a policy-forming body. The practices and priorities it has generated have always been restricted to those by which a group of users with equal rights could get along."** After noting that the IRAC has operated under a de facto rule of unanimity and that this had "resulted in a working rule of first-come first-served" and that "those to whom assignments have been made may enjoy them until they wish to give them up," it explained that this rule is not invariably followed in practice. "Back of the rule of unanimity and absence of compulsion has lain a complex process of bargaining and accommodation.... Although there has been no compulsion by directive, all the users have been under strong suasion to find mutually agreeable solutions in order to avoid having to seek decisions at a higher but technically unqualified level. Furthermore, to the communications specialist it is fundamental that the alternative to agreement is chaos."***

In the 1959 Congressional hearings, Dr. Irvin Stewart, who had been Chairman of the Communications Policy Board and is now Director of Telecommunications Management, elaborated this criticism of the IRAC "...it is a body composed of users. The situation is one in which naturally there is a desire to accommodate the wishes of the users who participate. There is nobody sitting in the position of arbiter. There is nobody who can ask too many hard questions. There is nobody who has an overriding task of requiring that the

* See "Telecommunications: A Program for Progress," p. 18

** Ibid., p. 198.

*** Ibid., p. 199.
necessity for a particular new assignment be established in the light of all the assignments that have been made in the past. It is natural for each Government department to emphasize the importance of its role; and there isn't inherent in the situation any necessary motivation to conserve frequencies in order that they might be available for non-government use. In many cases in the assignment of frequencies, security considerations must be taken into account, and that means that justification for the assignments cannot be made a matter of record. And then when you have no public record, you have another fertile ground for suspicion.*

Mr. Victor E. Cooley, Chairman of the Special Advisory Committee on Telecommunications (which had reported in 1958) said: "There is only one spectrum, and its efficient use is acknowledged to be essential to everyone...the public [private] side as administered by the FCC is handled in a very thorough manner. Public hearings are held...and...justification must be made for any assignment of frequencies....On the other hand, on the government side we don't find such a thorough and business like approach to the question of assignment, because there is no authoritative voice any place in the government, except the President, or the Director of the Office of Civil and Defense Mobilization acting for the President....Now NRAC is a Committee of representatives of agencies involved in the usage of radio frequencies, and they are very competent people. They understand the use of the spectrum...but there is no one on NRAC that has any authority whatever to say that the Defense Department shall prevail -- for instance, if Defense wants something and if Commerce wants the same thing...there is no one that can say, after hearing all facts, 'This frequency should go to Defense or that frequency should go to Commerce.' Despite this organizational deficiency, it is only fair to say that according to my understanding up to now, every agency has received by and large what they needed. But a lot of it has been through compromise and trading back and forth, not because any group or board with authority to handle such

*See Hearings on Spectrum Allocation, pp. 33-34.
things has decided after all examination that this frequency should go here or this one should go there. That is the main thing that I should say, the main conclusion that our committee came to, that there should be on the Government's side the kind of examination and study and evaluation of frequency assignments with an authoritative voice acting on behalf of the President to make these assignments that prevail on the non-Government side.*

The views expressed by Messrs Stewart and Cooley seem to be composed of three elements. The first of these is that a committee of users is inevitably inferior as an organization for the allocation of resources to a Board (not representative of users) doing the same job. The second is that, as a matter of fact, the existing organization is inefficient and unbusinesslike. The third is that the present arrangements result in too great an allocation of radio frequencies for the use of government departments and too small an allocation of radio frequencies for private users (or at any rate they lead to an understandable suspicion that this may be the case).

It is not obvious why a committee of users (such as the IRAC is) would inevitably be inferior in performance to any Board which might be selected. Much depends on who the users are and what procedures they follow as well as who the members of the Board would be and what procedures they would follow. The argument that a dictatorship is superior to a democracy always has some plausibility; in some circumstances, it is no doubt right; but it is not necessarily always right. What seems to have led to the belief that the substitution of a Board for IRAC would be an improvement was the contrast between the relative informality of the proceedings of the IRAC and the highly formal proceedings of the FCC, which conducts public hearings in the course of which various claimants for radio frequencies present reasons why they should be granted the desired facilities and why other claimants should be denied them.

The belief that the FCC has done a much better job in allocating radio frequencies than the IRAC comes out clearly in Mr. Cooley's

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testimony. According to him the FCC carries out its task "in a very thorough manner" and it would be desirable if there were on the Government side "the kind of examination and study and evaluation... that prevail on the non-Governmental side" (the full quotation was given in an earlier paragraph). Later in his testimony, Mr. Cooley elaborated this view:

...we felt that the operations and the activities of the FCC are well carried out and that they are knowledgeable people. There are seven Commissioners, and they have a substantial staff, and thus the means of carrying out their work, although I know they are very busy. But that is not true on the government side, and it just isn't fixed enough. The responsibility is not organizationally placed and again there isn't the authoritative opportunity under present practice to be certain of the proper and the effective use of the radio spectrum.*

It is difficult to imagine what could have led Mr. Cooley to hold this high opinion of the way in which the FCC functions. A very different view, which accords in the broad, if not perhaps in detail, with the conclusions which have been reached by most students of the FCC, was expressed by Mr. James M. Landis, recently Advisor to the President of Regulatory Agencies, in his report on the Regulatory Agencies which he prepared for the President-elect and which was issued in December 1960. This was what he said about the FCC:

The Federal Communications Commission presents a somewhat extraordinary spectacle. Despite considerable technical excellence on the part of its staff, the Commission had drifted, vacillated and stalled in almost every major area. It seems incapable of policy planning, or disposing within a reasonable period of time the business before it, of fashioning procedures that are effective to deal with its problems. The available evidence indicates that it, more than any other agency, has been susceptible to ex parte presentations, and that it has been subservient, far too subservient, to the subcommittees on communications of the Congress and their members. A strong suspicion also exists that far too great an influence is exercised over the Commission by the networks.

The quality of its top personnel is, of course, primarily responsible for these defects. The members of the Commission do not appear to be overworked in the sense that the Commission's docket is bulging with cases calling for disposition. Nevertheless disposition lags. Only 32 cases, all dealing with broadcasting licenses, were decided by the Commission during fiscal 1959, other than cases dismissed or in which the examiner's report became final. Commission action following the examiner's report in 9 of these cases took from 6 to 12 months and in 10 cases from one year to two years. In broadcast license cases no criteria for decision have evolved. True, criteria of various different kinds are articulated but they are patently not the grounds motivating decision. No firm decisional policy has evolved from these case-by-case dispositions. Instead the anonymous opinion writers for the Commission pick from a collection of standards those that will support whatever decisions the Commission chooses to make.

Observers of the procedures employed by the Commission agree that the issues litigated are unreal and a mass of useless evidence, expensive to prepare, is required to be adduced. The uselessness of much of this evidence derives from several causes. The first is that programming proposed by applicants is of high-sounding moral and ethical content in order to establish that their operation of a radio and television station would be in the "public interest." The actual programming bears no reasonable similitude to the programming proposed. The Commission knows this but ignores these differentiations at the time when renewal of licenses or the station is before them. Nevertheless, it continues with its Alice-in-Wonderland procedures. Also because of the varying standards that the Commission employs a vast amount of unrealistic testimony is adduced to support each of these standards, incumbering the record with useless data.

On major policy matters, the Commission seems incapable of reaching conclusions. The UHF debacle has been plainly apparent for some 5 to 6 years. Nothing of any substantial consequence has yet been accomplished by the Commission to relieve the situation, although they are now purporting to make available additional VHF channels in one and two V-channel markets.

The procedures employed by the Commission in adjudicatory matters as well as in purely exploratory matters seem primarily at fault for these deficiencies. Leadership in the effort to solve problems seems too frequently to be left to commercial interests rather
than taken by the Commission itself. No patent solution for this situation exists other than the incubation of vigor and courage in the Commission by giving it strong and competent leadership, and thereby evolving sensible procedures for the disposition of its business.*

When one takes into account the expense of FCC proceedings, the long delays extending often to years before decisions are made, the FCC's susceptibility to political and other pressures, the apparent errors in the decisions it has taken, it would seem the height of folly to adopt the FCC form of organization and procedures as a model for the allocation of frequencies to Government departments, unless one is convinced that the IRAC functions in a way which is not merely inefficient but extraordinarily inefficient. This does not mean that the procedures of the IRAC might not be considerably improved. But the reason adduced by Messrs Stewart and Cooley for thinking that its procedures are defective are anything but convincing. We are told that the IRAC has a working rule of "first come, first served," by which is meant, of course, that those who are first granted the use of a radio frequency are not easily displaced by a newcomer. However, it would be difficult to envisage an efficient administrative arrangement in which this would not be true. Certainly, the FCC is no exception. Its assignments of radio frequencies to particular users, once they are made, are rarely disturbed. Indeed, there is reason to suppose that the setting up of a Board with procedures modelled on those of the FCC might make desirable readjustments in usage more difficult to attain than it is with the IRAC. Curiously enough, although they fail to see its significance, Messrs Stewart and Cooley both note that there is available in the IRAC a means of adjusting frequency usage which is absent in the case of the FCC. They refer to a "complex process of bargaining and accommodation" and to "compromise and trading back and forth," but they do so in a way which suggests that they regard this "trading" as a defect rather

* See The Report of Regulatory Agencies to the President-elect, pp. 53-54.
than as an advantage (since it clearly allows for adjustment in usage) of the IRAC form of organization.

The third element leading to a desire to change the present system of allocation is the view that it has resulted in an excessive use of radio frequencies by Government departments. What this implies is that radio frequencies are used by Government departments for purposes which have a relatively low value as compared with what the same frequencies would be worth if they could be made available to a private user. This may well be true. We have seen that it is difficult for the FCC not to agree to the use of radio frequencies by Government departments, particularly when the military departments are involved. Mr. Cooley's statement that "up to now, every agency has received by and large what it needed" and the lack of friction between departments over the usage of frequencies certainly suggest that radio frequencies have been made fairly freely available to government departments. On the other hand, it is difficult to understand why the substitution of a Board for the IRAC would alter this position. Would not a Board in the executive branch of Government be as reluctant as the IRAC to surrender frequencies for non-Governmental use?

But this does not mean that the question of the proper allocation of radio frequencies for governmental and non-Governmental purposes is not of extreme importance or that the uneasiness over the present dual control of the allocation of radio frequencies is without justification. The problem is to find a satisfactory alternative. One obvious solution would be for the FCC to allocate all radio frequencies and there seems little about that the FCC was in fact reaching out in that direction in the late 1930s. But this move was resisted by the Governmental departments, particularly the military departments, and the final result of successive reorganizations was to place the FCC, if anything, in a subordinate rather than a dominant position. The President's Communications Policy Board in 1951 decided against making the FCC responsible for all radio frequency allocations: "The two most important considerations against placing
new functions in FCC, and in our opinion the conclusive ones, are these: First, the FCC in its capacity as representative of the interests of non-Federal Government agencies, is in effect a user. As such, it would never be accepted as an impartial arbiter by other Federal users. Second, it would be unwise and improper to give the FCC the power to make decisions which affect the administration of executive agencies, or which relate closely both to foreign relations and to national defense. These must be made by the President.\(^*\)

And when in 1951 Senator Edwin C. Johnson introduced a bill which would have given the FCC authority to allocate frequencies to Federal Government as well as private users, a bill which failed of enactment, the Chairman of the FCC wrote to say that the FCC believed it preferable to await the implementing of the recommendations of the President's Communications Policy Board. Of course, it has been suggested that a superboard should be created to control the operations of both the FCC and the IRAC.\(^**\) But this idea has not received any strong Congressional support. It certainly would not be easy to bring it about. The military departments would not support the creation of such a superboard if they did not dominate it; and it is difficult to see how it could be established if the military departments are opposed to it. Of course, this leaves the possibility of establishing a superboard dominated by the military; but as the main support for a superboard comes from those who feel that it is required to reduce the power of the Government departments and to increase the allocation of radio frequencies for private users, such a proposal would have very few friends.

The difficulty of bringing about a unified control of the allocation of radio frequencies may be illustrated from the history of the Telecommunications Coordinating Committee. This committee was established in 1946 in the hope that it would become a high level policy determining body. It was sponsored by the State Department

\(^*\)See Telecommunications: A Program for Progress, p. 197.

\(^**\)See Hearings on Spectrum Allocation, pp. 200 and 204.
and consisted of one representative from each of the following: The Departments of State, Treasury, Commerce, Army, Navy, and Air Force and the FCC. It was intended that the representatives should be of Under Secretary or Assistant Secretary level for the non-military departments and the chief communications officers of the armed forces for the military departments. The subsequent history of the committee illustrates the kind of problem which any such attempt at coordination is bound to encounter. First of all, although several efforts were made by member departments to have the organization set up by executive order, this was never done. "The FCC...pointed to its statutory responsibilities for policy formation and advice to Congress on such matters, and stated that its participation in any group such as FCC would not relieve it of these obligations or bind it in any way." The committee adopted the rule of unanimity and could therefore act only when the "departments are in agreement or can be brought into agreement by intragovernmental persuasion and diplomacy." The technical aspects of the question discussed made it difficult to maintain a high-level membership. "Under Secretaries and Assistant Secretaries have been replaced at meetings by Directors of Offices; Directors of Offices have been replaced by technical specialists, so FCC meetings are often conventions of IRAC representatives acting under different instructions."* An account by the Office of Civil and Defense Mobilization (written in 1959) summed up the position in the following words: "...although it has a long history of trying to establish itself as a mechanism for the formulation of national policy, it [The Telecommunications Coordinating Committee] has proved to be ineffectual and today is advisory only to State."** It is difficult to resist the conclusion that those who established this committee and had such high hopes for its future had but newly arrived at the center of power.

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*This short account is based on the section dealing with the Telecommunications Coordinating Committee in ibid., pp. 201-203.

**See Hearings on Spectrum Allocation, p. 132.
The experience in the United States with the administrative structure which has been devised to handle the allocation of radio frequencies illustrates very vividly one of the dilemmas of planning. The attempt to control everything from the center is liable to lead to paralysis. The delegation of control leads to inconsistency of action. If central control is instituted, the necessity of referring all questions to the center involves expense in compiling and transmitting information and delay before decisions can be made. Nor are the decisions necessarily better when they are made. The remoteness of the center from the areas affected by the decision may lead to a failure to understand the significance of the issues under consideration. The pressure of many decisions needing to be made at the center will make it difficult to give enough attention to each. On the other hand, if control is delegated to relatively autonomous authorities, decisions made by each of these individual authorities will almost certainly fail to give sufficient weight to the effects of their decisions on activities coming under the control of other authorities. The transfer of resources between these authorities will take place with difficulty. In view of these circumstances, some misallocation of resources is bound to occur.

The division of control of the allocation of radio frequencies between the FCC and the IRAC has no doubt led to misuse of radio frequencies. It may well be that it has resulted in too great an allocation of radio frequencies in total for the use of Government departments. But there is every reason to suppose that an attempt to avoid such misallocations by extending the powers of the FCC to cover Government stations or by establishing a new Board to supervise the allocation of frequencies to Government departments (using procedures similar to those of the FCC) or by setting up a single super Board to control the allocation of all frequencies in the United States, would impose additional expense and delay and would bring about new misallocations. It is no doubt desirable to realize the inefficiencies inherent in the present system. But the solution to the problem is not to be found along the lines which have so far been suggested.
III. THE RADIO FREQUENCY SPECTRUM AS A SCARCE RESOURCE

THE NATURE OF THE PROBLEM

"The radio spectrum must be regarded as finite and similar in all respects to other natural resources."** This bold statement, taken from a recent report on Space Telecommunications, expresses a view which is now generally accepted and which is also, as it happens, true. We use the radio frequency spectrum to expand the volume of production, to increase the variety of our consumer goods and to strengthen the national defense. It plays a role in our modern society similar to that of land or electric power or oil or steel or human labor. But those who write or speak on this subject always hasten to add that the radio frequency spectrum is not simply a resource; it is also scarce. There is less of it available than we would like to have. And this is also true.

In the Report of the President's Communication Policy Board, the situation is described in the following words: "Nature has presented the inhabitants of this world with what used to be called the 'ether,' the medium through which radio waves of all frequencies are propagated. Like the air we breathe, the radio spectrum is there for all to use. Unlike the air, there is not enough of it to accommodate all claimants. Everyone who uses a portion of the radio frequency spectrum automatically excludes others from using this same portion at the same time, unless the other potential user is far enough away geographically to cause or suffer only tolerable interference."** In the past, the situation has been alleviated by an increase in the usable spectrum. The FCC has explained that its "rules in 1934 viewed the then total spectrum as extending in frequency from 10 kilocycles to 500 megacycles, inclusive," but "its

*See Policy Planning for Space Telecommunications, Staff Report prepared for the Committee on Aeronautical and Space Sciences, U.S. Senate, 86th Congress, 2d Session, p. 33.

**See "Telecommunications: A Program for Progress," p. 185.
current frequency allocations include frequencies to above 30,000 megacycles. Until recent years, this extension permitted a phenomenal growth in the number of users of the spectrum. As bands allocated to the various services became overcrowded or as new developments occurred in higher bands, families of bands were allocated to those services." But this way out is no longer possible: "There are approximately a dozen petitions for reallocation of spectrum space on which the Commission has been unable to take affirmative action because of congestion in the bands which might otherwise be made available. These petitioners can be satisfied only by taking spectrum space from other non-government services or by acquiring additional space from government services."

The discovery that a particular resource is scarce is hardly likely to excite an economist. There are, it is true, some resources that are not and these the economist calls "free goods." Air, mentioned by the President's Communications Policy Board, or water in certain parts of England or sand in the Sahara, are examples of "free goods." But most resources do not fall into this category. That there is less of a resource than we would like to have is the usual situation. If we use more of it for one purpose, there is less available for others. If we use it to increase the supply of one good, we decrease the supply of others. Indeed, it is this decrease in the supply of other goods and services which is the cost of using the resource to increase the supply of any given good or service. The cost of accomplishing one thing is what we give up elsewhere in order to do so. This is what we mean when we say that a resource is scarce: there is a cost of using it.

It is this scarcity of radio frequencies which has been seen as the justification for the existing administrative machinery for the allocation of radio frequencies. In a Supreme Court decision, Mr. Justice Frankfurter explained why the kind of regulation which exists in the radio industry is necessary. "The plight into which radio

*See the Annual Report of the FCC for 1959, pp. 159-160.
fell prior to 1927 was attributable to certain basic facts about
radio as a means of communication -- its facilities are limited;
they are not available to all who may wish to use them; the radio
spectrum simply is not large enough to accommodate everybody. There
is a fixed natural limitation upon the number of stations that can
operate without interfering with one another. Regulation of radio
was therefore as vital to its development as traffic control was to
the development of the automobile. In enacting the Radio Act of
1927, the first comprehensive scheme of control over radio communica-
tion, Congress acted upon the knowledge that if the potentialities
of radio were not to be wasted, regulation was essential.... The
facilities of radio are limited and therefore precious; they cannot
be left to wasteful use without detriment to the public interest."*

What Mr. Justice Frankfurter does in this opinion is to draw atten-
tion to the fact that a radio frequency is a scarce resource. From
this he concludes that it is essential to have the kind of regulation
imposed by the FCC.

It is not difficult to see why Mr. Justice Frankfurter came to
this conclusion. The use of a radio frequency by one person, if the
frequency is really a scarce resource, will make this frequency less
useful to others (perhaps even causing them to abandon its use alto-
gether). This means that the gain which accrues as a result of the
use of a radio frequency by one person is always accompanied by a
loss which results from the impairment of its usefulness to others.
It is obvious that a person should be allowed to use a radio
frequency only in those cases in which the gain exceeds the loss.
Otherwise there is a "wasteful use" of this "previous" resource.
The function of the FCC is to prevent such "wasteful use."

The FCC was thus seen, and rightly, as performing an essential
function. From this, Mr. Frankfurter concluded that FCC regulation
is essential. But it would only be valid to make this jump in the
argument if there were no other way in which this function could be

*National Broadcasting Co. v. United States, 319 U.S. 190, 213,
215-17 (1943).
performed. If there were, it would be necessary to show that this "other way" would, on balance, perform this function worse than would the FCC before it would be possible to be sure of the correctness of Mr. Frankfurter's conclusion. But Mr. Frankfurter did not consider this question, no doubt because he thought that no alternative to FCC regulation existed. If he had thought that there was any alternative, he surely would have considered it. But in proceeding as if the FCC type of regulation was the only way of solving this problem, Mr. Frankfurter was wrong. And it is a strange error to make; and stranger still that it is commonly made in the discussion of frequency allocations problems. The basis of the argument is that the radio frequency is a scarce resource. But all resources (apart from free goods) are scarce. And yet, somehow the American economic system seems to manage without needing to have Commissions for each resource, entrusted with the task of allocating the resource to those who want to use it. If, as the quotation given at the beginning of this section says, the radio spectrum is "similar in all respects to other natural resources" why is it necessary to treat it differently? Scarce resources (natural or otherwise) are normally allocated to users in the United States by means of the pricing mechanism. Private property is created in the resource and its owner disposes of it to those who will pay the most for it (or its use). To obtain a resource (or the use of a resource) it is necessary, with this system, to outbid others who want to use it. Someone considering using this resource will only do so if the price (the cost of the resource to him) does not exceed the value of that resource in whatever employment he is considering using it. Since, however, the price to him (the cost of the resource) will be the value of that resource to another user, the potential user will in fact compare the value of the resource if he uses it with the value of the resource if someone else uses it. The pricing system therefore provides a precise monetary mechanism whereby the value of a resource in alternative uses is compared and that use is selected for which the value is greatest. It operates to maximize the value of
production. The resource is allocated to users, "wasteful use" is avoided and all this without the need for any administrative action by a Commission.

The possibility of using the pricing system is something which never crosses the mind of those concerned with policy concerning the use of the radio spectrum. Mr. Doerfer, when Chairman of the FCC, said that it would be desirable to have a "mechanism whereby you could have an exchange of frequencies between government and non-government"* without apparently realizing that the pricing system provides such a mechanism. And in the Cooley Report (The Report of the Special Advisory Committee of 1958), we are told that "in certain parts of the radio spectrum, the demand for frequencies has become greater than the supply, and...the trend in volume of applications...indicates that the situation will grow progressively worse."

Consequently, "it is plainly of great importance to our national security and welfare that the mechanism of allotting and assigning frequencies, particularly in the government field, be reviewed and strengthened to the end of assuring the most effective use of a scarce but essential resource."** It does not seem to have occurred to the members of the Committee that a situation in which the demand has become greater than the supply is not an extraordinary one and that for most resources in the United States, the problem would be easily solved, and the necessity for suppliers to select those who are to receive the resource eliminated, by a rise in price which would result in some people ceasing to demand. This tendency for the price to rise would of course cease when the excess of demand over supply had disappeared. The working of the pricing system would ensure "the most effective use," namely, the use which would maximize the value of production. And all this would be accomplished without any administrative machinery of the government being set in motion. If there is one lesson that has been demonstrated many times in

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*See Hearings on Spectrum Allocation, p. 194.

**See Hearings on Spectrum Allocation, p. 42.
recent history, it is that rationing is an inevitable result of maintaining a price lower than would prevail in a free market. In the case of radio frequencies, as the price that is charged is, of course, zero, it is hardly surprising that we find a situation in which there is an excess of demand over supply and there is need for some governmental body to decide who among the many claimants shall be granted this valuable resource. Those in positions of authority who deal with the problems of allocating the radio spectrum seem to be unaware that the rest of the American economic system largely works on different principles. Mr. Cooley, in testimony in a Congressional hearing, emphasized the need for adopting his Committee's proposals by saying: "There are more applicants in some bands than there are frequencies. It is like seats at the box office, when there are more people that want seats than there are seats. That being the case, it seems to me essential that an organization be developed that can properly and in the public interest handle this whole thing."* But Mr. Cooley does not seem to have considered how we are able to get along without a Federal Seating Commission. And Mr. Frank Stanton, President of Columbia Broadcasting System, when asked in the course of a Congressional inquiry, whether it would not be desirable to dispose of television channels by awarding them to the highest bidder, could only reply that this was a "novel theory," as if he had not noticed how the American economic system operated and was under the impression that CBS obtained the services of Mr. Jack Benny as the result of an allocation from the Federal Labor Commission.**

It seems probable that the main reason why the present system has come to be regarded as the only workable arrangement for the allocation of radio frequencies is that the alternative to the

*See Hearings on Spectrum Allocation, pp. 50-51.

**See R. H. Coase, "The Federal Communications Commission," Journal of Law and Economics, October 1959, p. 17; where the relevant quotation from Mr. Stanton's testimony can be found.
present system is thought to be the situation which existed just before the passage of the 1927 Act. And this situation was rightly considered to be intolerable. But one of the features of the period before 1927 was that no one operating a radio station had any rights (or at least they were very ill-defined). In consequence, a station operator could choose whatever frequency, power or location for his transmitter that he wished without regard to the effects of his actions on other station's operations. This situation, in which no one had any rights, is one in which the pricing system could not function, since there were no rights which anyone could acquire by paying for them. As had been explained on another occasion, * if there were no property rights in land, so that if a man used a piece of land for growing crops, another could come along and build a house on the land on which the crop had been planted and then another was able to come along, pull down the house and use the space as a parking lot, it would no doubt be proper to categorize the situation as one of "chaos" or "bedlam." The situation described, however, does not arise at the present time and the reason is a simple one. Property rights exist in land and someone wishing to use the land has to pay the owner in order to be allowed to do so. That is why we do not find a state of chaos when we contemplate the way in which that "scarce but essential natural resource," land, is used in the United States. If the pricing system is to be used to allocate radio frequencies, there would have to be well-defined property rights; and that was not true in the pre-1927 period.

THE WORKING OF THE PRICING SYSTEM

The fact that the pricing system is not at present used to determine the allocation of radio frequencies makes it difficult for people to envisage how it would operate and, in particular, why it would bring advantages which are not achieved with the present system. It is the purpose of this section to demonstrate the nature of the advantages which would be gained by such a use of the pricing system.

But because it is easier to demonstrate this by starting with the familiar and then moving to the unfamiliar, this discussion will start by glancing at what would be lost if, instead of using the pricing mechanism to determine the use of land as is at present the case in the United States, a Federal Land Commission were established and operated along the lines of the FCC. Having seen the character of the disadvantages that would be suffered from the substitution of such a Commission for the pricing system in the case of land, it will be easier to understand the kind of changes that would occur if the allocation of radio frequencies were determined in future by the use of pricing system instead of as a result of decisions by the FCC and IARAC.

Imagine a situation in which a Federal Land Commission (the FLC) was given control over all the land in the United States and was instructed to dispose of it to users without charge. The position then would be that land could be obtained from the FLC for nothing or it could not be obtained at all. In these circumstances, applications for land from business, industry, and individuals would pour in to the FLC. Existing users, who would gain no financial advantage from disposing of their land to others, would resist any attempt to dispossess them of the land they were using. The excess of demand over the supply of land in many parts of the country would be appalling. The reasons advanced by the various claimants to show why they needed the land would be compelling and, up to a point, true. Extensive hearing would be required to determine what use should be made of any piece of land. The purposes for which the land was required would have to be examined, the character, competence and financial qualifications of the various applicants investigated. When land was awarded for use for one purpose, continuing inspection would be required to make sure that the way the land was used had not been changed without first having obtained permission from the FLC. The question of what constituted a change of use would have to be determined. The purely administrative problems faced by the FLC would be prodigious. At the same time, the external
pressures exerted on the FLC would be strong and unremitting. Business groups would oppose any proposed change which would expose them to additional competition. Politicians would oppose any proposed change which would tend to reduce the income of their constituents or their own influence. No business would have any interest in economizing in its use of land. Changes in land-use would come about only with great difficulty and would depend to a large extent on land becoming valueless in existing uses. Economic growth in the United States would be slowed by the shortage of land and the problem would no doubt call for Presidential attention.

But it is unnecessary to examine this imaginary example in detail or to catalog the many inefficiencies that would be likely to result from the establishment of a Federal Land Commission. Few would deny that it would have consequences similar to those mentioned. In the case of land, the wisdom of allowing its use to be largely determined by the working of the pricing system is not usually disputed. There appears to be little desire to establish a Federal Land Commission. Nor is there any obvious reason why such a Commission should be established. We saw, in the previous section, how the pricing system operating within a framework of private property would result in land being used in such ways as would maximize the value of production. On the one hand, a potential user would not be willing to pay for the land unless what it would contribute to his business was worth more than the amount he would have to pay (which is equal, of course, to the fall in the value of production elsewhere if it were diverted to his use). On the other hand, he would not even acquire land in these circumstances if some other resource were available which would enable him to accomplish the same end at a lower expenditure (thus resulting in an even smaller fall in the value of production elsewhere); for example, by adding stories to his existing building, it might be possible to obviate the need for more land.

No Commission could reproduce this process. Without a market for land, it would lack the precise monetary measure of cost and benefit. In judging the value of land in different uses it would
have to go by what people said its value was (without their ever being put in the position of having to demonstrate the truth of their statements by actually paying this amount). Furthermore, a Commission cannot possess all the information about the uses of land which is known to every single person who might enter the market for land. Finally, a Commission has to carry out its work while subject to pressures which the ordinary person buying and selling in the market is not exposed to. It is therefore clear that the way a Commission would allocate land to different uses would be quite different from the way a market would operate, even though the exact basis for the Commission’s decisions would be very difficult to discover.

THE PRICING SYSTEM AND THE ALLOCATION OF RADIO FREQUENCIES

The advantages of using the pricing system are perfectly well understood where land is concerned. But when we come to consider the arrangements for allocating radio frequencies, we find that a different attitude prevails. This is very strange since it has always been realized that the radio spectrum was a natural resource, just like land. An early commentator said: "In a certain sense the development of radio has opened up a new domain comparable to the discovery of a hitherto unknown continent."* Furthermore, there is no dispute that there is inefficiency in the allocation of radio frequencies and that the administrative bodies have not developed satisfactory criteria for making their decisions. But the basic reason for this unsatisfactory condition has eluded the critics. To a large extent, it is the result of a faulty approach. The allocation of the radio frequency spectrum as between different uses is essentially an economic problem; but it has been thought of as an engineering problem. The Joint Technical Advisory Committee of the Institute of Radio Engineers and the Radio-Television

Manufacturers' Association summarized its view of ideal spectrum occupancy in the following terms: "The ideal condition of spectrum occupancy may be defined as follows: The limit of spectrum occupancy occurs when all portions of the spectrum are fully, continuously, and uniformly utilized and each frequency assignment is employed by many stations so arranged that their service areas are adjacent but do not overlap."* To an economist there is ideal occupancy of the radio spectrum when it would not be possible to increase the value of production by any change or rearrangement of the use of radio frequencies. This cannot be discovered by looking at engineering data. It is true that Joint Technical Advisory Committee also states: "Without a measure of [economic and social] values, it is difficult to arbitrate for or against the admission of new services or the enlargement of established ones at the expense of other services. It is necessary to measure at every stage in the introduction of a new service, its actual and potential value relative to the older service it tends to displace. This measurement takes the forms of an assessment of certain costs and values, some of which can be expressed simply in terms of money, others of which involve such intangibles as the general public welfare, protection of life, national defense, and the prejudices and desires of the individuals collectively served or protected."** But the Committee does not seem to realize that there should be continuous measurement of the value of all services if there is to be an ideal use of the radio spectrum together with a mechanism which will select those uses which enable the value of the services contributed by the radio spectrum to be maximized. And it is not easy to see how this can be achieved except with the aid of a market for radio frequencies. It is the absence of such a market which is the main cause of the present difficulties.

The views expressed by James M. Landis and others about the inefficiency of the present arrangements and the misuse of radio


**Ibid., p. 194.
frequencies are no doubt quite correct. But the remedy is not to be found in a change in the administrative structure or even an increase in the numbers and improvement in the quality of the personnel concerned with the allocation of the radio frequency spectrum. Without a market, it is inevitable that the criteria employed to decide on the use of the radio spectrum will be vague and the policies inconsistent. Dr. Doerfer, when giving testimony as Chairman of the FCC, said that the shortage of frequencies might come about largely "because we are not using it [the radio spectrum] correctly and nobody seems to know, nobody can know with the machinery we have today...."

It is true that Mr. Doerfer seemed to think that the situation might be improved by the creation of a superboard to control the whole radio spectrum; but it is improbable that this would constitute an improvement; and highly improbable that such a change would be made. The attempt to control the use of a resource such as the radio frequency spectrum without employing the pricing system is bound to create problems for the governmental administrative bodies concerned which are overwhelming. Even to discover how radio frequencies are in fact being used is no small task. The President's Communications Policy Board commented on this question as follows: "Efficient utilization of radio frequencies can be obtained only if the user and regulatory agencies constantly keep watch over the use of frequencies. Only in this way can the regulatory agencies know which users make full use of their frequency assignments and which have too many frequency assignments. It is estimated that a thorough analysis and control program for the United States and possessions would cost $50 million a year." At the time this report was prepared, the total expenditures of the FCC were about $5 million per annum.

* See pp. above.

** See Hearings on Spectrum Allocation, p. 193.

*** See "Telecommunications: A Program for Progress," p. 27.
The most conspicuous feature of the present allocations procedure, particularly that of the FCC, is its rigidity in the face of changing conditions. One aspect of this is the long delay which occurs before the FCC is able to make a decision. An example would be the "freeze" on the construction of new television stations from 1948 to 1952 while the FCC was considering what frequencies were to be allocated for television. But any proposal for a change which would mean displacing an existing user would encounter opposition and would be agreed to, if at all, only with reluctance. As Mr. Doerfer said: "The practical problem is taking it [the right to use a frequency] away from them, and there isn't anybody that wants to take something away from somebody and cause him a financial hardship or pull the rug out from underneath him after he has done years of planning, or take it away from him after he is making pretty good use of it without the balance being heavily weighted for another use."* One of the results of this is that it is extremely difficult to replace the existing operator of a broadcasting station by another by FCC action. However, here the market emerges to demonstrate that it is able to accomplish something which the FCC would not be able to do. The owner of a broadcasting station can sell it, and although he has no property right in the frequency he uses, the FCC will normally approve the transfer of the license to the new owner and therefore his use of the frequency. The consequence is that, in fact if not in law, the right to use a frequency can be sold. As a result certain rearrangements in ownership can take place, although without the market they would not occur. Of course, such rearrangements do not extend beyond changes in ownership. It is not possible to purchase a broadcasting station in New York and transfer its license to a station in Los Angeles. Nor is it possible to use the frequency for any purpose other than broadcasting.

An excellent example of the rigidity of a system in which no market transactions are possible is afforded by the present UHF television situation. Mr. Doerfer, when Chairman of the FCC, said in

*See Hearings on Spectrum Allocation, p. 213.
Congressional testimony: "Part of our problem in the television broadcasting business is this: We have 70 UHF channels which we have been unable to get off the ground. Now, we have that space and we feel that if there were some way of making a switch with the government, if we could get some V's so that you could build a receiver economically, a receiver that could span from channel 2 to channel 32, or whatever you want, or 52, so that there consecutive alignment.... We feel that the people eventually not immediately - would acquiesce, they would buy that and then we would have adequate television service. ...

I think if you had a mechanism whereby you could have an exchange of frequencies between government and non-government and if you had an agency which would take all of the economics into consideration, the impact upon industry, the expenditures of the budget of the government, the impact upon the public and you get those relative values and a decision must be made, it will be made, I am confident, where the economic impact will cause the least burden or hardship."* And later Mr. Doerfer elaborated on his view that the "shortage of frequency space" may be the result of a misuse of the radio spectrum. "Just think that portion which is devoted today to radio broadcasting in the aural band -- I am talking about the radio you have in your car and that type of thing -- takes up approximately 1,100 kilocycles. One television channel ties up 6 megacycles or 6,000 kilocycles, so the ratio is 6 to 1. Now we have 70 channels in the UHF portion of the spectrum which makes it a ratio of about 420 to 1. To me, unless we can find some way of getting this off the ground, that is a waste of spectrum space. That is not a shortage. That brings me back to where the FCC and the military begin to bargain back and forth for space which the FCC thinks would be used and would be acceptable to the people.... The military says 'Yes, we can use the UHF for this, but to do so it is going to cost a billion dollars.' My answer to that is going to be, 'Maybe it would be advisable to spend a billion to make $10 billion in national wealth.' They say, 'You go up to Congress and try to get the billion dollars

*See Hearings on Spectrum Allocation, p. 194.
to obsolete this equipment,' and we say, 'Well, that is part of your duty.' We go back and forth..."* If, as a result of the switch of VHF and UHF frequencies proposed by Mr. Doerfer, the value of the VHF frequencies released by the military for civilian use was greater than the value of the UHF frequencies which would have to be transferred to the military to accomplish the same purpose by an amount which exceeded the additional equipment cost imposed on the military, and this seems to have been Mr. Doerfer's belief, then it would clearly be in the national interest that the switch should take place. But it is very understandable that the military departments would not want to go to Congress for authority to spend an additional billion dollars which would not improve the defenses of the United States. As the defense position would remain unchanged after the switch, to ask the military departments to do this is to ask them to support a proposal which brings less defense per defense dollar. It is easy to see that the position would be very different if there were a market for frequencies. If the sum of money which the military could obtain for their VHF's was greater than the sum of money they would have to pay for the UHF's needed to replace them by an amount which exceeded the additional equipment cost imposed on them by this change in frequencies, the military departments would have an interest in doing this. The same defense would be obtained at lower cost. There would be more defense per defense dollar if the switch from VHF to UHF were carried out through the market whereas there would be less defense per defense dollar operating with the existing allocation system. The introduction of a market would tend to bring the interest of the military departments and the national interest into closer conformity. But this is not, of course, only true for the military. As the characteristics of different frequencies vary, there must be many cases in which a rearrangement of frequency use would increase the value of production.

But, leaving aside the costs of making such transactions and of

*See Hearings on Spectrum Allocations, pp. 235-236.
inducing the FCC to sanction them, rearrangements of frequency use
with the existing system would only be agreeable to those who would
be involved if, for every single user, the frequencies he would
obtain in the exchange were sufficiently more productive than the
frequencies he used previously to offset the additional equipment
costs which the exchange would force him to incur. All in all,
these are very restrictive conditions. The market, by enabling
existing users of frequencies to be paid the value of those fre-
quencies to other users if they dispense with them clearly facili-
tates the carrying out of these beneficial exchanges.

So far this discussion has been confined to the problem of
exchanges of frequencies between existing users. But the problem
can be stated in more general terms. The absence of a market price
(which measures the value of a frequency to another user or in
another use) means that a user has little idea of when he is using
a frequency "wastefully" and no financial inducement to find out.
Obviously, a frequency should not be used for a particular purpose
if it prevents the accomplishment of some other purpose of greater
value or if the same purpose could be achieved by the use of another
resource which would mean a smaller fall in the value of production
than the use of the frequency. It is clear that such wasteful use
must be very common with the existing system. Any user with the
existing system will not willingly surrender frequencies that he has
been allocated so long as their use (or potential use) has a value
greater than zero and this even though there may be others to whom
the frequency has a higher value (apart from the changes in owner-
ship which are sanctioned for broadcasting stations). Mr. Doerfer
pointed out that it is understandable that the military should hoard
frequencies. "He [a military man] has to have a standby service for
the same reason that a municipality may have a whole system of water
hydrants and never use but 1 per cent of them. He needs that stand-
by service and it is his fear that when the shooting starts, or when
the dire emergency presents itself, that he cannot get it. That is
why he tries to sit on it. I think that a civilian authority would
be sympathetic with that viewpoint, but my question is, Do we have twice as many fire hydrants as the city needs? Are they sitting on more frequencies than the emergency would warrant?"* The difficulty with Mr. Doerfer's argument is that to any given user additional radio frequencies appear to be advantageous so long as they contribute anything to the purpose he is endeavoring to achieve. As long as this is true, he would never agree that he has more than he needs (or might need). But this, of course, does not mean that these radio frequencies would not make a more valuable contribution if transferred to some other user. On the other hand, how can any given user know whether this would be true? This would be so even if the information on usage of the radio spectrum were accurate and complete; but in fact it will not be. As Mr. MacQuivey has said: "The lack of information concerning radio-frequency usage is generally considered to be one of the principal weak links in the existing administration of radio-frequency assignments. Until some means can be developed to prevent the use of such information for purposes of 'raiding' the assignments to one agency by another, it is unlikely that there will be a substantial change in this direction."**

Were there a market for radio frequencies, such difficulties would not be encountered. One user would not have to compare the usefulness of a radio frequency to him with what it would yield to someone else. If he was a businessman, all he would need to consider was whether his profits would be increased by paying for the use of additional frequencies or, if, say, one of the defense department, whether by spending more on radio frequencies it would be possible to obtain more defense per defense dollar. The examples which have so far been given here have concerned the comparison of the value of radio frequencies in different uses. But there is also the problem of choosing between using a radio frequency or some other resource to achieve a given purpose. Dr. D. W. Everitt, Dean

*See Hearings on Spectrum Allocation, p. 212.

**See MacQuivey, op. cit., pp. 218-219.
of the School of Engineering of the University of Illinois who had been a member of the President's Communications Policy Board has said: "We...have found more efficient ways to use spectrum as we have developed applications such as single side band, better frequency control or we can even look forward in the future perhaps to more efficient ways of modulation. However, all of those uses generally also involve a decision between a problem of how much money you want to spend and what you want to get accomplished. Almost any method of making use of the spectrum more efficiently requires much more elaborate apparatus at both the transmitter and the receiver..."* The position, as explained by Dr. Everitt, is that it is possible to economize on the use of radio frequencies by incurring additional expense for equipment. But when would it be worthwhile to incur additional expense in order to reduce the demand for radio frequencies? Without a market price for radio frequencies, no one is in a position to make such a comparison and certainly no one has any financial inducement to use fewer radio frequencies and incur the additional expense for more elaborate transmitting and receiving equipment when this would enable a given end to be achieved in the least costly way (one, that is, which would minimize the fall in production elsewhere). Of course, the additional capital equipment necessitated if a given end is to be achieved with a smaller use of radio frequencies need not be transmitting and receiving equipment. For example, the use of radio may enable a firm to undertake a given volume of business with a smaller fleet of automobiles or trucks. Whether it would be desirable to operate with a larger fleet or a smaller fleet plus the use of radio frequencies depends in part on the value of the radio frequencies. A business will normally take into account the cost of the radio required for such a change; but it has no means and is not required to take into account the value of the radio frequencies used. Mr. MacQuivey has described how the General Services Administration decides whether to install radio equipment in their cars: "A fairly definite cost-
versus-utility measure of the use of radio telephone in these mobile vehicles has been developed. For example, taking into account the fair-proportion of the base-station cost, the unit cost per vehicle for an installation amounts to about $600, and this amount must be depreciated in a ten-year period. Taking into account this monthly depreciation and salary of the driver of the vehicle, it costs about 48 cents a mile to run a government car with radio. This cost is compared with other costs of providing transportation together with other factors such as speed and flexibility of service, its availability when required, and so forth, and the determination made then whether to install the radio equipment. That decision must, of course, be accompanied with a decision to attempt to obtain a frequency assignment accordingly.** It is apparent from this account of the procedure followed by the General Services Administration (the GSA) that, in coming to a conclusion whether to introduce radio into its vehicles, the GSA takes account of the cost of all resources that would be involved except the radio frequency. This way of calculating cost is bound to give too low a figure (although it is impossible to say by how much in the absence of a price for a frequency). All users will, of course, follow a procedure similar to that of the GSA. If there were a market price for radio frequencies (which would then be treated like other resources), the cost would be properly calculated and simultaneously the need to have a Commission to allocate radio frequencies to users would disappear.

The discussion in this section of the part which the pricing system could play in the allocation of radio frequencies among users may have given the impression that the alternatives between which we have to choose is one in which the allocation is wholly determined by government regulation and one in which it is wholly determined through the working of the pricing system. It might also have been thought that it was being maintained that the pricing system is inevitably superior in all circumstances to government regulation. Neither of these views would be correct. It is quite possible to have private

**See MacQuivey, op. cit., p. 141.
property and the pricing system together with some regulation. Thus we find private property in houses and a market for houses notwithstanding that there are building regulations and zoning laws. Furthermore, such regulation, although it may be unwise, is not necessarily so. When the costs of carrying out market transactions are high (and this is particularly likely to be true when a large number of parties would be involved in the transaction), it may be better to allocate resources as a result of government regulation rather than through the operation of the market. Of course, in deciding whether to make certain areas of economic activity subject to government regulation, account needs to be taken of the costs of government administration, the inappropriateness of the regulations in many individual cases, the effects of political pressure and administrative ineptitude. But there is no reason to suppose that the right conclusion will always be that there should be no regulation. Similarly we would not expect the existence of regulation to preclude the operation of the pricing system. If we look at the present arrangements for allocating resources in a wide range of American industries, we usually find that use of the pricing system is combined with regulation of one kind or another. The peculiarity of the situation in the case of radio frequencies is that the allocation is wholly determined by government regulation and that the pricing system (if we except the sale of broadcasting stations) plays no part in their allocation. This represents such an extreme position that it seems highly improbable that it is really the best solution to the problem of allocating radio frequencies.

PROPERTY RIGHTS IN RADIO FREQUENCIES

The adoption, and maintenance, of a system which makes no (or virtually no) use of the pricing system in the allocation of the radio frequency spectrum between the many competing claimants, suggests, I think correctly, that those who have been concerned with policy have felt that there was an insuperable obstacle standing in the way of a market solution to the problem. The nature of the supposed insuperable obstacles is not hard to find. If there is to be a market in radio frequencies (or their use), property rights would have to be established in radio frequencies, since, unless a person acquiring a radio frequency knew what he had a right to do (which others could not), there would be nothing to acquire. Without a delimitation of property rights, the "chaos" or "bedlam" observed in the period before 1927 would be inevitable. Those concerned with policy in this area seem to have assumed that the delimitation of property rights would be extremely difficult, if not impossible, and consequently that it was inconceivable that there could be a market in radio frequencies which would operate in a satisfactory way.

It would be idle to pretend that the problem of the delimitation of property rights is one which is easily solved. But the summary rejection of the possibility of having property rights in radio frequencies probably stems from a misunderstanding of what property in a resource is. The nature of private property is a right to do certain things, which right can be transferred to others. In the case of radio frequencies, what is being allocated is the right to radiate electrical impulses in certain ways. We commonly think of the process of allocating radio frequencies as being similar to that by which stone which is extracted from a quarry is allocated to various users. But, in looking at the question in this way, we tend to forget that the stone can only be used in certain ways. What the owner of a piece of stone can do with it is strictly limited; but what he can do with it defines the property rights which adhere to ownership of a piece of stone. And the same would be true for the
ownership of radio frequencies. Indeed it might be better if we did not refer to the allocation of radio frequencies, since this way of speaking is very liable to mislead. As I said on a previous occasion: "Every regular wave motion may be described as a frequency. The various musical notes correspond to frequencies in sound waves; the various colors correspond to frequencies in light waves. But it has not been thought necessary to allocate to different persons or to create property rights in the notes of the musical scale or the colors of the rainbow. To handle the problem arising because one person’s use of a sound or light wave may have effects on others, we establish the rights which people have to make sounds which others may hear or to do things which others may see."* Property is not something physical but a right to do something or to stop others from doing something or to require them to do something. Property rights refer to actions which the owner can perform or can cause others to perform. The introduction of private property rights in radio frequencies would mean that the rights of people to perform actions which involve the radiation of electrical impulses were defined and that these rights could be transferred and recombined. But no attempt will be made here to change accepted modes of expression. It is enough to point out the nature of the problem under discussion.

One difficulty in understanding the similarity between the problems of property in other resources, such as land, and the problems of property in radio frequencies (to use the commonly accepted phrase), arises from the fact that the detailed delimitation of rights in the case of land has come about as a result of a long historical process. No one has ever had to tackle the whole problem, except for lawyers tidying up after the event. If we now know what property rights in land are, it is because a body of law has been built up from the multitude of cases which have been decided in the past, and if the delimitation of rights seems to work in a fairly satisfactory way, it is because unsatisfactory arrangements have been

abandoned or modified. It is not to be expected that a scheme for introducing property rights in radio frequencies will be able to solve all problems once and for all. No doubt property rights in radio frequencies would evolve through the passage of new statutes and the modification of old statutes and through that detailed process of delimitation which comes about as a result of court decisions. But to grow it is necessary to be born and this evolutionary process cannot begin until some form of property rights in radio frequencies is established.

Of course, it would be wrong to think that it would be necessary to develop a completely new set of property rights for radio frequencies. Many of the problems that would arise would be adequately covered by existing property law. Indeed, in the period before 1927, the courts found little difficulty in applying existing principles to the new problems posed by the emergency of radio communication.* And exactly the same kind of question that would have to be answered if there were private property in radio frequencies has already been treated in another branch of law, that dealing with the emission of electrical radiations by one business which impede the operations of another.** For example, in the course of operating electrical railroads and streetcars, electrical impulses are radiated which may impede, or even render impossible, the operation of telephone and telegraph lines or cables.

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**See Deier on The Law of Conflicting Uses of Electricity and Electrolysis (1911).
Electrical power lines may have similar effects. There are a
series of cases dealing with these problems.* The issues in these
cases are not essentially different from those that would have to
be handled by the courts if there were private property in radio
frequencies.

A very recent case (United States v Wrathall (Radio Station
KSAY), Civil Co. 36702 (N.D. Calif. S.D.), illustrates the compe-
tence of the courts to handle the problems that would arise if
there were private property in radio frequencies. In this case,
the operation of Radio Station KSAY in San Francisco, California
caused high frequency electricity to be induced in various mechani-
cal devices, including cranes, used in the Army Terminal at
Oakland, California with the most serious consequences; "The induced
electricity on the cables and hooks of the cranes is a dangerous
fire hazard. The loading or unloading of ships carrying explosive
or other cargo at times when the cables and hooks of the cranes are
carrying induced electricity could cause fire or explosion highly
dangerous to life and property and which would interfere seriously
with the normal operations of the base. The loading and unloading
of ships carrying explosive and flammable cargo is a usual and
necessary part of the operation of the Terminal." Furthermore,
n personel had been burned by touching the equipment. The Army was
forced "to discontinue the use of the affected equipment during the
hours on which Radio Station KSAY operates. The change in method
of operation has cost plaintiff $6,000 per month over and above the
normal cost of operation and is continuing, and will continue to

*See Cumberland Telephone and Telegraph Co. v United Electric
Ry Co., 42 Federal Reporter 273-284 [1894], 29 Southwestern
Reporter 104-116 [1894]; Lake Shore and M.S. Ry Co. v Chicago L.S.
and S. B. Ry Co., 92 Northwestern Reporter, 189-113 and 95 North-
western Reporter 596 [1910, 1911]; Phillipsey v Pacific Power and
Light Co., 207 Pacific Reporter 957-960 [1922]; Yamhill County Mt
Telephone Co. v Yamhill Electric Co., 224 Pacific Reporter 1061-
1085 [1925]; Postal Telegraph Cable Co. v Pacific Gas and Electric
Co., 202 California Reports 382-390 [1927]. See also A.L.R.
Annotation to Phillipsey case, 1257-1262; 33 A.L.R. Annotation to
Yamhill case, 380-381; 9 Ruling Case Law 1230-1231.
cost at least this much as long as defendants' transmitter continues to operate as at present." An injunction was demanded to stop "defendants from operating said transmitter until they have taken such steps as may be necessary to prevent further interference with plaintiff's operation of the Army Terminal. Plaintiff also demands a declaratory judgment that defendants' interference by means of radio emanation, with plaintiff's operations at Oakland Army Terminal constitutes a nuisance. Plaintiff further demands damages in the amount of $150,000."* The defendants argued, among other things, that as they were operating in accordance with the conditions of a license granted by the Federal Communications Commission, "the plaintiff is estopped from maintaining this action."

** In answer to this last contention, it was pointed out that a "broadcasting licensee acquires no property right by reason of the granting of a license." In addition, it was argued that "no license, permit, or franchise authorizes the creation or maintenance of a nuisance." It was also claimed that it was "obvious that Congress, in authorizing the issuance of licenses by the FCC, did not intend to waive any of the sovereign or property rights of the United States."*** It is not necessary to discuss the merits of the various arguments used in this case, which was apparently settled out of court by a change in the location of KSAY's antenna so as to avoid the objectionable effects at the Army Terminal. What is important about this case is that it demonstrates the ability of existing procedures to determine the rights possessed by a person who transmits electrical radiations.

The establishment of private property in radio frequencies would merely pose an old problem in a new context. It is a problem which governments and the courts have been handling for ages. This does not mean that to decide what the exact character of private property in radio frequencies ought to be will necessary prove to be a simple

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* See The Complaint, pp. 2-3.

** See The Answer, p. 4.

*** See The Brief In Support of Motion, pp. 8-9.
problem, any more than the determination of the rights of the owner of the house or an automobile or a dog has proved to be a simple matter. But the problems which would be faced are, at any rate, similar in kind to those which have been encountered and solved in the other spheres.
CHAPTER IV

PROPERTY RIGHTS IN RADIATION: ALTERNATIVE APPROACH

As we saw, it was the desire to control interference in order to preserve the quality of radio transmissions that gave rise to the current system of regulating the use of the frequency spectrum. This approach involves the technique of licensing -- the assignment of the right to use a frequency in an area to specified individuals and the protection of these rights by the denial to others of the use of the same frequency at the same time and in the same area.

The present system goes much further than this, however, in that it involves detailed specifications as to the use to which an assigned frequency may be put, the power of the transmitter, the size, location, and height of the antenna, polarization, modulation of the transmission, and so on. If this system results in the use of the "proper" combination of resources required to maximize the value of production with the frequency spectrum, from among all of the possible combinations, it is either because the licensing agency has at its disposal, and utilizes, all of the information concerning the value of the resources in alternative uses, or it is fortuitous. In light of the fact that changing technology is continually enlarging the range of alternative combinations, and that additional uses for the spectrum develop over time, it seems unlikely that a system of rigid input specifications will result in an efficient use of the spectrum.

Clearly, the value of the radio frequency spectrum lies in the ability of its users to deliver signals of some acceptable quality. Consequently, property rights intended to insure the efficient use of the frequency spectrum must be defined in such a fashion that their enforcement will preserve the quality of delivered radio signals. However defined, these rights would consist of the right to deliver a signal of some level of power to various points, coupled with the right to deliver it sufficiently free from interference so as to preserve its quality.
Allocation by a central agency attempts to achieve this by specifying in detail the inputs of the sources of transmission and by limiting the number of sources of transmission in a given area. Because of the fundamental nature of radiation, the establishment of the locations and allowable inputs of transmitters also establishes geographical output patterns of radiation over areas whose sizes are determined by the strength of signals received on their boundaries. This follows because as we saw above the nature of radiation is such that a signal, once emitted, continues on and on. It attenuates with distance, however, so that it becomes undetectable at distances remote from its source. Thus the boundaries of an area covered by a signal can be meaningfully specified only in terms of power levels at distances from its source. (This is analogous to specifying the "area" covered by a light. Obviously, a light ray does not proceed some distance from its source and then cease abruptly. It continues on and one, declining in strength as it does so, so that the area covered by it can be meaningfully specified only in terms of its intensity at various distances from its source.)

Because of this technical relation between inputs and outputs, an alternative method of defining rights in radiation would be to do so, not in terms of input, but in terms of output. This could be accomplished by granting a right holder permission to utilize a specific frequency bandwidth to radiate a signal at a specified time such that its strength at the perimeter of the relevant area did not exceed some specified level.

In order to preserve the value of this right it would also be necessary to grant the right holder the power to refuse others permission to "enter" the specified area. "Entrance" would, of course, also have to be defined in terms of power levels not to be exceeded by others at the boundaries of the right holder's area.

In addition, if it were desired to allow the market to allocate the spectrum, these rights would have to be comprehensive in that the owner could do as he saw fit with his rights, and they would have to
freely transferable among individuals.*

Thus, a set of property rights in radio frequencies that would allow the market to allocate them into their highest uses would consist of the following:

(1) **Emission Rights**

Emission rights would consist of the right to radiate energy on a specified frequency bandwidth, at a specified time within an area defined in terms of a power level not to be exceeded at its boundaries. In addition, the amount of spurious radiation emitted on other frequencies (adjacent and harmonic) would have to be controlled so as not to exceed some specified amount. (The necessity arbitrarily to establish "some specified power level," "some specified time," and "some specified amount" is not peculiar to this definition of rights. It must be done under any system of rights that is to preserve the value of the spectrum.)**

(2) **Admission Rights**

The right holder shall have the right to refuse others permission to radiate energy in excess of a pre-determined level on the frequency and within the area to which his rights pertain, and at the time to which his rights pertain.

(3) **Use**

The uses to which a right holder puts his property shall be determined by him -- he shall be free to choose from among those alternatives legally open to him.

(4) **Transferability**

As with rights in other resources, admission and emission rights in radiation shall be transferable to others, in whole or in part, at the discretion of the right holder.

*The freedom involved here need not be complete since the principles of a market economy apply even though restrictions are placed on the property owner's range of alternatives, so long as he is free to choose from among those that are available. See pp. , infra.

**These arbitrary specifications would be necessary only in the initial definition of the proposed rights. As will be demonstrated below, the market would adjust these specifications if they were initially, or became, non-optimal.
The Basic Advantages of Defining Rights in Radiation in Terms of Output

In principle, defining and enforcing radiation rights in terms of output would make it unnecessary to specify inputs. Different combinations of inputs can be used to achieve a given level of received power at a point distant from the source of transmission and, so long as the originally determined output levels were not exceeded, no excessive interference would occur. It would, from the standpoint of the maintenance of some quality of delivered signals, be immaterial how the delivered power levels were achieved.

The combination of resources actually used by a right holder to achieve a given output power level would depend upon economic considerations -- the costs and revenues involved. If, for example, it were profitable (lower cost) to substitute transmitting antenna size or height for (some amount of) transmission power to achieve a given power level at the perimeter of the relevant area, the owner of the rights would so do since the resulting gain would accrue to him. Similarly, if it were to his advantage to conserve the bandwidth to which he had title by utilizing a certain combination of input power and modulation so that he could gain by devoting it to other uses or disposing of part of it, he would do so. The right holder would be motivated (by the fact that the resulting gain would benefit him) to take advantage of the technological combinations available in order to reduce the costs of obtaining a given output level, and to increase his revenues by improving the quality of his output and/or making available part of his rights for other uses.

Allowing rights in radiation to be transferred between uses and/or users would also tend to result in an efficient use of the spectrum. A right holder would have an incentive to devote his resources to new uses as they arose, or to transfer the right to another user, if by so doing he could realize a gain. A gain could be realized by such reconstitution of rights if a new use was more profitable (and thus more "valuable") than existing uses, or if a new user would be willing to pay him to give up his rights. A new user would be willing to make such an arrangement only if the use to
which he could apply the resource was profitable to him, with profits being found in his ability to devote it to valuable uses.

In contrast, under the present system of allocation a licensee holder has a tendency to treat the frequency bandwidth assigned to him as a free good. This does not result from the fact that no price is paid for the resource, but because of the restrictions that are placed on the uses to which the resource may be put. This makes the cost of the bandwidth the same whether it is used in whole or in part. Consequently, the bandwidth will be "economized" only by the FCC forcing the licensee to do so by changing the specifications of inputs. Otherwise it will be economized only if the licensee incurs some costs (with no offsetting benefits to himself) to narrow his use of the bandwidth in order to make it possible for the FCC to give it to another user.

It must be remembered that in a market system the individual can gain only by using what he owns in an efficient manner -- producing those things that are most valuable to the market as indicated by the demands expressed for the products capable of being produced, and doing so at the lowest possible cost.* Since cost reflects the value to the society of the resources in other uses, the process of the individual pursuing his own gains tends to result in the maximization of the value of production.

[The extent to which property rights will be transferred or reconstituted will depend in part upon the costs involved in the exchange itself. In general, these costs will be greater the larger is the number of individual right holders involved in a particular reconstitution, and the greater is the amount of search that is necessary to identify these right holders -- to discover who owns the separate rights whose reconstitution is desired. However, the fact that identification is easy and the number of separate right holders is not large is not sufficient to assure efficient reconstitution.

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*He can also gain by imposing monopolistic restrictions on the operation of the market. This means that the society must proscribe and impose penalties on this type of behavior. See pp. ____, infra.
For example, consider the case of radiation rights as currently
defined by the FCC. The content of these rights is very specific
and the identity of the individual right holder is readily obtainable
from any FCC office. If on economic grounds the reconstitution of
these rights would be desirable, however, this reconstitution may not
take place because the current institutional arrangement itself makes
the cost of negotiation very high -- nearly impossible. If, say,
even a simple reconstitution such as a different antenna height or
location is desired, who is to be negotiated with and upon what
basis? Even if it were desirable to alter only a particular input
mix, without affecting other right holders, the cost (difficulty) of
negotiating for this change may be such as to prevent it.

The case in which the number of participants to an exchange may
make the exchange too costly can be illustrated by assuming that
radiation rights inhere in land rights -- that land owners are given
the rights of radiation over their land. Thus, anyone desiring to
radiate energy through space would have to obtain permission to
"enter" each individual land owner's space. Even though the iden-
tity of the individuals with whom negotiations must take place is
known, the sheer number of individuals involved may prevent the
reconstitution.

Similarly, if contracts concerning rights must periodically be
redrawn -- the case of rent or lease -- the cost of reconstitution
will be higher than if one set of negotiations was sufficient.

Consequently, it appears that the manner in which rights are
defined, and the number of individuals to whom they are initially
distributed, affects the efficiency with which the market can recon-
stitute them. This raises the question as to how the emission and
admission rights in radiation are to be initially defined and dis-
tributed. Within broad limits, however, the initial distribution
of the proposed set of rights is not critical to the manner in which
the market would reconstitute them. The fact that reconstitution
would tend to take place after the initial distribution may be
illustrated as follows:
Assume that the emission and admission rights to a particular frequency bandwidth were initially distributed to a single individual for the entire United States. The cost of supplying the various types of services and the demand for these services would determine the pattern of use that would eventually emerge.

The cost of supplying a given service is affected by the nature of radiation -- the fact that the level of power decreases as the distance from the source increases. Therefore, it may cost more to supply a service by installing a gigantic transmitting antenna in the middle of the United States than to supply the service by using several antennas, each radiating energy into smaller areas.

Demand considerations will determine the value of particular types of services in different geographical areas, and the rights may be more valuable when used to produce one type of service in area A, and a different type of service in area B. Similarly, the value of the rights may be increased when they are subdivided in time and frequency bandwidth. Neither these divisions nor the uses of them will tend to be the same in all geographical areas of the United States.

In light of the above discussion, one would expect that the value of the rights would be maximized when they are subdivided in time, frequency bandwidth, and geographical areas. The subdivision and the rearrangements of the rights will take place until no other changes in the rights will increase their value -- until the cost of further changes exceeds the increase in value that results.

It is clear, therefore, that both the dimensions of the area and the specification of power levels on its perimeter will ultimately be determined by the nature of the costs of producing the services and the relative geographical demands for the services. This raises two distinct alternatives: (a) should the rights of radiation on a given frequency bandwidth be given to an individual for the entire United States, letting the subdivision and rearrangement of these rights take place through market transactions? Or (b) should the rights on a frequency be defined for smaller areas, letting the rearrangement take place through market transactions?
These alternatives imply an element of asymmetry, the basic reason for which is that the costs involved in making exchanges, and thus the extent to which reconstitution takes place, may be different for the two methods of initial distribution. Even if it could be established that based on this consideration the first method is the better, two additional factors must be considered.

First, resource reallocation becomes desirable as economic variables change over time -- as population grows and changes geographically, as demands for different services emerge, and as technologically changes take place. Although the first method of distribution of the rights may have been the more efficient choice initially, it is on the same footing with the second in the efficiency with which resource reallocation is brought about over time.

Second, at present there are certain rights of radiation already established in the economy. How are these rights to be treated? Should such rights be first preempted and portions of the frequency bands for the entire United States be disposed of, say, to the highest bidder, or should they be redefined in terms of output and assigned to current holders? The first approach is the simpler one for the distributor of the rights initially, but it offers possible disadvantages of political acceptance and may impose relatively high transitional costs in moving from the present system to a market system. It is not clear that one method has any clear technical advantage over the other. Neither is it clear that the method actually used is critical to the efficient reconstitution of these rights after they are once distributed.]*

*The manner in which initially to distribute property rights in radiation is an issue separate from the problem of how to maximize the value of production with the spectrum. Regardless of the manner in which the initial distribution is made, the operation of the market will tend to reconstitute the rights in such fashion that they move into the hands of those to whom they are most valuable, and into the uses that are most valuable. Since value finds its source in the strengths of the demands for the outputs of a resource, this results in the resource being used where it is most in demand. (This assumes that the rights are not so widely distributed as to make the number of transactions involved in the reconstitution prohibitively costly. It also assumes that information as to who the rights holders are is
The foregoing general discussion of the manner in which output rights in radiation could be reconstituted through a market exchange system is open to the legitimate criticism that it does not adequately take into account the unique technological characteristics of radiation and the difficulties these characteristics introduce in defining and enforcing rights expressed in terms of outputs. Knowledge of the technological nature of radiation gives rise to objections that take the following general forms: (1) Because of the effects of uncontrollable natural phenomena, radiation outputs cannot be defined in single-valued power levels. This fact will make the definition, measurement, and enforcement of rights defined in terms of output impossible. Put another way, it may be said that output rights cannot be defined and enforced when outputs are (to some extent) beyond the control of the right holder. (2) The additive nature of aggregate interference from radiation sources is such that modification or reconstitution of output rights could not take place in a market exchange system because all rights holders would be affected by any change in the rights. Consequently, it may be believed that the number of individuals involved in the most simple reconstitution of rights would be so large as to make the reconstitution prohibitively costly.

The following sections attempt to anticipate some of these objections by illustrating the manner in which various types of reconstitutions of output rights could be brought about, given the technological facts of radiation. For the purpose of illustrating the types of reconstitutions that could take place, it will initially be assumed

available to the market at relatively low cost.)

The initial distribution of rights is a matter to be decided upon on grounds of social and political feasibility and will involve the reconciliation of conflicting (subjective) opinions concerning "equity." This problem is not unique to the frequency spectrum, nor is it any more insoluble where the spectrum is concerned than it is in the case, say, of the distribution of rights in land when a frontier is opened. Rights in land were initially distributed in different (and perhaps "unfair") ways but after the initial distribution the market for land reconstituted these rights so as to devote land to its most valuable uses. See yp. infra, for some discussion of the manner in which initially to distribute rights in radiation.
that outputs are not subject to variability -- that they can be
defined and maintained in single-valued terms -- and that the cost
of enforcement and measurement of these rights is zero (that measure-
ment and enforcement is not required). These assumptions will later
be relaxed and the effect of variability in output strengths on the
viability of rights defined in terms of outputs will be examined.
The illustrative transactions will, however, take into account the
fact that radiation is additive in nature, and the effect of this
phenomenon will be examined.

RECONSTITUTION OF OUTPUT RIGHTS, THE PURE CASE -- NO VARIABILITY,
ZERO ENFORCEMENT COST

Reconstitution of property rights may involve the combination
or division of existing rights, or modifications in the uses to
which the rights are put. All property holders whose individual
rights are affected by the change must be parties to the transaction
and the larger is the number of individuals involved, the more costly
is the alteration. Where property rights in radiation are concerned,
it may appear on the surface that the additive nature of radiation
sources contributing to the level of aggregate noise or interference
is such as to require an abnormally large number of parties to any
change in existing rights so as to make the cost of such changes
prohibitively large. It may be believed that this factor would make
a market exchange system for radiation rights unworkable, requiring
instead resort to centralized allocation and control of this resource.

The additive nature of aggregate interference. As we have seen,
the reception quality of a given signal depends on the strength of
the signal relative to the level of (total) interference received
with it. The level of interference is the result of the energy
radiated by all other sources into the particular frequency bandwidth
being used. The additive phenomenon of radiation defines a technical
relationship between the total level of interference and the individual
sources contributing to it -- total interference is equal to the
square root of the sum of the squares of the individual interferences.
Furthermore, the level of total interference increases roughly in proportion to the square root of the number of separate sources radiating a given amount of energy.*

The full import of this phenomenon is that fixing any two of the factors will determine the third. Establishing the total level of interference and the number of sources contributing independently to it will establish the level of power on each source.** Alternatively, a given level of (total) interference and a given level of power that any one individual source can generate establishes a certain number of independent sources. This means that before a maximum level of power outside an area can be specified on an individual basis, one has to know initially the number of independent sources and, thus, the total level of interference that is desired. It also means that with a given number of separate emission sources, an increase in the power of one will raise the level of aggregate interference impinging on all others, and that an increase in the number of sources through the subdivision of rights or the issuance of new rights will also raise the level of aggregate interference. The presence of this phenomenon raises two related questions: (1) If radiation rights were to be defined in terms of outputs, is there an adjustment mechanism that can bring about changes in the number of sources of radiation and their power levels when an existing level of aggregate interference is optimal, and that is capable of altering the level of aggregate interference present in an area if it is not optimal? (2) Can these adjustments take place without necessitating an excessively large number of negotiations between rights holders? Much of what follows attempts to give answers to these questions.

There are three sources of radiation that contribute to the level of aggregate interference on a frequency band -- sources

*Total interference is equal to the simple sum of the separate interferences when they are "statistically independent."

**But see note *, supra.
surrounding an area and operating on the same frequency band; sources operating on adjacent and harmonic frequency bands within and without an area; and source whose primary function is not the transmission of information (industrial and automotive equipment), and natural phenomena.

For the sake of simplicity, and because they may lend themselves to different treatments, the effect of each of these sources on the reconstitution of property rights will be analyzed separately, with the assumption that the contributions to the level of aggregate interference by the other two sources is given.

**Additivity from Sources Operating on the Same Bandwidth and the Reconstitution of Property Rights Defined in Terms of Output**

Given an initial geographic distribution of rights on a particular frequency bandwidth, with geographic areas defined in terms of power isouants not to be exceeded, there are two types of reconstitution of such rights that might take place -- reconstitution of the geographic rights could take place with the level of aggregate interference as a datum (either because it is optimal or because it is arbitrarily fixed), or reconstitution could take place to alter the level of aggregate interference if it were not optimal.

**Reconstitution of Geographic Rights to a Frequency Bandwidth within the Constraint of a Given Level of Aggregate Interference**

Assume an initial distribution of geographic rights to a frequency bandwidth and a level of aggregate interference that is given, either because it is optimal or because it is arbitrarily established, so that any reconstitution of these rights that takes place must do so without altering the level of aggregate interference. Such reconstitution might occur either because existing rights are combined or subdivided, or because some central agency later issues additional rights on the frequency bandwidth in question.
Combination or Subdivision of Existing Rights

If all of the rights on a frequency bandwidth are initially distributed, and if the level of aggregate interference is given, the question arises as to what, precisely, one right holder could transfer to another. The answer, essentially, is "anything" so long as the admission rights of others are not infringed -- so long as the level of aggregate interference is not increased. Such a reconstitution may be illustrated by referring to Fig. 1. Assume that Fig. 1 represents the initial distribution of geographic rights on a frequency bandwidth. These rights may be subdivided and rearranged by the individuals involved in any fashion they desire so long as the level of aggregate interference is not increased and/or do not receive a greater amount of radiation without their consent.

If, for example, right holder A, Fig. 1, wishes to subdivide his rights geographically and sell part of them to F, as shown by the dashed line, the constraints upon him are given by the fact that the resulting total rights of A and F cannot exceed A's original rights. Put another way, F's emission rights must be defined in such fashion that the admission rights of other right holders (B, C, D, and E) are not violated -- the energy transmitted by A and F together (determined by the additive principle) must be no greater than the amount of energy that A alone was allowed to radiate into the other areas.

Similarly, consider a situation in which F later sells to D the right to radiate energy into F's area in excess of the amount originally specified in D's emission rights. That is, the power level present at the old boundary between A and D (shown by the solid line) is to obtain on the new boundary between F and D (shown by the dotted line). Strictly speaking, D now radiates higher power isoquants not only into F's area but also into the areas of the other right holders. In addition, the combined amount of radiation of D and F on other right holders is now higher than it was. While this radiation may not be significant in practice, in principle F must, to consummate the sale, negotiate with other right holders to obtain their permission for this increased radiation or nullify the effect by reducing
Figure 2: Hypothetical distribution of rights.
his radiation into the other areas.*

It thus appears that given an initial geographic distribution of rights to a frequency bandwidth and an established level of aggregate interference, individual rights defined in terms of output levels are capable of being reconstituted and that the additive nature of radiation does not pose any insuperable problems for this reconstitution. It simply means that the reconstitution must take place within the constraint that the relationship between separate sources of emission and the total level of interference is not the simple sum of the separate sources, but is the square root of the sum of the squares of these sources. This constraint, however, is determinate.

Issuance of New (Additional) Geographic Rights

It is possible that when the initial geographical distribution of rights to a frequency bandwidth is made the issuing agent (the government) may, for whatever reason, withhold the rights in certain areas for later issuance. The question may arise as to the effect the later distribution of these withheld rights would have on the existing right holders. The answer depends in part upon whether the government, in defining the power isoquants of the initial right holders, did so with the effect of the issuance of the withheld rights in mind -- if the initial issuance defined the power isoquants to allow for the later issuance of the undistributed rights.

If the government defined the initial right holder's power isoquants such that the level of aggregate interference would be the "desired" level when the withheld rights were distributed, the actual

*The simplest type of reconstitution would involve the transfer of time rights. The seller could simply agree not to use his rights at certain time periods, transferring to another the right to do so and ceasing operations for the time period specified. This would involve no problem of increases in the level of aggregate interference or infringement on the admission rights of others. Or, he could subdivide his geographic rights at certain times. This would involve the type of adjustments involved above, but would not complicate the problem further than this.
issuance of these rights would create no problem since it would simply raise the level of interference to the desired level.*

If the government did not allow for the effect of the issuance of the withheld rights when it defined the power levels of the initial right holders, so that the initial level of aggregate interference was optimal, the later issuance of these withheld rights would raise the level of interference above the optimal. Consequently, either the withheld rights would have to be issued with power levels (considerably) below those originally intended so as to add no appreciable interference, or they would have to be issued at the originally intended level, raising the level of aggregate interference. In the first case the newly issued rights might be of such power as to be worth relatively little in that they would not provide the desired service in the geographic area for which they were intended. In the second case the value of the original right holders' rights would be reduced because of the increase in the level of interference and consequent reduction in the quality of their service. This, in essence, consists of imposing a tax on the initial right holders. As we will see below, however, central control is not necessary because of this problem -- negotiations between the individuals involved could bring about a solution.**

It thus appears that a system of rights defined in terms of output isoquants lends itself to reconstitution in the form of

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*Prior to the issuance of the withheld rights, the level of interference might be less than optimal. This might result in negotiations on the part of the initial right holders to raise the existing level of interference so that the issuance of the withheld rights would raise the level of interference above the optimal. Since the government retained the right to issue the withheld rights at some future time, however, these negotiations would be only interim negotiations. At the time the new rights were issued, the original right holders would have to return to their initially specified power levels.

**The problem here is essentially one of "equity," involving a transfer of wealth between individuals similar to that involved in tax-transfer activities of the government. It would take place regardless of the allocation system used and is separate from the question of whether the market could reconstitute rights efficiently.
combination or subdivision of geographic rights, and the issuance of new geographic rights. The owners of the separate geographic rights are known and the number of individuals with whom negotiations must be carried on to reconstitute these rights does not appear to be prohibitive, even in light of the additive nature of radiation. Another technological aspect of radiation that has not been considered is capable of further reducing the complexity of negotiations involved in reconstitution. This is the fact that the normal spherical pattern of radiation is capable of being modified by the use of directive antennas.

Effect of antenna directivity on the reconstitution of rights. It is clear that with a simple spherical radiation pattern any change in established power isoquants would affect every right holder surrounding an area in which a change takes place, the number affected being limited only by the normal attenuation of radiation. However, by using directive transmitting antennas energy can be concentrated in any direction, reducing the number of right holders affected by a given change. In addition, by the use of multiple antennas almost any desired radiation pattern can be created, reducing even further the number of right holders affected by a given change. (Figure 2 illustrates some of the possible shapes of power isoquants that can be achieved in this fashion.) The nature of the effect of antenna directivity on the extent of negotiations required to bring about a reconstitution of rights may be illustrated as follows:

Assume that Fig. 3 represents an initial geographic distribution of rights on a given frequency bandwidth. With spherical radiation patterns, an arrangement between A and B to allow B to extend his emission power into A's area (A selling some of his admission rights to B) would also involve the other right holders. By using directive antennas, however, B can concentrate energy in A's direction only, leaving unchanged the boundaries between himself and other right holders. As a result, only B and A are involved in the arrangement which allows B to enlarge his area of radiation in such fashion that his power level at the old boundary between himself and A now obtains at the new boundary, indicated by the dashed line. Because of the
14. Rhombic Antenna. — The rhombic antenna consists of four nonresonant wires arranged in the form of a diamond or rhomboid as in Fig. 39. Such an arrangement gives greater directivity than can be obtained from a single long nonresonant wire, and

![Diagram of rhombic antenna with phase angles and spacing in wavelengths]

Fig. 38.—Horizontal radiation patterns of arrays of two vertical antennas fed with currents of equal magnitude, showing effect of spacing and phase. The circle superimposed on each diagram has the same area as the field pattern actually attained.

Furthermore, it provides a convenient means of terminating the antenna system to obtain the nonresonant condition.

The directional characteristics of the radiation from each leg of the rhomboid are as shown in Fig. 29, and when the tilt-angle θ, as defined in Fig. 39, has the optimum value according to Fig. 40, all four legs have major lobes that tend to be pointed in the

![Diagram of rhombic antenna with directions and terminating resistances]

(a) Non-resonant V

(b) Rhombic antenna

Fig. 39.—Rhombic antenna showing how the radiation from the individual legs combines to produce a maximum in the direction of the terminating resistances, direction of a line drawn through the apices, and at the same time tend to add in phase in this direction.


Figure 39
Figure 4. Hypothetical distribution of rights.
additive nature of radiation, of course, B and A together are now emitting more power into C's area. Either B and/or A must acquire additional rights from C, or A must reduce his emission toward C by appropriate adjustment in power and antenna directivity so that the combined output of B and A does not exceed the original output of A on the boundary between A and C. If the latter course is taken, negotiations are required only between B and A and result in A having reduced by sale his original rights.

A different type of subdivision of rights, using directive antennas, may be illustrated in area E, Fig. 3, where the solid lines show the geographic rights (defined by power isoquants) initially issued to E. Assume that E decides that point-to-point communication in his area is a more valuable use of his rights than, say, general broadcasting. Through the use of directive antennas, E can provide East-West service. He may also, through the use of directive antennas, provide North-South service himself, or he may, if he wishes, sell this right to another, say F. Their combined emission powers (and timing of emissions) can be arranged so that E's original emission rights are not exceeded and, consequently, the other right holders are not affected by, and need not be involved in, the transaction.

Thus, while the number of parties to a transaction designed to reconstitute geographic rights to a frequency bandwidth does not appear to be prohibitive even without the use of directive antennas, the use of such devices can limit the number of individuals affected to the number involved in the immediate transaction. The point to be stressed is that geographical subdivision of rights within the constraints of a given level of aggregate interference is capable of accomplishment without undue negotiation, granting the fact that radiation is additive in nature.
Reconstitution of Rights on a Frequency Bandwidth to Change the Level of Aggregate Interference

We considered above the manner in which the market could reconstitute geographic rights defined in terms of output isoquants on a frequency bandwidth, taking as given the level of aggregate interference. The question now arises as to the manner in which the market could reconstitute rights to alter the level of interference if such alteration became desirable.

The level of aggregate interference in an area might be non-optimal for several reasons -- the original definition of power isoquants assigned to rights holders may have been in error so that the resulting level of interference was less (more) than optimal; economic or technological conditions may alter over time, allowing a higher (lower) level of interference; or previously withheld geographic rights may be issued, resulting in an increase in the level of interference above the optimal. Two general situations might arise in which the level of interference becomes non-optimal:

1. The situation in which all geographic rights on a frequency bandwidth are initially distributed and the resulting level of interference in an area is, or becomes, less (more) than optimal; and
2. The situation in which the initial level of interference is optimal but undistributed rights are later issued, resulting in an increase in the level of interference above the optimal.

Combination or Subdivision of Existing Rights

Assume that in Fig. 3 the initial distribution of rights results in a level of interference this is optimal in all areas except A, where it is less than optimal. Under these conditions A would find it to his advantage to sell part of his admission rights to B, allowing B to emit higher powers into his (A's) area (the dashed line indicates B's enlarged area). Through appropriate modifications in power and/or antenna directivity, A can reduce his emission toward C so that A and B combined do not exceed the initial power radiation of A toward C. A's signal strength is the same as before in the area bounded by the dashed line on one side and the original boundary.
lines on the other sides. His signal level is, however, less in the shaded area. As a result, the level of interference relative to his signal has increased so that the quality of his service has changed.

As a result of this transaction, the value of the rights of C, D, and E have not changed since their admission rights have not been affected. The combined value of the rights of A and B have increased, however. B would be willing to pay A a sum of money for this arrangement only if the increase in the value of his rights was at least equal to the payment, while A would not accept that sum unless it exceeded the resultant reduction in the value of his rights. This leads to an optimal level of interference and an increase in the value of production, since the increase in the value of B's production exceeds the decrease in the value of A's production.

Similar rearrangements can, and will, take place in other areas where the level of interference is not optimal since it will be in the interest of the individuals involved. The most troublesome aspect of the problem of interference exists at the peripheries of the areas involved since normal attenuation reduces the strength of a signal as the distance from its source increases.* This type of reconstitution is facilitated by the possibility of altering the shape of power isoquants by the use of directive antennas, thus reducing the number of right holders involved in a specific rearrangement. It thus becomes necessary for a right holder to negotiate with relatively few others in order either to reduce or increase the level of interference in his area, and thus to approach the optimal level of total interference.

**Distribution of New Rights**

The rearrangements that may follow the distribution of formerly withheld geographic rights on a frequency bandwidth are analytically similar to those discussed above. Assume, for example, that in Fig. 3 geographic rights on a frequency bandwidth are initially

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*This does not necessarily follow if the adjacent frequency aspects of radiation are taken into account. This will be discussed shortly, and it will be shown that the main arguments are not affected.
distributed to individuals A, C, D, and E, with the area represented by B withheld at the time of the initial distribution of rights. If the power isocurves initially assigned to A, C, D, and E are such as to result in a level of interference that is optimal, the (later) issuance of the withheld rights to B will result in a level of interference that is above the optimal.

If B is granted emission rights such that the level of aggregate interference rises in any, or all, of the other right holders' areas, they can, collectively or individually, negotiate with B so as to pay him not to exercise the rights to which he has title. They can, in addition, negotiate with each other to bring about a reduction in the level of interference sufficient to offset the effect of B.

Alternatively, B's rights could be issued to him subject to the condition that he negotiate with all (or some) of the other right holders, paying them to reduce their outputs before he can exercise his emission rights.

The point is that regardless of the "fairness" of the manner in which these withheld rights are distributed, once they are distributed, the market is capable of bringing about a reconstitution so as to result in an optimal level of interference.*

Thus, insofar as the reconstitution of geographic rights on a frequency bandwidth is concerned, given the additive nature of interference, there does not appear to be any insurmountable problems involved either in the reconstitution of rights with a given level of interference, or in reconstitution designed to alter the level of interference itself.

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*The manner in which to distribute these withheld rights involves the question of wealth or income distribution. If the government issues the withheld rights in such a way that other right holders must negotiate with the new right holder, the value of their rights (their wealth) has been reduced -- a tax has been imposed upon them. On the other hand, if the new right holder is constrained by the fact that he must negotiate with the others, his rights are not as valuable as they otherwise would be. Regardless of this, however, the market can bring about the required reconstitution.
ADDITIVITY OF SOURCES OF RADIATION CONTRIBUTING TO THE LEVEL OF
AGGREGATE INTERFERENCE FROM ADJACENT AND HARMONIC FREQUENCIES AND
THE RECONSTITUTION OF RIGHTS

The foregoing examination of the effect of the additive nature of radiation sources on the same frequency bandwidth took place with the assumption that interference resulting from the emission of energy on other frequencies and from mechanical and natural sources was given. The purpose here is to examine the effect on the reconstitution of radiation rights of contributions to the level of interference by sources on other frequencies. This will be done on the assumption that interference from sources on the same frequency and from mechanical devices and natural phenomena is given.

We have seen that radiating energy on a given frequency bandwidth also involves emitting energy on other frequencies -- frequencies adjacent and harmonic to the central frequency. These spurious emissions are caused by the characteristics of the antenna tubes and the circuitry. For example, FM transmitters produce a continuous spectrum of sideband noise -- their radiated power is distributed around the carrier with the amplitude of the power tapering off on both sides of the central frequency. The harmonic aspect of radiation is caused by the fact that energy radiated on a particular frequency is repeated with decreasing amplitude on frequencies that are constant multiples of the initial frequency.

The characteristics and the relative importance of the power distribution on a frequency band depend also on the type of radiation -- whether it is continuous wave (CW) or pulsed.* Pulsed systems, such as those used in radars, are particularly important for two reasons: (a) With pulsed systems the standard deviation of the distribution around the central frequency is greater than that of the CW system. The frequency composition of the signal is broadband in nature because of the rather abrupt changes in power

level that exist in a pulsed system. This means that a larger portion of the frequency spectrum is affected by pulsed than by CW systems. (b) Communication transmitters normally provide power outputs in the range of 100 milliwatts to 50 kilowatts. In contrast, radars usually have power outputs of 100 kilowatts to 10 megawatts. Although approximately 90 per cent of this power is concentrated within a transmitter bandwidth (which is equal to twice the reciprocal of the pulse width), the peak power of the system is so high that the energy radiated outside the bandwidth is of appreciable amplitude.

The nature of spurious emissions is such that they can be substantially minimized by shielding and filtering devices.* The filters can be considered to be of two types—separate or specialized filters that reduce the magnitude of power at the harmonics, and general filters that affect the rate of decrease in the level of power emitted outside the bandwidth. These are illustrated in Fig. 4 with the effect of the specialized filter being shown as a dashed line and the effect of the general filter as a dashed-dotted line.

In principle, therefore, by incurring costs spurious emissions can be reduced to the point where they cannot be detected on frequencies any appreciable spectrum distance from the central frequency. This is analogous to the fact that energy radiated on a given frequency continues on and on but attenuates so that it cannot be detected at distances remote from the source of emission. To specify in the emission rights of radiation that no perceptible amount of radiation should be emitted outside a particular bandwidth, even though technically possible of achievement, may impose a very high cost on the use of a frequency. It was for this reason that it was proposed that the definition of property rights in terms of outputs contain a specification of an amount of radiation not to

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*Sources and control of these emissions are discussed in radio handbooks. For example, see Frederick E. Terman, Radio Engineers' Handbook, 1st ed. (New York: McGraw-Hill, Inc., 1943), pp. 621-673.
Figure 9. Hypothetical power spectra.
be exceeded outside the bandwidth.*

The contribution of spurious emissions to the level of aggregate interference also is additive in nature. That is, the establishment of the number of separate emission sources, together with the specification of the level of power that each source is not to exceed outside the particular frequency bandwidth, will establish a definite level of interference due to spurious emissions that is present in an area on a particular frequency bandwidth.**

Given the fact that such spurious emissions do exist, that they do contribute to the level of aggregate interference, and that they are additive in nature, the question arises as to the effect they will have on the ability of a market mechanism to reconstitute rights defined in terms of output specifications, both on a frequency and around a frequency. Several types of reconstitution might be called for — reconstitution designed to alter the level of aggregate interference; reconstitution designed to subdivide or combine frequency bandwidths; and reconstitution necessitated by the issuance of rights to a frequency bandwidth initially withheld from distribution.

*This specification is arbitrary but would be adjusted through reconstitution of the rights. Clearly, the closer is the specified level to the optimum level (where the cost of suppressing the emissions is equal to the value of the frequency conserved as a result of the suppression) the lower will be the costs associated with the initial transactions to alter these emissions. As technology changes over time, reducing the costs of suppression, the rights would be reconstituted to take advantage of the new situation.

The costs of the initial transactions designed to bring about the optimal level of these emissions (if the initial specifications are non-optimal) might be considered as part of the costs of instituting this system of rights. They also indicate, however, the extent to which the current situation is non-optimal.

**The nature of the shape of the power distribution, the effect of filters on the level of power and the rate of its decrease on frequencies farther away from the central frequency of a particular bandwidth, suggests that only a few sources would have to be considered in the specifications of power levels not to be exceeded outside a particular bandwidth.
Reconstitution of Frequency Rights to Change the Level of Aggregate Interference

Assume that Fig. 5 represents an initial distribution of (all of) the geographic rights to two frequencies, \( F_1 \) and \( F_2 \), such that there are two rights holders in each area -- one on frequency \( F_1 \) and one on frequency \( F_2 \). Assume further that the total level of interference is optimal in all areas except area \( A \), where it is less than optimal. (The emission rights of the individuals involved are defined both in terms of a geographic area the boundaries of which are established by the power isoquant not to be exceeded, and in terms of a bandwidth whose spurious emissions are not to exceed some specified amount. The admission rights of the individual are, of course, the emission rights of the other individuals -- for frequency \( F_1 \), in area \( A \), these are shown as solid and dashed arrows, respectively.) The opportunities for negotiations designed to raise the level of interference are many.

The owners of rights to the two frequencies (\( F_1 \) and \( F_2 \)) in area \( A \) may negotiate with each other to raise the level of interference in area \( A \). This could take the form of an arrangement whereby one or both could increase his spurious emissions in that area and/or his power output. In the event that these actions affect the admission rights of individuals in the other geographic areas, further negotiations are required similar to those discussed in the preceding section.

Alternatively, one of the individuals (say, \( F_1 \)) in area \( A \) could negotiate with another (say, \( F_1 \)) in area \( B \) in such fashion that the output rights of the individual in area \( B \) were enlarged on frequency \( F_1 \). If no additional spurious emission occurs as a result of this transaction, the transaction is identical to those discussed in the preceding section where we saw that such arrangements could take place through offsetting modifications in the seller's power and/or antenna directivity so that other right holders are not affected.

If this transaction did involve an increase in spurious emissions into frequency \( F_2 \) in area \( A \), or elsewhere, either party to the
Figure 5. Hypothetical distribution of rights.
agreement could enter into additional arrangements with \( F_2 \) right holders in the areas involved. Alternatively, either party could control his spurious emissions by the use of filtering devices.

**Subdivision or Combination of Bandwidths**

If economic conditions develop which make profitable the subdivision of a bandwidth in an area (say, \( F_1 \) in area A) so that duplicate facilities were feasible, each using one half of the original \( F_1 \) bandwidth, the question arises as to what rights the original owner of the frequency could sell. The answer, essentially, is that any subdivision that is technically feasible can take place so long as the combined outputs of the resulting rights, both in terms of power isoquants and in the level of spurious emissions (recognizing the additive nature of radiation) do not exceed the outputs specified in the original set of rights for the frequency.

On the other hand, if economic conditions make the value of the rights to two (adjacent) frequency bandwidths in an area -- say, \( F_1 \) and \( F_2 \) in area A -- greater if they are combined and used to provide a different service, the combination could take place so long as the resulting output did not violate the admission rights of other right holders. For example, emission on the combined frequency into other geographic areas could not exceed the sum of the initial radiation on either of the (former) frequencies and the spurious radiation on the other. In addition, the spurious radiation of the combined frequency could not exceed the sum of the initial spurious radiations on the previously separate frequencies.

**Issuance of Undistributed Rights**

Finally, when undistributed rights on some frequencies in certain areas are distributed, their effect on the existing rights is essentially the same as that of the undistributed rights discussed in the preceding section. All that needs to be added is that when previously withheld rights on a particular frequency bandwidth are distributed, they not only will affect the level of interference present in an area on that bandwidth, but also will affect the level
of interference on other frequencies due to spurious emissions.

It thus appears that: (1) The impact of spurious emissions on the reconstitution of rights defined in terms of outputs is analytically similar to the effect of energy radiated by sources on the same frequency bandwidth, and (2) although the presence of spurious emissions increases the number of sources of radiation that contribute to the total interference in an area on a particular frequency bandwidth, individual rights can be defined and appear to be capable of efficient reconstitution.

One result of the increase in the sources of radiation contributing to the level of interference is that it offers an increased number of alternatives to an individual right holder in his attempt to change the level of aggregate interference and the utilization of his rights. The increase in the number of sources contributing to the level of interference does not, by itself, increase the cost of negotiation or otherwise limit the extent to which rights may be reconstituted since, as we have seen, rearrangements may take place among relatively few right holders, without involving others. It thus appears that the existence and additive nature of spurious emissions does not alter the fact the efficient reconstitution of rights is possible through the operation of a market mechanism.

EMISSIONS BY MECHANICAL DEVICES AND NATURAL PHENOMENA

It is customary to speak of the reductions in the intelligibility of a received signal that are due to radiation by other communication systems as interference, and to speak of the reductions in the intelligibility of the signal that are due to the emission of energy by all other sources as noise. The latter is conveniently divided into three groups -- natural noise, inherent noise within receivers, and man-made noise.*

Natural sources of noise include atmospheric disturbances, star activity, solar activity, and precipitation static. Atmospheric

noise is produced primarily by lightning discharges in thunderstorms. The level of atmospheric noise is dependent on frequency, time of day, weather, season of the year, and geographical location, and is the most significant source of natural noise on frequencies below 100 mc. Noise due to star activity is measurable on frequencies up to 900 mc, and that due to solar activity is measurable on frequencies up to 10,000 mc. The effect of precipitation static is ordinarily intense in the low and medium frequency ranges.

Inherent noise generated within a receiver is due to so-called thermal agitation, shot effect, and similar causes. Their effect can be reduced in the construction of the receiver and their magnitude depends partly upon the quality of the particular receiver. While receiver is occasionally capable of radiating energy and thus interfering with the reception of another receiver, the internal noise of a receiver normally affects only the reception quality of the receiver itself.*

Insofar as the holder of emission rights is concerned, it is clear that natural noise and noise inherent in receivers are constraints that he must take as given. While the presence of natural noise will reduce the value of emission rights, and while the relative magnitudes of natural noise over time can be anticipated, the sources of such noise are not subject to control, given the present state of knowledge. Similarly, inherent receiver noises must be taken as given by the emission right holder since the right to choose a particular quality of receiver is not part of the rights

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*It is useful to distinguish between the rights of radiation and the rights of reception. The existing way of allocating the rights of radiation has created a close administrative link between the two sets of rights and has given rise to an apparent need to provide measures by which public investment in receiving equipment is "protected." For a discussion of reception rights see pp. , infra. To anticipate that discussion, there is no general necessity to provide administrative protection for the rights of receivers since the value of radiation rights ultimately depends on the reception of the services provided by those radiation rights. The radiation right holder's self interest forms the mechanism by which the reception rights of the community will be protected.
of emission and admission, but inhere in the person who has acquired the right of reception. To insist that a receiver of a specific quality be used is analogous to insisting that a near-sighted person use particular eye-glasses when viewing a picture, or that a listener have a "good" ear. Man-made noise, however, has a different impact and requires some consideration.

It is important to distinguish two sources of man-made noise:

(1) Sources that affect only the reception of the individual using them as, say, within a household,* and (2) sources that radiate energy and interfere with the ability of others to receive signals.

In the first case there is no problem of additions to the level of aggregate interference since only the user of the equipment is affected. If modifications of wiring systems or the use of filters and shielding will enable the individual to operate these equipments concurrently without mutual interference, he will incur costs in order to do so if the results are worth it. Alternatively, he will have to time the activities so as to minimize their effects.

The source of man-made noise that does require attention is that which results from the use of devices that add to the level of aggregate interference. Radio and television receivers are capable of generating energy and radiating it to other receivers. Welding equipment of different types generates radio signals on certain frequencies. Radio frequencies are employed by industrial heating equipment and electrical-medical devices such as diathermy machines and electro-surgical apparatus. Incandescent, fluorescent, mercury, and sodium lamps, as well as engine ignition systems, generate radio frequency energy. Finally, household appliances and business machines may radiate energy indirectly through power supply circuits.

The contributions of these sources to the level of aggregate interference can be considerable, particularly in densely populated and industrial areas, although the amount of radiation from these

*Common examples of this type are household devices such as food blenders, electric sewing machines, vacuum cleaners, electric shavers, etc.
sources can be controlled by proper shielding, by the use of filters, and by the use of other devices. The question that arises concerns the type of institutional arrangement that seems appropriate to control the contributions of these sources to the level of aggregate interference.

Considering the number of the sources of such emissions, the cost of their detection and the number of individuals involved, it appears that it is appropriate to rely on some type of regulation for their control rather than to rely on individual negotiation, since negotiation and enforcement costs would most likely be large.

Regulation might require the manufacturers of radio and television receiver sets to use proper shielding and filtering devices so that the sets themselves will not radiate energy. Ordinances may be enacted, if they are not already in existence, which would require the use of techniques in wiring systems that reduce the radiation of energy through power input connections.

Discussions in the literature on the nature of shielding and filtering devices lead one to believe that the costs imposed by such regulations would be minor. Perhaps with the exception of receiver set radiations, however, it is extremely difficult to assess the value of regulations designed to limit the amount of radiation caused by power input connections and automotive engine ignition systems -- it is impossible currently to determine whether reduction in the level of noise would be worth the cost of achieving it. However, the nature of the problem is clear. If the value of the reduction in the level of noise obtained by such regulation is at least as great as the cost of bringing it about, the enactment of special regulations designed to limit the amount of such radiation would be worthwhile.

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*FCC rules currently require receivers sold to the public to conform to standards which minimize unwanted radiation.

**This would eliminate most of the noise created by household appliances, and business machines, as well as the noise generated by other equipment such as incandescent, fluorescent, mercury, and sodium lamps. Similar measures would also decrease the level of noise generated by automotive engine ignition systems.
The case of welding, industrial heating, scientific, and medical devices may very well be treated differently. The shielding and filtering devices required substantially to eliminate the radiation of radio frequency energy by these sources may impose costs that exceed the value of the frequency bands affected by such equipment. Therefore, rights of radiation, similar to those issued for other uses, to the frequency bands used in such activities could be issued as individuals.* Only a few frequency bands would be necessary for this purpose since these devices do not interfere with each other.** These rights could be issued either to individuals or to an industry (free or for a price). The holders of such rights could then be held responsible for violations of the rights if and when they occur.

Thus, contributions to the level of aggregate interference stemming from natural noise, inherent noise in receivers that does not affect others’ ability to receive signals, and man-made noise stemming from power input connections and engine ignition systems are to be taken as given by the holder of radiation rights. If on economic grounds a reduction in the level of noise from these sources can be justified, special regulations may be enacted in order to reduce the level of noise caused by power input connections and engine ignition systems. The level of such noise will differ with the time of day, the weather, the season of the year, the geographical location, and the frequency. Generally, the level of such noise will be higher in densely populated areas, and also on lower parts of the frequency spectrum. This means that radiation rights will be affected differently by such noise in different locations and on different frequencies.

*It might be considered desirable to have public regulation specifying minimum standards of performance for certain types of equipment in order to limit spurious radiation. This might be more efficient than to rely on other right holders to enforce their admission rights, since the number of individual users of this type of equipment who would have to be involved in such action might be prohibitively large.

**The FCC currently has set aside the use of specific frequencies for welding equipments and has provided limits on spurious emissions. Several bands of frequencies between 13 mc and 18,000 mc have been assigned for industrial, scientific, and medical devices.
Consequently, if contributions to the level of interference from these sources are selective with respect to frequency, and if their sources can be identified, special regulations may be designed to deal only with those sources which contribute noise on lower parts of the frequency spectrum.

Where radiation from welding, other industrial, and medical equipment is concerned, industries or individuals could be assigned exclusive rights of radiation on certain frequency bands. Enforcement of their emission and admission rights could take place through an industry association, or directly by a public regulatory agency.

**SUMMARY**

Given the assumptions that signal levels do not vary and that there is no cost of enforcing radiation rights, it appears that such rights could be clearly defined in terms of output levels (power isoquants and levels of spurious emissions). It also appears that once defined and issued they would constitute a viable set of rights amenable to reconstitution, both geographically and in terms of bandwidths, through the operation of the market.
VARIABILITY OF SIGNAL LEVELS AND RIGHTS IN RADIATION

The preceding section explored the possibility of defining property rights in radiation in terms of output, rather than input, and examined the manner in which the market might reconstitute such rights. This discussion took into consideration the technological nature of radiation as it relates to the additivity of aggregate interference and examined the effect that this characteristic might have on the reconstitution of rights defined in terms of output power levels. It was assumed, however, that radiated power levels did not vary and that the cost of enforcing the rights was zero.

As a matter of fact, of course, radiation outputs are subject to variability. In addition, property rights in any resource have to be enforced if they are to be effective. These facts raise the following questions: (a) Can property rights in radiation be effective, given that radiation is variable and, specifically, is it realistic to suggest radiation rights defined in terms of output power levels when those power levels are partly determined by factors beyond the control of the right holder? (b) What are the effects of the uncertainty that results from variability on the measurement and enforcement of radiation rights defined either in terms of input parameters, as is currently done, or in terms of output power levels as has been suggested here? It is the purpose here to examine, and attempt to answer, these questions.

It may be argued, and it is probably generally believed, that radiation is so unique in nature that it cannot be allocated by the institutional arrangement -- the market -- that is relied upon to allocate the majority of the society's resources. The characteristics of radiation, it is said, are such as to require special institutional arrangements (in the form of centralized control) for its allocation. This belief is generally illustrated by such statements as the following:

It has become increasingly clear that the spectrum is public domain which must be conserved as carefully as if it were farmland, forest preserves, water power or mineral wealth. It might be added that this resource is extraordinary in
that it is both uniformly distributed and widely prevalent, not just through the Earth, but through the entire universe. However, unlike many other resources, it cannot be consumed; it can be neither publicly nor privately owned; it cannot be physically confined within jurisdictional boundaries. Yet for effective utilization, it must be skillfully managed, treasured, and delicately allocated as though it were a rare and limited mineral.*

The question immediately arises as to how centralized control either alters these unique characteristics or makes them more manageable. Certainly, centralized control of a resource is not called for simply because the resource is scarce, nor will it alter the fact that the resource is scarce. All of a society's economic resources are scarce and the institutional arrangement used to allocate them cannot alter this fact. If they were not scarce, no allocative mechanism would be required. Similarly, if a resource can be neither publicly nor privately owned, the institutional arrangement used to allocate it will not make it ownable.

Probably the main characteristics of radiation that are thought to require centralized control are its supposed unconfinability, and its (uncontrollable) variability. These two characteristics may be thought to render impossible the definition and enforcement of property rights in radiation in terms of output power levels.

**CONTINUABILITY OF RADIATION**

While the radio frequency spectrum may be geographically unconfinable, certainly radiation is, for all practical purposes, confinable. It is true that in principle a signal, once emitted, continues on and on through space. It is a fact, however, that the signal becomes undetectable at distances remote from its source.** If this were not

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**It is also a fact that the distance at which a signal becomes undetectable is influenced by the frequency used -- in general, the higher is the emitted frequency, the greater is the rate of dissipation of energy with distance.
the case, it would be unnecessary to build transmitters of ever increasing power in order to extend the range of communications or to construct space relay stations for radio signals. If radiation were not, in fact, practically confined by the principles of attenuation and the effects of the layers of the atmosphere, viewers in Los Angeles would have no difficulty in receiving direct television programs from New York or Europe.

It thus is simply not true, in any practical sense, that radiation is unconfinable. If it were confinable, centralized control and the specification of input parameters would not make it so. It is the technical characteristics of radiation that confine it geographically, not the particular institutional arrangement that is chosen for its allocation and the control of its use. Although the technical nature of a resource may influence the institutional arrangement that is chosen to effectuate the use of the resource, the choice of a particular institutional arrangement does not give one the freedom to alter the technical nature of the resource. If radiation cannot in fact be confined geographically, neither the FCC nor any other government agency, nor a market system can make it confinable so long as it is emitted.

It may, however, be argued that although this is true in the abstract, it is of only academic interest, since in practice factors such as ionospheric and meteorological conditions will affect the signal levels and thus make impossible the delineation of geographical areas with boundaries established by specified output power levels. Consequently, it is said, the individual whose rights were defined in terms of output power levels would not have control over his radiation levels since he can neither control nor predict successfully the occurrence or effect of the natural events that affect signal strengths. These facts, it is argued, would render unworkable any definition of property rights in terms of output levels since the absence of control by the right holder over his signal levels and/or the impracticality of enforcing such rights will result in an undesired amount of interference. Because of this variability it is believed that centralized allocation and the detailed specification of input parameters, together
with the specification of the uses to which radiation may be put, is required. Thus, the consensus appears to be that where problems of radiation are concerned, they are best solved by some kind of dictatorial rule by a central agency. Aside from mistaken notions about the nature of a market exchange system, that part of the justification for centralized control of radiation that relies on the technical facts of radiation is erroneous.

THE SOURCES AND NATURE OF VARIABILITY

The factors that influence the received power level of a given signal may be divided into two categories -- factors that are subject to the control of the individual emitting the signal, and those that are not subject to his control. In the first category belong such factors as the height and directivity of the transmitting antenna, the polarization of the wave, the power input at the transmitter, the frequency used, the type of modulation employed, and the general topography. The second group consists of those elements of nature that at present are not under the control of man -- ionospheric and meteorological conditions.

It is important to understand that uncontrollability by itself is not crucial. The vagaries of nature may affect the efficiency with which property rights in radiation will function, not because of the order of magnitude of their effects on attenuation of the signal levels or their uncontrollable nature, but because of the inability precisely to predict, and thus offset, their behavior over time and between geographical locations. To illustrate this point, consider three possible cases of these effects: one in which the effects are large, stable, and predictable; another in which they are large, variable, but predictable; and a third in which they are small, variable, but unpredictable.

The first situation is the simplest case and causes no problem for the definition and enforcement of rights. All it says is that a large amount of energy is dissipated in wave propagation. Although the sources are uncontrollable, their effects are constant and would introduce no variability in output.
In the second case, the signal level would vary between relatively high and low values, but the magnitudes of these changes could be predicted for a given time or geographical location. Consequently, the signal level could be stabilized by appropriate changes in those factors that are controllable such as power input. Input power could be reduced when the signal was expected to be high and reduced when it was expected to be low.

In the third case the signal level would vary with location and time and, since the effects may not be predicted, there would be no way to smooth out the resulting variability short of halting radiation completely. Analytically, it is useful to look at this variability as residual variability due to factors that are unpredictable, whether or not they are controllable. Therefore, a given variability in a signal level can be explained by first allowing for the factors that are controllable -- for example, the effect of the type of modulation used. Another portion of the variability can be explained by all the factors that are predictable, whether or not they are controllable -- for example, the effect of day-night and seasonal variation. The remainder of the variance is due to ignorance in general, whether it is the inability successfully to predict weather phenomena, or "unsolved" problems in electronics.

Therefore, in order to evaluate the effect of variability in signal levels on the efficiency with which property rights in radiation would function in a market system, one needs to consider that part of the variance of radiation output that is caused by factors whose effects, both in terms of magnitude and timing, are not predictable. Furthermore, one also needs to compare this result with the effects of these uncertainties when radiation rights are defined and used within the framework of a centralized system of allocation such as that provided by the FCC.

CENTRALIZED CONTROL AND THE EFFECT OF VARIABILITY

It seems legitimate to ask in what sense a centralized system of allocation and the specification of the input parameters of radiation solves the problem of variability of radiation output and the
interference that results. Put another way, are the undesirable effects of variability peculiar to a system of property rights defined in terms of output, or are they inherent in any system -- can the specification of input parameters, a practice that is strongly defended by experts in the field of electronics, reduce or eliminate interference that results from variability?

If a centralized system of control is superior to a set of output rights operating within the framework of a market mechanism in this respect, it has to be shown that on technical grounds the specification of input parameters either (a) reduces the variability of emitted energy compared to what would obtain if outputs were specified, or (b) that for one reason or another the variability of radiation output would not only be larger, but also more "important," if private rights of radiation were defined in terms of power isoquants and were functioning in a market exchange system than when radiation is controlled by laws that fix input parameters.*

Clearly, a centralized system, by controlling the use of radiation, can establish geographic separation of the sources of emission so as practically to eliminate interference.** For example, consider the extreme case in which there is only one source emitting on a given range of frequencies. Although no interference will occur when the signal level varies, at times the signals may not be detectable in remote areas. Now assume that the number of independent sources of emission on this frequency range is increased. Conceptually,

*Property rights in radiation, or any property rights, will function properly only within a well defined and established legal system. Therefore, the laws referred to above are not those required in order to enforce property rights, but are those that are intended to substitute for property rights in a market system.

**This, however, is not desirable if a "full" use of the spectrum is to be achieved. In addition, it is not a result that can be achieved only with centralized control, since the same result can be achieved by defining output rights in terms of power isoquants, together with restrictions on their divisibility, that will define similarly separate geographical areas.
the process of adding new geographic sources of emission on the particular frequency may continue until some interference results when the signal level fluctuates. Assuming that this is the "desired" result, no additional sources of emission on the frequency would be allowed.

Under a centralized system of allocation the permitted sources of emission would be given rights of radiation (licenses). These licenses would be defined not in terms of the level of radiation within a given geographic area, but in terms of inputs -- the location, size, and height of the transmitting antenna; the power input at the transmitter; the type of modulation to be used; the polarization of the wave; and so on. The reason such a system would work, however, is that as we have seen, each set of input specifications will result in a given power isosquant, or output. The same result could thus be achieved by specifying outputs instead of inputs. Thus, if the specification of inputs is preferred over the specification of outputs because of the variability of radiation, it must be because there is some element of asymmetry in the two systems.

In principle, one may think of three possible reasons for such an asymmetry. It is possible that the specification of inputs will result in less interference due to variability than would the specification of outputs because input specifications reduce the variability of output on technical grounds; or because the use of sound engineering principles in establishing inputs such as the mode of propagation, or the uses to which radiation may be put, will minimize the impact of variability and thus result in a more productive use of the resource; or finally, because the presence of variability in radiation output will make monitoring and policing of rights defined in terms of output very costly as a practical matter -- the enforcement of output rights in a market exchange system would give a less satisfactory result ("too much" interference) than would a system of central regulation of the uses to which radiation may be put, together with detailed specifications of input parameters.
Reduction in Variability on Technical Grounds

The specification of input parameters which are both controllable and predictable in no way changes the effects of the natural phenomena which are, as we noted before, the cause of variability of output. Therefore, to assert that on technical grounds the variability of signal levels can be reduced by specifying inputs is to assert that such specifications increase the ability to control factors that are uncontrollable or that it increases knowledge of how to predict their effects on signal levels. Clearly, however, it cannot be assumed that specifying those parameters whose effects are predictable will result in this added knowledge or ability.

Consequently, the situation is symmetrical in the sense that a particular output can be identified with inputs. This is simply to say that there exists a radiation relationship that is based on the technical information provided by the science of electronics and that is able to define the resultant output on one side of the relationship when the inputs on the other side are changed. It is, of course, perfectly true that there are variables whose effect is not predictable with the available knowledge. This, however, simply means that for a given combination of input parameters of radiation one cannot specify with certainty a single level of output that will obtain at all times. One can, however, specify a range of outputs with as high a probability as one chooses. Conversely, one can state with a certain probability whether a particular set of inputs is consistent with a range of outputs.

To deny this is to argue that there exists no electronic principles in the relationship between input and output in radiation. In the absence of such principles, any discussion of rights in radiation either defined in terms of output or in terms of any kind of regulation is meaningless. If the resultant output levels cannot be predicted in principle, then no amount of specification of inputs will enable us to know the resulting signal strengths, or to solve any related problem, including that of reducing the amount of interference. It is clear that this reason for any asymmetry between
rights defined in terms of outputs and those defined in terms of inputs cannot, in principle, be accepted. In addition, it is not consistent with the real world where, in fact, one can infer from the results of radiation an underlying relationship which is systematic and relatively stable.

There is, thus, no basis for presuming that centralized control and the specification of inputs will reduce the variability of radiation that is due to factors that are uncontrollable and unpredictable. Consequently, if centralized control is still preferred, it is necessary to demonstrate that it will bring about a reduction in the amount of interference, not by controlling variability, but by regulating the use of radiation rights so as to minimize the effect of variability.

Minimizing the Effect of Variability

It may be argued that it is necessary to specify the uses to which radiation may be put and the type of equipment to be used in order to insure an efficient use of the spectrum because of the varying degrees of "protection" that is required by different services and/or systems of radiation.

It is true that the relative signal to noise power that is required for a particular quality of reception will depend upon whether the intelligence is in the form of voice or code, as well as upon the type of noise that is present. Therefore, it is said, admission rights that refuse others the right to radiate in excess of a certain level of power will force a greater separation of emission sources providing the same service, and still farther geographical separation of sources providing different services but operating on the same range of frequencies, than would the specification of inputs. Using engineering principles, it is said, the parameters of radiation (including the kind of service and the type of equipment to be used) can be specified such that the distribution of use over the spectrum and over geographical locations will result in maximum utilization of the resource. Consider, for example, the case of pulsed and continuous wave systems of radiation:
The distinguishing characteristics of a pulsed system of radiation is that the signal level is discontinuous, and produces a greater variation in the amplitude of signal strength than does a CW system. Therefore, the potential level of interference of two geographically separate transmitters of equal power input, operating over the same frequency range, will depend upon whether both use CW, one uses CW and the other pulsed, or both use the pulsed system. If interference is not to occur at all -- time-wise -- then the two transmitters have to be separated farther when one uses CW and the other pulsed than when both use the same system, whether CW or pulsed. This is true because when one transmitter uses CW and the other uses a pulsed system the maximum effective radiated power of the pulsed system must be below the signal level of the other. If both transmitters use the pulsed system, it is possible to synchronize their operations so that when one has its maximum effective radiated power, the other has its minimum level of power -- blanks out. Both may then use the same maximum power.

The above argument raises two important facts: First, the optimal amount of noise or interference that is present in a geographical area will depend on the type of service for which the rights are used. Second, there are alternative uses for rights of radiation, and alternative ways in which they can be provided.

It is true that if there were only one way to produce a given output with a resource, and only one kind and amount of output for which the resource could be used, there would be no problem since no decisions would have to be made. The fact is, however, that where radiation is concerned, there are not only numerous alternative services in which the rights of radiation can be used, there are also various ways in which a given output can be produced. The most economical solution as to what should be produced and how it should be produced neither implies the absence of interference nor that the "proper" amount of interference can be objectively evaluated by engineering principles. The correct criterion for the use of resources is to maximize the value of the outputs the resource is used to produce. Where radiation is concerned this would be achieved
when the amount of interference is optimum in the sense that a change in it would reduce the value of some rights more than it raised the value of others, and the pattern of use is such that a change would reduce the value of one use more than it raised the value of another.

In the previous section the sense in which the level of aggregate interference was an optimal amount was discussed, the various ways in which rights might be rearranged were analyzed, and the existence of a mechanism by which the level of aggregate interference might be changed was demonstrated. Of course, the science of electronics will provide the technical information concerning the production possibilities of different kinds of services, and the variety of ways that each can be provided. However, the kinds of services actually to produce and the particular resource combination to use in their production rests on economic principles. For example, what principle in electronics might one use to decide whether a particular frequency band should be used for FM radio or television broadcasting, or how much of each kind of service should be provided in a community?*

*For example, consider the "usefulness" of a newly developed modulation technique (SSB FM) as seen from a technological viewpoint, in conjunction with the present system of allocation. With this modulation technique, "the resulting modulated signal will have a one-sided spectrum about the carrier frequency and be compatible with existing FM receivers. The advantage is a decrease in signal bandwidth; the disadvantage, the loss of a constant transmitter output level." (Edward Bedrosian, "The Analytic Signal Representation of Modulated Waveforms," The RAND Corporation, RM-3080-1-PR, September 1962, p. 18.) Although the possible "usefulness" of the new modulation technique in "crowded" frequencies is recognized, it is stated that, "From a practical viewpoint, this form of FM may find little acceptance in wide-band systems, not only because of the unfavorable peak-to-average power ratio required of the transmitter, but also because of the lack of any particular pressure to conserve the radio spectrum at present in services such as broadcast FM or specialized military and civilian communication systems." (Ibid., pp. 18-19.)

The "lack of any particular pressure" reflects, if anything, the result of the system of regulation which has been in force for some time. Clearly, the regulation of the use of a resource may result in an otherwise valuable resource having a negative value. Note, for example, the so-called VHF and UHF problem where TV licenses
More specifically, one might ask why the pattern of use in the case of CW and pulsed systems of radiation would be different depending upon whether the rights of radiation were defined in terms of are given back to the FCC because of their unprofitability. If TV licenses had been issued on UHF frequencies first (for the same geographies covered by the VHF licenses), the opposite would have occurred -- the VHF licenses would have been found unprofitable on the average. This is the result of the allocation of the resource by regulation, even though the engineering criterion alone finds little difference, if any, in the suitability of UHF and VHF frequencies for TV broadcasting. If anything, engineering criteria favor UHF for this purpose.

The assessment of the value of the new modulating technique, or the value of the reduction of bandwidth based on the general negative relationship between power and the width of the frequency band, based on the lack of "pressure to conserve the radio spectrum at present" is erroneous on two counts: (1) Even if there were no "pressures" to conserve frequency in a particular portion of the spectrum, it does not follow that the value of the resource is uniformly low for all possible uses since, for example, there is no technical reason not to use the FM band for TV broadcasting. It is not likely that the "pressures" existing in the present system of allocation will appropriately reflect the value of the resource in alternative uses, especially when these uses are restricted by law. (2) The conclusion that there is a lack of pressure on the FM band seems inconsistent with the FCC's recent thoughts of reducing the power inputs of metropolitan FM stations so that surrounding smaller communities may have their own local FM stations. (It should be mentioned that such pressures are apt to be more appropriately reflected when stated in terms of the price than an individual is willing to pay for a set of radiation rights, rather than in terms of the amount of the spectrum that he is willing to take at essentially a zero price.)

The "need" for more stations can be provided for by redistributing the given pie geographically. Alternatively, it can be satisfied by "conserving radio frequency" in the FM band either by simultaneously decreasing the bandwidth and increasing the power inputs of FM stations generally, or by the use of the new technique of SSB FM. In both cases, the conserved part of the frequencies may be licensed to local or other communities. (Note that if SSB FM is used, the existing FM receivers are not affected since SSB FM was found to be compatible with them.) Therefore, not only are the pressures underlying the recent move for changes in input powers pressures to conserve the spectrum, the current way of solving the problem is in direction the reverse of the one suggested by the technological trade-offs possible between bandwidth and power. In fact, this method is conducive to "wasting" rather than conserving the spectrum.
output patterns and a market system, or in terms of sound engineering principles and a centralized system of allocation. Assume, for example, that two individuals, A and B, hold rights of radiation defined in terms of power isoquants on a particular frequency band in two adjacent geographical areas. Assume that individual A is using CW and B is using the pulsed system of radiation. As indicated above, the use of two different transmitting systems will force a greater geographical separation of the transmitters than if both used the same transmitting system. This means, in effect, that the same quality of services(s) could be supplied over a larger area if both A and B used the same system of radiation.

Now, if this is desirable -- if enlarging the area of coverage adds more to the value of the service(s) than it adds to the cost of providing them -- then both A and B can increase the value of their rights of radiation by using the same system of radiation. Consequently, both A and B will have incentive to reconstitute their rights.

For example, A may offer to pay B a sum of money in order to exceed his (A's) emission rights in a particular way. He may agree to use the pulsed system of radiation in such fashion that his emitted energy in B's area is greater than before, but timed so that his maximum effective radiated power occurs when B's signal strength is at its minimum level. Alternatively, they may agree that each may increase his power level, timing the pulses so that the peaks of one coincide with the blanks of the other.

Thus, the utilization of engineering principles and available technical alternatives does not necessarily require that they be forced on the users by a regulatory body such as the FCC. Rights of radiation defined in terms of output and allocated by a market system would result in the utilization of available techniques if they promise to result in an increase in the value of individual rights and, thus, in the total value of the output produced with the resource.

There is, of course, no reason to believe that a system in which rights of radiation are defined in terms of outputs and allocated
by a market mechanism will require less technical information than a centralized system. On the contrary, one might expect that the value of such information will be more readily realized, and applied, under a market system than under a centralized system. This follows because under a market system the increase in value of the rights that arises from the use of new or more efficient techniques benefits the individual right holder. Clearly, this kind of direct relationship between the returns to the right holder and the application of technical information, instead of being a hindrance, will be conducive to inventive activity.

Variability and the Cost of Monitoring

It thus appears that there are no obvious reasons for preferring detailed input specifications and a centralized system of allocation to a system in which rights are defined in terms of output and allocated by a market mechanism on the grounds that a centralized system will either reduce, or minimize the effects of, variability in output levels. This conclusion, however, is conditional upon the manner in which the monitoring and enforcing of rights defined in terms of output is affected by the fact of variability in signal strengths. Questions can be raised as to the effectiveness of property rights in radiation in the face of variability of radiation output, the resulting practical considerations involved in enforcing such rights, and the necessity for monitoring and measuring radiation outputs. Along these lines it will be useful first to discuss the need for monitoring in general, and the problems associated with the measurement of radiation output in particular.

General Necessity to Monitor

Rights in electromagnetic radiation, as with rights in any resource, can have operational meaning only if the state will enforce them, however they are defined, against others. This enforcement involves "measurement" -- the identification of cases in which rights are exceeded. The question arises as to whether the enforcement of rights in radiation defined in terms of output would require widely
different (and more costly) techniques of detection, measurement, and enforcement than if rights are defined in terms of input specifications.

Consider, for example, the enforcement of rights in radiation as they are currently defined by the particular specification of inputs in a license. A violation of these rights would occur if a licensee is found to be operating not in accordance with the specifications of his license. Therefore, in order to enforce these rights it is necessary ultimately to check the actual inputs of the licensee for the purpose of comparing them to the allowable inputs. However, the necessity to check a licensee's inputs may initially be determined by monitoring his outputs. Such monitoring may take the form of recording emitted frequencies and radiated power levels.

Such general monitoring will provide information concerning not only those licensed sources who seem to be operating in excess of their licenses, but also will identify non-licensed sources of emission. In addition to the fact that monitoring outputs is necessary to provide information concerning non-licensed sources of emission, a task that cannot be accomplished by investigating the specifications of licensed sources, its use may be justified on economic grounds where licensed sources themselves are concerned. It may cost less initially to obtain information concerning possible violations by licensed sources by monitoring outputs and then checking input specifications, than to investigate continuously or in some random fashion the input parameters specified in the licenses. It is also clear that the ultimate reason for monitoring is to enforce the rights of radiation and that the need for it does not depend on the particular fashion in which the rights themselves are defined. Monitoring is required under the present institutional arrangement, and it would also be required under a system of rights defined in terms of output in order to weed out radiation by sources who are exceeding their rights.

*In addition to providing information that may result in checking input specifications, monitoring outputs may also serve two
One might, however, argue that the purpose for which radiation output is measured is conditioned by the particular way the rights of radiation are defined. It may be believed that if rights of radiation were to be defined in output levels the measurement of radiation output would take on a different role than it does under the current system. This, however, does not necessarily follow. If the situation is symmetrical, the monitoring process described above in the enforcement of input specifications is reversible and would also apply to rights defined in terms of outputs. Consider, for example, two hypothetical situations:

1. The FCC is aware of the existence of variability in signal strengths and has decided that the public interest requires licenses to be issued such that in not more than 5 per cent of the time should the signal strength of an emitting source exceed some particular power level within another adjoining area. Stated another way, the probability of the signal strength exceeding a certain level of power should be equal to or less than .05 (the probability of the signal strength being less than the specified amount should be equal to or greater than .95). Licenses then are issued specifying in detail the inputs that are consistent with this goal. A monitoring station, located at the boundary between the geographical areas in question will record radiation output and emitted frequencies. No problem of identifying violations of the licenses exists so long as the recorded signal strengths are less than the specified level. However, if a signal strength exceeds the prespecified level, uncertainty sets in -- does the incident represent a case included in the (allowable) 5 per cent? Clearly, one would not expect the monitoring authority to take action based on a single occurrence.

additional purposes. On the one hand, data on signal strengths may be collected for scientific investigations such as those of the National Bureau of Standards in conducting experiments to obtain data on signal strengths and their variability. On the other hand, monitoring may assist in determining the resultant radiation of certain types of equipment or devices. For example, the inferred effects of filtering devices at the transmitting antenna may differ from that actually observed at some distance from the antenna.
Although one may construct rules of statistical decisionmaking as to when to take action, for our immediate purpose all that is necessary is to assume that "enough" such incidents occur to give rise to the suspicion that some investigation is desirable. What the monitoring agent must do in order to determine if a violation has occurred is to investigate the input mix at the transmitting antenna. No violation of the conditions of the license has occurred if the transmission has been obtained by adherence to the exact specifications of the parameters contained in the license.

2. Suppose now we take the licenses existing under the situation described above and redefine them in terms of output power levels. That is, for each set of specifications contained in a license we find the critical power isoquant that is not exceeded more than 5 per cent of the time. Then, new licenses are issued which define the rights of radiation on a certain range of frequencies in terms only of the particular output power levels so derived. How would these rights be monitored and enforced?

The monitoring station again will record emitted frequencies and power levels. As in the above case, when the signal strength of an emitting source exceeds the critical level, a decision has to be made as to whether to regard the occurrence as an indication of a possible violation, or to attribute it to cases allowed for by the specifications of the 5 per cent probability. Once again, an investigation of the inputs at the transmitting antenna may be used to infer whether the excessive radiation is due to uncontrollable factors allowed for by the provision of the 5 per cent, or whether it is due to the use of a set of inputs that result in the radiation of energy in excess of the specified level more than 5 per cent of the time. While the former situation would not constitute a violation of someone else's rights of radiation, the latter would.

These two cases bring out the main issue involved. In the first situation, with radiation rights defined in terms of inputs, the existence of a violation is finally decided by determining whether the actual inputs employed diverge from those specified in
the license. The measurement of radiation output, however, provides the information which leads to such determination. In contrast, in the second situation, with rights defined in terms of outputs, the existence of a violation is decided upon on the basis of the level of radiated power, but the evidence of such a violation may be the result of an investigation of the input combination at the source of the emission.

Put another way, in the first case measured output levels can initially be used to infer inputs, with the actual inputs subsequently being checked. In the second case, the input mix can first be used to infer the output level, with the actual output level subsequently being measured. In this sense the two situations are symmetrical. So long as the results are based on technical information that is provided by the field of electronics, an input mix can be specified that is consistent with a given range of outputs. It should, thus, be equally possible to specify a distribution of power levels for a given set of inputs since both use the same technical information. Consequently, the degree of success or failure is the same in both situations.

It thus appears that not only is the necessity for monitoring largely independent of the manner in which rights of radiation are defined, but also that the measurement of radiation output is not the necessary requirement for determining violations of, or enforcing, rights that are defined in output levels.* Any right holder who wishes to know whether the variation in the strength of the signals emitted into his area is due to factors beyond control, or constitute

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*The amount of monitoring service used may differ under the two systems of rights. The demand for monitoring will differ because the relationship between the cost of monitoring and the resultant protection of the value of the rights will differ. Under the proposed system there will be a close relation between the costs of resources used to monitor, and the increase in the value of the rights that results from monitoring, since both the costs and the benefits will accrue to the right holder. This does not mean, however, that more resources would be "wasted" in monitoring the proposed rights, because for the monitoring to take place the resulting reduction in interference (and increase in value) would have to be at least as great as the costs involved.
a violation of his rights, simply has to have a check made on the input mix of the other party.

It may, of course, be argued that while this is true in principle, practical considerations of measurement and definition may make the enforcement of output rights less feasible than the enforcement of rights defined in terms of inputs, and thus call for centralized allocation and input specifications. The question may be raised, for example, as to whether it is possible at all times to know the exact use of inputs, especially those whose rate of use can be varied rapidly and with ease (such as power consumption). The use of inputs can be, and as a matter of fact is to some extent, recorded continuously in a manner similar to the way in which meters record the private consumption of gas and electricity. Note, however, that the working of rights in radiation, no matter how defined, does not depend on whether inputs actually can be recorded. Even if there were inputs whose use could not be recorded, unannounced checks could be made on their use such that the probability of finding a possible violation would be maximized. Alternatively, signal levels can be recorded for some time period and from the pattern of variability portrayed by the observations inference can be made as to whether the inputs used are consistent with the power isocount specifications defining the rights of radiation.

Questions may also be raised as to the type of data that is required, and the feasibility of obtaining such data, in order to obtain the probabilities to be assigned to a particular power isoquant used in defining radiation rights in terms of output.

In principle, for a given set of input parameters of radiation, a signal strength may be defined by assigning certain "values" to the uncontrollable factors that give rise to variability. Therefore, with no change in the parameters, the actual level of radiation output will vary over time depending on changes in the extent to which these variables affect radiation. The information needed to assign probabilities to output levels is the relative occurrence of these events with respect to the magnitude of their effects. In the absence of additional knowledge about these factors, the required information
may be obtained by measuring radiation output over time. From these observations one can compute the percentage of time that certain power levels are exceeded. The appropriateness of these percentages in defining the rights of radiation in terms of outputs will depend on two considerations: (a) the length of the period during which the measurements were made, and (b) the relationship between the uncontrollable factors and the frequency used.

a. The length of the period of measurement. The required length of the period of measurement will depend on the behavior of the uncontrollable factors in relation to time. That is, is there a variability of signal strength within the day but not between the days; is there a distinct difference in the effects between the months of the year; or are there seasonal or yearly effects? If the pattern of variability is the same for every day and does not depend on the season or the year, then measurements taken during any one day are sufficient for stating unequivocally the probabilities with which a certain power isosquant will be exceeded.

If seasonal and yearly effects are present, the measurement of radiation output obtained during an appropriate number of years may be used to obtain the probabilities to be assigned. (If the magnitude of these, or other, effects were known separately -- if difference between night and day, seasons, and years were known -- it would be equally appropriate to define output rights on the basis of observations of daily signal strength variations, and expect the individual right holder to make adjustments in inputs to compensate for the other known effects.)

b. The relationship between the uncontrollable factors and the frequency used. In addition to the attenuation of signal strength that is due to energy spreading out into space, signal strength also attenuates because of factors such as ionospheric, meteorological, and topographical conditions, the effects of which vary depending upon the mode of propagation. Ionospheric conditions are affected by several factors which vary during the day, the season of the year, and over the years. Consequently, variability of signal strengths is "large" for frequencies using ionospheric propagation compared to
other modes of propagation. This has come generally to be known as the "high frequency" problem, with the frequencies between roughly 1 and 30 megacycles being subject to the greatest amount of variation, primarily because they are propagated by means of the ionosphere.*

Since different frequencies are affected to different degrees by the uncontrollable factors that give rise to variability, observations made on one range of frequencies might not apply to another range of frequencies. Observations might thus be called for on several ranges of frequencies in order to discover the relationships and to establish the probabilities associated with power isoquants. **

(It might be asked why boundaries could not be specified simply on the basis of signal levels determined only by the spreading principle, without resort to the necessity of establishing probabilities associated with variability. This would insure that these levels would only be exceeded if the input parameters were changed. Since the maximum signal level that is associated with a given input can be established exactly and easily, this would result in the desired level of interference never being exceeded, even though signal levels varied.

(a) If this definition were made effective, the resource would not be used efficiently, because for much of the time the given quality of service would be provided in a smaller area than that delineated by the maximum signal level specification.

(b) This criterion would also be ineffective if the input combinations were left to the discretion of the right holder, since from the beginning changes in the input parameters would take place to compensate for the loss of energy that is known to occur due to the factors that also make for variability. Once these changes took place, however, we would have completed a full circle and we would

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*The high frequencies are not bound solely to ionospheric propagation, however, as witness the propagation of frequencies from .5 to 1.6 megacycles by AM radio stations.

**Empirical observations on all frequencies would not be necessary in order to establish these probabilities for a frequency, since observations on the particular frequency would suffice.
be faced with the same question with which we started: "What is the content of the rights and, specifically, when variability of the signal level is observed, is it due to the uncontrollable factors, or is it due to deliberate violation?"

It might, of course, be argued that as the right holders engage in contracts for reconstituting their rights, a set of property rights will emerge over time. Although there is merit to this, it imposes costs of negotiation in the process of defining rights, and the efficiency with which they may be utilized through a market system is not assessable in advance. It seems important, therefore, to gather empirical data on the behavior of radiation output and to assess the manner in which such data could be used to define radiation rights, as well as to discover the effects of this behavior on the viability of rights defined both in terms of inputs and in terms of output.)

The Uses of Such Empirical Data

The uses to which such empirical data could be put are obvious. We have seen that a maximum signal level, or a minimum signal loss, for various input-mixes of radiation can be specified for different distances.* The extent and the pattern of the effects of the factors which give rise to variability in signal levels, and to the additional losses of power, depends on the mode of propagation. If the magnitudes and timing of these factors could be predicted precisely, a set of experiments to determine the additional loss of energy caused by different magnitudes of these variables would provide the information

necessary virtually to eliminate the variability of the signal level by appropriate adjustments of the input parameters.

One general approach to the reduction of variability would be relatively to reduce the power of transmission for the hours of the day, months of the year, and the years of the sunspot cycle when the signal loss is smaller than during periods in which the signal loss is larger. This does not mean that one could specify with certainty a given signal level at a given time and distance, but that the variability of the signal level could be reduced by relatively increasing the power of transmission during periods when the signal loss is known to be relatively great.

Another way in which the variability of the signal level could be reduced would be to change the angle of incidence and/or the power of transmission as the height and the density of the ionospheric layers change over time. Specific information about the height and the density of these layers is currently obtained by sending the so-called r-f pulses vertically into the atmosphere and then receiving the reflected pulses. The echo time indicates the height of the ionospheric layer, and the strength of the received pulse indicates the thickness of the layer. This type of information would complement the general relationships between signal strengths and time periods and would make possible more refined relative changes in the power of transmission. It would also provide the opportunity for changing the incident angle so that a greater proportion of the waves are returned within the desired geographical area, resulting in less variability of the signal level at a given distance.

Finally, receivers could be located at the boundaries of the areas of radiation to measure the signal strength as a means of providing additional information. The received level of signals could be used as a check on the particular rearrangements of the input parameters which were chosen as a result of the relationships between signal strengths and time periods, supplemented by current data on the height and density of the ionospheric layers.

It is not possible to say which of these three approaches, or what combination of them, would in fact be used. This would clearly
depend on the costs of making such changes and the value of the resulting reduction in the variability of the signal level. It is, however, technically possible that the observed variability of the signal level can be reduced by appropriate adjustments of the input parameters of radiation.*

The Impact of Variability on the Reconstitution of Rights

In general, rights of radiation will involve some element of uncertainty.** The degree of this uncertainty will vary depending upon location, frequency used, and the mode of propagation. As with any resource, contracts involving frequency rights in general would allow for these uncertainties, and the existence of such uncertainties would affect the value of such rights. The uncertainties associated with the rights of radiation will be greater for frequencies between 2 through 30 megacycles and the ionospheric mode of propagation. Irrespective of the frequency used, uncertainty will be greater for ionospheric propagation than for ground wave propagation. Finally, for ground wave propagation more uncertainty will be associated with the high frequency range than with higher frequencies.

It is clear that one need not worry about the general applicability of rights defined in terms of output if it could be shown not only that they are appropriate for the HF range of frequencies and the ionospheric

*It would not be necessary for rights holders to obtain the information about the height and density of the layers, and the recorded signal level on an individual basis. This type of information for a geographical location could be supplied either by a central agency, either public or private, or the monitoring services required for the enforcement of the rights could include the provision of this kind of information in a manner similar to that in which weather information is made available by a central agency.

**It is important to bear in mind that radiation rights defined in terms of output and operating within a market mechanism could function on some frequency bandwidths, while at the same time centralized allocation and control was used for the high frequency bands, if it were believed that the variability associated with these bands are output rights impracticable for them.
mode of propagation, but that they also would yield better results (judged by the criterion of economic efficiency) than central allocation and the specification of fixed inputs. In other words, if output rights would "work" for the HF range and ionospheric propagation, they would "work" for other frequencies and other methods of propagation.

In the preceding section the viability of radiation rights defined in output terms and the efficiency with which these rights could be reconstituted was examined on the assumption of an absence of variability. The presence of variability means that not only must the level of the power isoquant that is not exceeded more than some percentage of the time be considered, but that the whole set of power isoquants which are not exceeded with different probabilities need to be considered. The optimal level of aggregate interference would not be defined by one parameter only (the particular power isoquant) but would also depend on the variance of the signal level. Stated differently, the optimal interference in an area will be some function of power isoquants weighted by their corresponding probabilities.

To illustrate the effect of variability on reconstitution, consider one of the several cases discussed in the preceding section. Assume, for example, that right holder A in figure (3) decides that the level of interference present in his area is less than the optimum amount when B exercises his emission rights, a specified power level which is not exceeded more than 5 per cent of the time. A could enter into an agreement with B to allow him to increase his emitted energy such that the power level at the old boundary is now exceeded no more than 10 per cent of the time. Of course, similar to the previous cases, A must either make arrangements with other rights holders, or readjust his pattern of emission so as to compensate for the increased emission by B in order not to violate the admission rights of other individuals in the adjoining areas.

Analytically, a similar situation arises if B were to change from ionospheric to ground wave propagation. Without exceeding the specified power isoquant, since the variance of the signal level is smaller with the latter mode of propagation, the weighted average of the
different isoquants emitted into A's area is larger now than before. A will attempt to rearrange his rights as a result, if the level of interference were optimal before B's change in the mode or propagation, he may pay B to return to ionospheric propagation, or arrange with other rights holders to reduce the level of interference.

It is reasonable to expect that the introduction of uncertainty due to variability of signal levels will make the finer rearrangements of rights less economical than would be the case in which signal levels did not vary. The basic reason is that variability makes for the inability to use rights within a delineated area fully and uniformly.

This situation is obviously less than ideal. But this is neither surprising nor relevant. The uncertainty introduced by variability is a fact, present under any system of allocation. The question may thus be raised as to why the existence of variability would favor an allocative scheme which relies on regulation and the use of licenses containing detailed specifications of the input parameters of radiation over one that relies on output specifications and the use of a market system.

It should be obvious that the variance of the signal level will be at a maximum when constant input mixes are used, as in the case of FCC licensing.*

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*To the best of our knowledge, the only relevant exception to the general rule that FCC licenses fix inputs exists in those broadcasting licenses where some stations cease operating during a certain time in the evening and others continue broadcasting, sometimes with an increased power of transmission. The cases in which license holders, especially those for long distance communication, are licensed to emit more than one frequency are not exceptions to the general rule. The reason for permitting multiple frequency utilization is not to reduce variability, but to recognize the existence of it and, by providing multiple frequencies to be emitted separately at different times, to assure continuous communications.

The night and day variation in signal levels is one of several relationships that are known theoretically. The adjustment of inputs allowed by the FCC (such as those above) includes those for reducing the night and day differences in signal levels. The results obtained under the FCC may easily be duplicated under a system of output rights where the use of inputs is left to the discretion of the
However, the variance of the signal level can be reduced by appropriate changes in the input parameters, although the size of this reduction is not known. Consequently, a situation in which the particular combination, and the rates of use, of inputs are left to the discretion of the right holders (constrained by a specified output power level) would appear to result in a reduction of variability compared to a system of rigid input specifications.

It would thus appear that a system of output rights, even under conditions of uncertainty due to variability, is viable and is capable of being reconstituted efficiently by a market mechanism. One final argument may be advanced, however, in favor of centralized allocation. This involves the practical considerations of the cost of enforcing rights -- that it is more costly to enforce rights in which inputs can be varied at the will of the right holder.

Cost of Enforcement

It may be argued that the variability of signal levels, together with the inability precisely to predict the signal level at a given time and location, will be conducive to the practice of rights holders exceeding their specified isoquants and, when questioned, blaming the result on the "uncontrollable" factors. The legal and administrative costs in the case of disputes may act as a deterrent to enforcement and make this tendency a generally worthwhile enterprise, thus giving poorer results than a system of regulation by licenses.

Assume, for example, that the distribution of output power levels of a given input mix at a distance is obtained from empirical measurement during an "appropriate" period of time, say a year, and that the yearly differences are known.* Assume that the output rights of radiation are defined by the value of the power level which is not

right holder. There is no reason, however, to believe that the adjustments allowed by the FCC are the only, or the most advantageous, solutions. Depending on the relative costs and benefits of the different rearrangements, both stations may choose to continue broadcasting at night be reducing their power of transmission relative to that employed during the daytime.

*The sunspot numbers are predicted three months in advance and published by the National Bureau of Standards in CRPL "D" Series.
exceeded more than 5 per cent of the time.* Suppose now that a
right holder emits a signal that exceeds this level. Is it necessary
to wait, for example, for a year before a decision can be made as to
whether this particular incident is due to uncontrollable factors
which have been included in the probability attached to the power
isoquant, or whether it constitutes a violation?

The crucial question is how to distinguish, in the face of
variability of signal levels, between the cases attributable to the
uncontrollable factors and deliberate violations. The deliberate
violations may take two forms: (1) the input parameters of radia-
tion are not adjusted but are such that the emitted power is generally
higher than that specified by the rights of radiation -- inputs are
not reduced to allow for increases in signal strength due to vari-
bility. (2) the power of transmission and/or the angle of incidence
is varied so as to reduce variability, but generally in a way too
over-compensate for the effect of the given values of the uncontrol-
lable factors.

The detection of a violation of the first type is rather simple.
All that is required is to determine by the use of known relation-
ships between output and various combinations of inputs whether the
particular input mix being employed is equivalent to the radiation
parameters underlying the cumulative signal level empirically derived.
The detection of a violation of the second type is more complicated
and requires a comparison of the pattern of variability of the signal
actually observed with the extent of the changes in the parameters
that would be dictated by the known values of the uncontrollable
factors.

Suppose, based on a week's measurement of radiated energy, that
it was desirable to determine whether the observed distribution of

*If the recorded measurements are hourly medians, then the cumu-
late distribution should be adjusted for the variance of the signal
level within the hour. It has been found in various empirical studies
that signal level within the hour can be approximated by Rayleigh
distribution and its variance can be estimated fairly accurately. See
J. W. Cock, W. M. Beery, and H. P. Petric, "Experimental Studies of
Fading and Phase Characteristics of High-Frequency CW Signals Propa-
gated through Auroral Regions," NBS Report 5761.
the signal strength is consistent with the defined rights of radiation. Assume that only two pieces of information are available -- the height of the layers and a relationship showing the magnitudes of the changes in the power of transmission over the hours of the day. The changes in the angle of incidence that are required to maintain a given output as the height of the layers changes may be determined by a simple geometrical relationship. The actual angle of incidence and the power of transmission that have been used at a given time may be recorded by mechanical devices within the scope of today's technology. Presumably, the signal level will vary after the required adjustments have been made. This may either be because of the imperfection of the relationship that is used to decide on the relative magnitudes of the power changes, or because there are other unknown factors (or factors not adjusted for) which contribute to signal variability.

It can be determined by investigation whether the actual angle of incidence and power are equivalent to those dictated by the available information (from electronic principles and empirical studies) about the height of the layers and the extent and direction of signal changes over the hours of the day. No violation has occurred if no discrepancy is found in the actual and expected inputs. The excessive radiated power may be considered to belong to those cases provided for by the 5 per cent proviso in the rights of radiation.*

*The existence of discrepancies between actual inputs and expected inputs cannot be justified by the imperfections of the knowledge concerning the relationship between the hours of the day and the corresponding changes in signal strength. First, if the difference between the changes actually made and those expected to be made is because the right holder possesses a more accurate knowledge of the relationship, then clearly the variance of his signal level should have been reduced without necessarily exceeding the power level specification. Second, the claim for superior knowledge can be tested by comparing the resulting variance of the signal level with that obtained when the expected relationship is used. If this requires more observations, one might suggest that the right holder be asked to perform with somewhat lower levels of transmitting power in the meantime.

Finally, the factors which give rise to a relatively stronger signal level can be expected to have similar effects on the signal
There thus does not seem to be any particular problem in distinguishing between willful violations and the results of the vagaries of nature. Nor is there any strong reason to believe that the costs of monitoring services will be so high as to change this conclusion. This is particularly true when a continuous recording of signal level is not required, but may only be done upon the request of a right holder who believes his rights are being infringed. This information, coupled with the investigation of the inputs actually used, will provide the necessary data for determining violations.

General characteristics of the monitoring service. While it is not now possible to specify the particular technical details of a monitoring service, the general nature of such a service can be indicated. It might incorporate the following:

(a) It would probably consist of several stations scattered over the United States with each station providing services for a particular geographic region.

(b) Each station could be equipped with devices to measure and record signal levels and emitted frequencies.

(c) Each station could be supplied with statistical control charts which may be used to determine whether a particular signal should be recorded for future use in deciding on possible violations. The details of these charts would depend on the type of information available, and the power level specifications of the rights in the particular area.

(d) Right holders in general could be required to employ devices to record continuously their exact input utilization -- power of transmission, angle of incidence, and general devices for the purpose of controlling spurious emissions.

(e) The monitoring service would be similar in nature to the general policing services provided by other government agencies. The FCC seems particularly qualified to perform these services. There levels emitted on other frequencies within the same geographical area. Therefore, the observed signal strengths on other frequencies may provide additional independent information reinforcing the particular conclusion derived above.
is, however, no reason to provide the services free of charge.

(f) The FCC also could maintain a record of the titles to the rights of radiation, and have access to the individual right holder's records of his input utilization.

(g) The FCC might also perform an intermediary or quasi-judicial function since it would have both the technical competence and the necessary information to resolve disputes, and even to impose penalties. These decisions would, of course, be subject to review by the courts.
FURTHER CONSIDERATIONS

Additional questions may be raised concerning the workability of rights in radiation defined in terms of output and allocated by a market system. The more obvious ones concern the manner in which initially to distribute these rights; the cost of obtaining the information necessary to define such rights; and the general problems thought to exist in a system that grants freedom of use of individuals -- the effect of such freedom on reception rights, the threat of monopoly, and ethical and policy considerations.

Initial Distribution

The important point to be made in conjunction with the manner in which initially to distribute rights in radiation is that regardless of the manner in which this distribution is made initially, the market will tend to reconstitute them so that they are devoted to their most valuable uses. Consequently, the initial distribution is one to be made on grounds of expediency -- by whatever method will reconcile existing political and social pressures concerning "equity." It is desirable, of course, to distribute the rights in such fashion as to minimize the costs of instituting the system, and to minimize the costs of rearrangements after the distribution.

Perhaps as good (convenient) a way as any to define the content of the rights themselves would be to redefine the present licenses existing in the non-government sector, and the existing arrangement of use in the government sector, in terms of the outputs that result from the inputs as they are now specified. The actual combination of inputs to be used would be left to the discretion of those to whom these rights were assigned. Such rights would be transferable, in part or whole, among individuals and the uses to which they could be put would be constrained only by general law.

Alternative ways of distributing rights to individuals

There are essentially three different ways of distributing the rights, once they are defined, to specific individuals: They could be auctioned to the highest bidder; they could be distributed free
of charge, either to current holders of existing licenses or on the basis of any of numerous criteria; the spectrum could be stratified and the first technique used for part of it, the second used for the rest.

Under the latter method, strata for which different methods of distribution might be used are: (1) government versus non-government users, (2) in the non-government sector, use might be distinguished on the basis of whether it was for scientific purposes, educational purposes, by amateurs, or for commercial purposes.

It might be argued that the value of the rights would be higher when used by institutions for scientific and educational purposes than if they were to be used commercially, but that such institutions could not be expected to be able to outbid, say, the television networks for the frequencies. By the same token it may be said that amateurs have been able to render valuable services for the society but cannot be expected to obtain their frequencies in the market. Similarly, it may be argued that the government should not be expected to pay for its rights, since the agencies involved may not be able to convince Congress to appropriate the funds necessary for the purchase of these rights. As a result, it may be argued that both public and national interests would suffer if these rights had to be purchased.

There are two separate issues involved in such problems. On the one hand, there is no obvious reason to treat rights in radiation differently than those in other resources. If charitable, scientific, educational, and government institutions compete for the use of these resources there is no obvious reason to insist that they behave differently in obtaining the use of rights in radiation. On the other hand, if it is decided, for whatever reason, to subsidize such uses it can be shown that a more efficient use of resources results if the subsidy takes the form of a grant of general purchasing media -- money -- rather than being made in kind. Subsidies in general purchasing power tend to result in treating the rights as the scarce resource they are. Such subsidies will, at their worst, duplicate the results of allowing the "free" use of the resource. They will,
in addition, provide a wider choice of alternatives to the recipient and thus may result in a more valuable use of the subsidy. For example, the necessity to spend money for the use of frequencies, even if it is money received as a "gift," will stimulate a closer scrutiny of alternatives than a gift of the resource itself. It will also require the agency involved to make a stronger justification of the value of its use of the resource in order to obtain appropriations than would be the case if the resource could be had by a telephone call.

Cost of Obtaining the Information Necessary to Define Radiation Rights in Terms of Outputs

It may be argued that the cost of obtaining the information necessary to define output rights -- the cost of adopting such rights -- might be substantial. The question then arises as to whether the advantages of such rights are worth the cost. It must be remembered that these costs would be transitional costs and would be incurred only once. Any advantages accruing from the system, however, would accrue over an infinite time period. It must also be realized that there is already in existence a great deal of information of the type required so that the cost of obtaining additional information might be minor. Finally, a substantial part of these costs may not even be considered as the cost of instituting output rights since much of this information appears currently to be required for the operation of the present allocative scheme under the FCC and its counterpart, the IRAC. For example, the Department of Defense, as part of a general program for coping with the problem of interference, has instituted the Electronic Compatibility Analysis Center at Annapolis, Maryland. At a cost of several million dollars per year, the Center since 1961 has been obtaining spectrum signatures, power of transmission, location, and the time of operation of all the relevant equipment radiating in the United States.

Finally, there is no obvious reason why court costs involved in enforcing radiation rights should be any greater than those associated with enforcing rights in other resources.
The Implication of Transferability and Freedom of Use of Radiation Rights

Rights of Radiation and Rights of Reception

It may be argued in the case of broadcasting that if radiation right holders were permitted to change their emitted frequency, bandwidth, and modulation methods as they saw fit, the consequent "forced obsolescence" of receivers would result in the loss of the public's investment in these sets. The value of radiation rights, however, will depend on whether people are able to receive the emitted signals and this will provide a strong incentive for the radiation right holders, acting in their own interest, to "protect" public investment in receiver sets. This is essentially the same type of relationship that "protects" the public's investment in other areas. For example, it has not been deemed necessary to establish regulatory agencies in order to insure that as automobile producers change their models people will neither be frustrated by their old cars nor find themselves unable to obtain spare parts. Thus, since the value of radiation rights is closely tied to the ability of consumers to receive the service, there is little likelihood that any abrupt change would take place in the use of frequencies. Consequently, the market would protect the reception rights of the general public.

*The only way that this type of "loss" can be avoided, under any arrangement for allocating a resource, is never to allow change to take place. New techniques and improved processes always involve the obsolescence of the old, and this cannot be avoided if innovation is to take place. That the present institutional arrangement for allocating the frequency spectrum does not "protect" the public investment in receivers can be illustrated by the fact that after WWRD the frequencies used for FM radio broadcasting were changed, since it was concluded that the wrong frequencies had previously been assigned for that purpose. As a result, the existing FM receivers were rendered useless for the purpose for which the public had invested in them.

Only recently Congress enacted a law requiring that all new television sets have a receiver capacity of 83 channels. Since this increases the cost of receivers it means that the public will be forced to incur additional costs when they purchase new sets in order that they can receive (currently non-existent) UHF television stations, if and when they happen to be around one.
Along the same general lines, it might be believed that the fact that the value of radiation rights depends on their being received may render innovations in radiation that are technically feasible economically unfeasible. The idea here is that a technological "improvement" that altered the character of transmission might not be adopted because existing receivers could not receive the new transmission, thus it would not be economical to adopt it.

On strictly practical grounds this is not an argument against rights defined in terms of output since the same argument applies to rights defined in the present fashion. One might then ask which system would be most apt to bring about the adoption of such "improvements."

Under a system of input specifications and licenses there is practically no incentive on the part of a right holder to adopt new techniques since it imposes a cost on him with no offsetting increase in the value of the rights that will accrue to him. Such changes must be brought about by the licensing agency forcing them by altering the terms of the license. The central agency itself has as motivation only its sense of "duty" to carry out its mandate (as it sees it).

Under a system where increases in value accrue to the innovator himself the motivation is clear and direct -- if the increase in value exceeds the cost, he will adopt the new technique. There would, as a result, be a tendency for radiation right holders themselves to subsidize (pay part of the cost of) the alteration in receivers that was necessary. In addition, of course, the simple fact that such changes are not instantaneous -- that they take time to implement -- would work in the direction of bringing about innovation. Receiver owners would have advance notice of forthcoming improvements in radiation and would, thus, be forewarned so that the acquisition of new receivers would take into account the changes. If, of course, the innovation also improved the quality of reception, or offered a "new" service, the purchase of receivers would be worthwhile in itself.
It may also be argued that allowing radiation right holders to use their rights as they wish will result in certain types of services -- say, T.V. -- being "scattered all over the spectrum" so that the investment cost of television receivers will be prohibitive. General location theory, however, indicates that "like" services tend to cluster around each other. Thus, the frequencies used for a particular kind of service will tend to cluster around each other in the spectrum because the value of the rights of radiation will be greater if used in this fashion.*

Another argument that may be raised concerns the fact that the frequency bandwidth used per frequency channel may be altered by the right holder. This possibility would make it desirable to have receivers of variable bandwidth so that as the transmitted frequency changes, the receiver can be adjusted to it. This type of receiver is currently used for shortwave reception and it is likely that broadcast receivers could include this device at nominal cost. On the whole, it is likely that purchasers generally would become more discriminating in their purchases than they are under the current system.

Erroneous Domain

It may further be argued that allowing individual right holders to do as they wish with their rights (including leaving them idle) may prevent the implementation of certain services (perhaps governmental or military) whose frequency requirements are broadband in nature. That is, if a "desirable" service requires a broad frequency range that would have to be brought about by the consolidation of separate individually owned frequencies it may be possible for an individual who owns a frequency in the "middle" of those required to hold out for a high price for this rights, or to hold up the reconstitution indefinitely.

* This need not necessarily follow under paid television arrangements since for a given set of tastes a receiver of a limited capacity might serve the purpose and, in addition, cost less than the same quality receiver of greater capacity.
This, however, is not peculiar to radiation rights, but inheres in all individually owned resources. The problem is exemplified by the eminent domain proceedings in the acquisition of land for certain types of public services. There is no reason why the same procedure could not be utilized where privately owned radiation rights are concerned if the public "need" for those rights is sufficiently urgent to warrant the use of eminent domain to abrogate the normal workings of the market. It should be clear, of course, that not all "needs" justify the use of such procedures but only those where the conditions of the problem are those which make the eminent domain procedure desirable.

Advantages of Partial Application of Transferability and Freedom of Use

It should be clear that freedom and transferability need not be universal in order to reap some of the advantages associated with them -- that some flexibility has advantages over no flexibility.

There is no reason, for example, to insist that because the system could not be implemented on an international basis, it should not be utilized nationally. Different systems may be used in different zones, but within the constraints established by these zones flexibility will give advantages.

It is true, for example, that in the case of land its use is restricted domestically by zoning laws which establish categories such as "commercial," "industrial," and "residential," and that do not allow complete freedom of use. Within these zones, however, private property rights operate through the market. The international aspects of radio frequency utilization may, in fact, result in a similar zoning for the spectrum -- it may be specified that certain frequency bands may be used only for specified services, or that certain types of services may use only specified frequency bands. This means that rights of radiation would be restricted by these zones, but within the zones the market could operate to give all the advantages of flexibility in the use of resources resulting from the ability to alter inputs and users.
For example, given the fact that the international allocation has been established, if all of the FM stations in the United States cut their bandwidths in half and increased their emission powers, the number of possible FM stations in the United States could be increased substantially. As we have seen, the quality of a received signal depends on the strength of the signal relative to the level of interference so that the increase brought about by this adjustment does not mean that the quality of reception has been reduced. This subdivision would not, of course, go on indefinitely since at some point the value of further economized bandwidth would be less than the cost of increasing power inputs to economize it. The point is that if these adjustments are allowed to take place within the United States, the market would tend to maximize the value of production within the established constraints.*

The Threat of Monopoly

Concern may be expressed over the possibility that if radiation rights are traded in the open market there will be a tendency to acquire them in such quantity as to be able to monopolize the activity. As has been pointed out elsewhere, however, the effective way to control monopoly is not to present the resource to the monopolist free of charge.** In addition, the present system of allocation may foster monopoly by the protection it affords the license holders. There is no way to affect the profitability of the existing license holders by entry into the industry unless the FCC grants new licenses.

*This is similar to a situation in which rights might be restricted not only by output levels but also by specifying the uses to which they could be put. If resources are allowed to be transferred within these constraints, the market would bring about adjustments in the combination of inputs used that would increase the value of production. Further benefits can, of course, be realized by allowing transfers between uses (zones), but the value of production can be increased by allowing some (any) mobility over what would be obtained if complete inflexibility were required.

Finally, the FCC has never been legally empowered to combat monopo-
listic tendencies even in the general area of broadcasting, which is
covered by existing antitrust laws. The literature of antitrust is
replete with incidents in which the monopoly under attack was
fostered, not prevented, by licensing techniques.

Ethically and Socially Desirable Codes of Operation -- Censorship

It may further be argued that allowing radiation rights to be
used as the owner wishes will emasculate "socially desirable"
censorship -- control over the activities of the right holders.
This argument rests on the mistaken idea that the market and any
censorship (control) are incompatible. This, of course, is incorrect.
Censorship can be, and is, brought about by limiting the rights of
private property, allowing them to be exercised within constraints
established by the political process.

One may think of two distinct principles of censorship:
(1) The enactment of legislation that reflects the choice of the
majority, either by direct vote, or by the election of representa-
tives who represent the preferences of their constituents.
(2) Empowering a minority to decide what is "good" for the majority.

If the first method is chosen, no problem arises since laws will
be enacted and, as far as the majority is concerned, the rights
holders will not be able to "get away" with undesirable conduct --
types of programs that are undesirable. If the second method is
chosen, it may be said that the FCC arrangement provides a relatively
cheap way for a legislative body to accomplish censorship. The same
goal, however, can be achieved through a market system in which the
rights of radiation are somewhat constrained. This means that there
will simply be relatively less private property in radiation than
there otherwise would be, just as there is in other resources when
the rights of their use are constrained.

A simple solution, as far as program control is concerned,
would be to incorporate a proviso in the rights of radiation them-
selves -- similar to the licenses that are issued to taxicabs where
property rights in the use of the automobile are restricted. In a similar fashion, it could also be required that those who hold rights of radiation can engage in, for example, television broadcasting, if and only if they are able to obtain a license to do so.

Such a license could specify the required time to be devoted to certain types and quality of programs. There is no obvious reason why this method is inferior to the present method. However, one might ask if it has any advantages over the present system. First, the right holder would have open to him alternative uses for his rights in addition to television, say. Secondly, all of the adjustments -- adding to or subtracting from the total resources used for the particular service, and the substitution of some resources for others in the production of a service -- would still be attainable.* Thus, the market could still allocate the resources in question within the constraints established by the licenses.

Another way to accomplish the ends sought by censorship would be simply to subsidize certain "desirable" activities, as is currently done. There is no reason, for example, why certain programs could not be encouraged by a direct subsidy. However, rather than have the subsidy take the form of a "free" grant of radiation rights with the requirement that they be used only for the specified purpose, a direct monetary subsidy could be given to right holders for the production of the desired program.

*This would be true both for licensed and unlicensed activities. Any advantage that inheres in a set of rights as here suggested must be considered as true economic costs that should be added to the present (accounting) costs of administering censorship.
SUMMARY

The purpose of this chapter has been to explore the possibility of defining private property rights in radiation in order to allow the market mechanism to allocate the frequency spectrum into its most valuable uses. In addition, it was intended to examine the extent to which such rights would be viable — how, given the technological nature of radiation, the market mechanism would operate to reconstitute such rights.

It was concluded that because of the technical relation between the input parameters of radiation and the resulting output it would be feasible to define geographic property rights in radiation in terms of output power isoquants, and bandwidth rights in terms of a level of spurious emissions not to be exceeded. These would constitute an individual's emission rights to a frequency bandwidth. His admission rights — the protection of the quality of his emitted signals — would consist of the right to refuse others admission to his geographic and bandwidth rights. These rights, so defined, would then be transferable among individuals and among uses.

In order to demonstrate the mechanism by which such rights, once assigned, would be reconstituted in a market, it was assumed that emission rights could be defined in terms of single-valued power levels — that signal levels did not vary — and that there was no cost associated with enforcing these rights. The technical characteristic of additivity of the level of aggregate interference was, however, admitted. On these assumptions, various types of transactions designed to reconstitute rights in radiation were demonstrated. It was concluded that, given the additive nature of radiation, output rights could be efficiently reconstituted by transactions between individuals both within a level of aggregate interference, and to alter the level of interference if it were non-optimal. Under these conditions, there appears to be no necessity for centralized control of the frequency spectrum in order to prevent the emergency of "chaos" in radiation, or to preserve the value of the spectrum.
The assumptions of lack of variability in outputs and zero enforcement costs were then dropped and the effects of variability and enforcement were examined.

The nature of the sources of variability was examined and it was concluded that variability is inherent in radiation, regardless of the manner in which radiation rights are defined, allocated, and enforced. It was also concluded that the specification of inputs will not eliminate, reduce, or make less important the effects of variability. As a matter of fact, it would appear that variability in output levels will be greatest when inputs are fixed since controllable inputs could be altered to offset the effects of the uncontrollable factors that result in variability, thus maintaining a more stable level of output.

It was also concluded that the basic techniques of enforcement of radiation rights are the same, whether such rights are defined in terms of output or input.

It thus appears that there is nothing so unique about the nature of radiation as to require a centralized system of control for its efficient use. Such control will, as a matter of fact, tend to result in a less efficient use of the resource than would a system in which the market allowed the value of the resource to accrue to individual owners.

Additional arguments in favor of centralized control were briefly examined and it was concluded that they do not, singly or collectively, present any particularly convincing case. Everything that is capable of being accomplished with a system of centralized control also is capable of being accomplished under a system of private property rights and a market mechanism. In fact, so long as the criterion for the use of the spectrum is the value of its output, the present situation can be improved by allowing any adjustment in the use of resources. The more freedom that is allowed in taking advantage of the possibility of technological tradeoffs, the greater the improvement. However, any freedom to make adjustments in the utilization of the resources involved would be an improvement. The rigidity of strict input specifications imposes severe restraints on the efficient use of the resources involved.
V. INTERNATIONAL FREQUENCY AFFAIRS

THE HISTORY OF INTERNATIONAL ALLOCATION AND ASSIGNMENT

The first practical application of radio was in telegraphic communications, i.e., wireless telegraphy, near the end of the 19th century. Almost immediately thereafter, this new communications technology became the subject of international regulation. Such regulation was largely occasioned not by interference problems, but by the energetic efforts of the Marconi interests to establish an international monopoly in radiotelegraphy -- a monopoly encompassing manufacture of equipment, construction and operation of stations, and the provision of operators. Headquarters for the Marconi group were in England (Marconi Wireless Telegraph Co., Ltd. was the parent company), and England was the group's chief voice in international political circles, though Italy also was its ally.

Potential suppliers in other parts of the world, as well as prospective users of radiotelegraph, took a rather dim view of the behavior of the Marconi combine. By the time Marconi and radio-telegraph had entered the picture, telegraph via land lines and submarine cables had been the subject of international regulation for something over 50 years. The long history and continuing acceptance of international telegraph agreements provided a convenient rationale for regulating radiotelegraph under similar agreements.

The first international agreement on radiotelegraph grew out of a conference held at Berlin in 1906. As a prerequisite to the use of their equipment, the Marconi Company had established a policy requiring users to accept no communications from senders who used other types of equipment -- the object, of course, being to discourage purchases of non-Marconi equipment. The main purpose of the Berlin conference was to undermine the Marconi monopoly endeavors by effecting an international agreement requiring telegraph stations to accept messages regardless of the type of equipment used by the sender.

With minor compromises, the conference succeeded in establishing the international obligation to accept messages. At the same time,
by including several provisions designed to control interference, the conference also established a basis for the whole complex structure that now attempts to govern the use of frequencies at the international level. It is from these early covenants that the International Telecommunications Union, International Telecommunications Convention, and the Radio Regulations, as we know them, have grown.

The International Telecommunications Union is a political organization, i.e., only governments of countries or territories are members. The International Telecommunications Convention signed at Geneva in 1959 and currently in effect states:

"The countries and groups of territories which become parties to the present Convention constitute the International Telecommunications Union."

The Convention sets forth the purposes, the organization, the procedures, and the general regulations agreed to by the parties who ratify it. Regulations of a more detailed and specific nature are annexed to the Convention. There are four sets of Regulations—Telegraph, Telephone, Radio, and Additional Radio.

The purposes of the International Telecommunications Union are covered in Article 4 of the Convention.

1. The purposes of the Union are:

(a) to maintain and extend international co-operation for the improvement and rational use of telecommunication of all kinds;

(b) to promote the development of technical facilities and their most efficient operation with a view to improving the efficiency of telecommunication services, increasing their usefulness and making them so far as possible, generally available to the public;

(c) to harmonize the actions of nations in the attainment of those common ends.

2. To this end, the Union shall in particular:

(a) effect allocation of the radio frequency spectrum and registration of radio frequency assignments in order to avoid harmful interference between radio stations of different countries;
(b) coordinate efforts to eliminate harmful
interference between radio stations of different
countries and to improve the use made of the radio
frequency spectrum."

The ITU concerns itself with a number of international telephone
and telegraph matters that lie outside the field of frequency usage,
e.g., international telegraph tariffs, but radio regulation has come
to dominate its work.

**THE NATURE OF THE PROBLEM**

The emphasis placed on the economic nature of frequency rights
in previous chapters carries over to the international aspects as
well. Because frequency rights are an economic good, they are valu-
able. The right to radiate energy is a form of wealth. Like other
forms of wealth, people want to acquire it; they want to use it for
their own ends. Governments want to establish control or jurisdic-
tion over frequency spectrum *viz-a-viz* other governments precisely
because such control bestows wealth on their constituents.

The invention of radio meant that a valuable new resource had
been discovered — frequency spectrum or, more correctly, the right
to radiate. Such discoveries are not novel, of course, but in most
cases, e.g., new oil fields, either because of precedent or for
practical reasons, no question arises as to what nation has cognizance
over the resource. Where it is clearly recognized that a single
nation has jurisdiction, disposition of the new resource is left to
it — internal national policies determine what rights of use will be
granted, and to whom they will be granted.

This recognition of a single jurisdiction was not true in the
case of frequency spectrum. There were no conventions or generally
recognized precedents spelling out the rights of each nation to con-
trol and dispose of the new resource. The question of national
jurisdiction over it was unsettled. At first this did not pose a
serious problem because the nations who were using radio were still
naive about the value of the right to emit energy. At the time there
were only a few radio sending or receiving sets, most of these were
on board ships, and the resulting transmissions placed no strain on
the available spectrum. Interference did occur, but it resulted from the fact that all of the transmitting equipment was designed to operate on one or two frequencies, not because there seemed to be a limited number of frequencies available. As the number of sets multiplied and new uses for radio developed, however, particularly broadcasting, the inherent value of rights to radiate became clear. Nations discovered that the quality of their radio communication systems could be degraded by other nations who authorized emissions on the same or adjacent frequencies.

The source of the problem was lack of jurisdiction over admission rights, i.e., the admission of energy from outside a nation's borders; as distinguished from jurisdiction over emission rights, i.e., emission from a locale within its borders. A nation could unilaterally exercise emission jurisdiction, but not admission jurisdiction. If jurisdiction over emission was to be meaningful, nations somehow had to get other nations to limit the emissions they authorized. Not very surprisingly this led to conflicts between nations over rights to authorize the use of frequencies. In the meantime, for entirely different reasons the principle of international control of radio communications had been established, and it was an easy step to enlarge the purpose of international regulation to envelop the question of rights to radiate energy.

It is important to emphasize, however, that there is no physical reason why jurisdiction over rights to radiate should be defined less clearly than jurisdiction over land. This does not mean that there is no international frequency problem; but only that the source of the problem is not something inherent in the physical nature of radio that prevents us from specifying jurisdiction. If geographic boundaries were (as they have been on occasion) poorly defined, e.g., if each of several nations claimed it had the right to authorize settling in a new territory, the situation with respect to land would be much like it was and to some extent still is for frequencies. Squatters of diverse nationality would be busy staking conflicting claims, while their governments contended for jurisdiction. Two
squatters farming, mining, or building on the same piece of land would interfere with each other in precisely the same fashion as two broadcasters trying to radiate simultaneously at the same frequency in the same area. The potential for confusion and conflict does not require elaboration.

The solution we have come to in the case of land is the establishment of permanent national sovereignty over most of the land areas of the world. As we shall see from a brief examination of the history of international frequency affairs, a similar trend has been present to establish permanent national jurisdiction in rights to radiate, but there has also been a conflicting current — a tendency to perpetuate centralized control in the hands of an international agency.

THE BERLIN RADIOTELEGRAPH CONVENTION

The provisions of the Berlin Radiotelegraph Convention of 1906 were concerned with maritime communications from ship to ship or from ship to shore. Twenty-seven nations signed the Convention and the annexed Radio Regulations. Two frequencies were designated for public correspondence between maritime stations -- 500 kc/s and 1,000 kc/s. The bandwidth from 187.5 kc/s to 500 kc/s was reserved to military and naval stations. Coastal stations were also authorized to use frequencies below 187.5 kc/s for long distance communication. Each nation was to provide the International Bureau (the paid staff agency of the Union) with a list of the coastal and ship stations under its authority.

Regulations were also adopted to minimize interference, e.g., superfluous signals were banned and standard procedures for contacting stations were proscribed to reduce the time necessary to conduct business. The signatories agreed "to organize the working of their radio stations in such a manner as not to disturb the services of other radio stations,"* but provided that "all of the restrictions

on radio stations, both in the Convention and the Radio Regulations, concerned only those stations "open to public service." All others, "especially naval and military installations," were exempted from all of the provisions of the Convention and Regulations, with the exception of the non-interference rule (above).*

**THE LONDON RADIO/TELEGRAPH CONVENTION**

The Berlin Conference was followed by the London Conference of 1912. Coming shortly after the Titanic disaster, the London Conference was preoccupied with questions of maritime safety. Only minor changes were made in frequency allocations. The question of national jurisdiction over frequencies came up in connection with efforts (again directed at the Marconi interests) to obligate fixed stations to accept messages regardless of the type of equipment used. The principle that differences in equipment could not be grounds for refusing to correspond was adopted, but again with a proviso.

"However, each country retains its complete liberty in regard to the organization of the service of correspondence between two fixed points ..."**

One interesting sidelight on the question of national sovereignty was the opinion expressed by the Russian delegates to the effect that if the services of fixed stations were to be regulated, it would also be necessary to investigate the remuneration to be given to intermediate countries through whose atmospheric space the radio waves traveled.***

**THE WASHINGTON CONVENTION**

Fifteen years elapsed between the London Conference and the next international conference held at Washington in 1927 with

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*** Codding, George Arthur, etc., p. 101.
delegations from over 80 nations.* By that time the nature of radio had changed radically. Broadcasting had come into its own; increasing numbers of aircraft were being equipped with transmitters and receivers; new technology had greatly expanded the usable radio bandwidth; transoceanic radiotelephony had just been placed in operation; etc.

The Convention and Regulations executed at Washington were designed to broaden the scope of international agreement in accord with these changes, and they established a framework that was to persist 20 years.

Radio conventions and regulations that were in effect prior to the Washington Conference had applied almost exclusively to public maritime correspondence. The Washington Convention and Radio Regulations, however, applied its provisions not only to all public correspondence, but to radio uses generally.

The table of frequency allocations adopted as part of the Regulations made allocations to the following general services: Fixed, Aeronautical, Broadcasting, Direction Finding, International Call and Distress, Mobile, Not Open to Public Correspondence (the designation for military and official government uses), Radiobeacons, and Meteorological. All frequencies from 10 kc/s to 60 mc/s were covered in the table. The principle of allocation of frequencies on a regional basis was recognized by differentiating the European region in respect to certain frequency bands.

Despite the expansion in scope of the radio conventions and regulations, the Washington Conference reserved to the individual contracting nations most of the power concerning frequency utilization. Indeed, it is fair to say a foundation was laid for the development of a system for endowing individual nations with exclusive "property" rights in specific frequencies. The cornerstone of this development was contained in Article 5 of the

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*The USSR was an important exception. The United States had refused to invite the USSR though she was legally a member since she had signed the London Convention.
Convention which provided that:

"1. The administrations of the contracting countries may assign any frequency and any type of wave to any radio station within their jurisdiction upon the sole condition that no interference with any service of another country will result therefrom.

2. These Administrations, however, agree to assign to stations, which by their nature are believed capable of causing harmful interference, frequencies and types of waves in conformity with the rules for allocation ... set forth below.

3. The administrations also agree to consider the table of allocation of frequency bands as a guide giving, for the different services, the limits which must be observed by all new stations and to which they shall adapt all existing stations with the least practicable delay, without diminishing the quality of the service which these existing stations maintain, and taking into account the present state of their installations."

Article 5 clearly implies that nations acquire some kind of right to frequencies through prior use. If frequency assignments can be made without restriction except when interference results, the implication is that stations already established have a superior right.

On the other hand, Article 16 of the Regulations provided:

"16. The frequencies assigned by Administrations to all new fixed, land or broadcasting stations which they have authorized or of which they have undertaken the installation must be chosen so as to avoid so far as possible interference with international services carried on by existing stations that frequencies of which have already been notified to the International Bureau. In the case of a change of the frequency of an existing fixed, land or broadcasting station, the new frequency assigned to this station must comply with the condition mentioned above.

The interested Governments shall agree, when necessary, upon the determination of the waves to be assigned to the stations in question as well as to the conditions of use of the waves so assigned. If no arrangement to prevent interference can be reached, the provisions of Article 20 of the Convention may be applied."

* Codding, George Arthur, etc., p. 125.
** Ibid., p. 126.
The Article 20 referred to states in part:

"In the case of disagreement between two contracting Governments in respect to the interpretation or the execution either of the present Convention or of the Regulations provided for by Article 13, the question in dispute must, at the request of one of these Governments, be submitted to arbitration."*

At one point during the Conference the question of priorities was discussed explicitly. Specific proposals were made by Switzerland and Lithuania to give priority rights to previously installed stations. Ultimately it was decided not to include such a provision in the Convention, because the situation was assumed to be covered by the paragraphs of Article 16 of the Regulations cited above. Records of the discussion disclose one rather astonishing statement made by the United States delegate to the effect that the United States could not subscribe to any provision which would give any country, administration, or private company, an absolute control over the use of any particular frequency.**

Acceptance of the principle of priorities continued to grow after the Convention. An important contributing factor was the practice, initiated in December 1926 by the International Bureau, of publishing a list of the frequencies notified to it by administrations. The Washington Convention had repeated the provision that had appeared originally in the Berlin Convention and which required that parties to the Convention notify the Bureau whenever they authorized the establishment of transmitting stations. In complying with the request of the Washington Convention that frequency assignments be made on a non-interference basis the Bureau undertook to publish a list of these notifications as a service to interested nations.

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* Codding, George Arthur, etc., p. 126.

** Codding, George Arthur, etc., p. 187.
This seemingly innocent step lent status to the principle of priority on the basis of first notification because it implied recognition by the staff of the Bureau of rights to the listed frequencies. During the next few years, further status was lent to that principle by the actions of the CCIR (Radio Consultative Committee), the international technical radio advisory committee. In 1929 this Committee requested that the form of the list be amended, and asked member administrations to be sure to advise the Bureau as to the frequencies they were using or wished to use. At the 1931 meeting of the Committee the Bureau announced that it was going to include the date of notification in its published list so that it would be possible to determine to whom priority appertained. The Committee then adopted a resolution recommending that the date of registration be included in the list, and went on record to state that the list should be considered an official document of the Union.

**THE MADRID CONFERENCE OF 1932**

The next radiotelegraph diplomatic conference was held at Madrid in 1932. The 13th International Telegraph Conference and the 4th International Radiotelegraph Conference were held simultaneously. Out of that conference there emerged for the first time a single unified convention covering telegraph, telephone, and radio services. At this conference the frequency allocation table was extended to cover frequencies from 22.3 megacycles to 28.0 megacycles.

The Madrid conference also further emphasized the use of a regionalized approach to the problem of frequency allocations and assignments. The impetus for this approach came from two sources. First, nations with different geographic locations often wanted to use the same frequencies for different purposes. Allocation of a block of frequencies to one purpose in Europe, say, broadcasting, though agreeable to the European contingent, might not be agreeable to Canada and the United States who wanted that frequency for military use. In order that the United States and Canada could continue to use the low and medium frequency bands as they saw fit, the Madrid Conference divided the allocation table into the
"European region" and "other regions." Second, allocation of broadcasting rights in Europe had become such a difficult problem that it was decided that a separate conference of the European nations would be held for the purpose of making European broadcasting allocations. The broadcast problem was inherently more serious in Europe than elsewhere because of the modest dimensions of European nations relative to the distance over which each could broadcast. Consequently, for a nation to utilize a specific frequency free of interference, agreement was required with a large number of nations. The situation was further aggravated by the fact that the U.S.S.R. had not been invited to the Washington Conference and had not been a party to the Convention. As a result, the U.S.S.R. had begun to use frequencies outside the allocations laid down at Washington. Because of these complications, the question of European use of specific frequencies for broadcasting could not be solved in the context of the Madrid Conference, and provision was made for a separate conference to be held later.

The discussion that took place at Madrid regarding the question of what rights, if any, a member acquired as a result of prior notification to the Bureau is of considerable interest. The Conference adopted the frequency list as an official Union document, but what this adoption meant in practice was, to say the least, unclear. The following account leaves little doubt as to this lack of clarity:

"... during the discussions of a sub-committee of the Technical Committee the delegate of Great Britain declared that if the aeronautical military services did not notify their frequencies to the Bureau in the required form, and did not at the same time observe the regulations applicable to all services, 'all privileges, notably that of priority, should be withdrawn ipso facto.' The delegates of Italy and the United States requested a clarification of the statement. The latter delegate remarked that it had not yet been decided that a privilege of priority could result from the notification of a frequency. The British delegate, without attempting to explain his stand on the principle of 'priority,' submitted a note to the sub-committee in which he expressed the opinion that high frequency stations must register their frequencies in the form prescribed by
the Regulations, and must adhere to all the Regulations concerning the type of waves, tolerance of frequencies, etc., before the notifying administration could claim 'a right that resulted from such notification.' When the sub-committee examined the British statement, the Japanese delegate pointed out that the exact nature of the rights or privileges resulting from notification had still not been clearly established. He felt that if any particular principle was to be recognized it was necessary to take into consideration all of the radio services, and not just the high frequency stations mentioned by the British delegate. The British delegate, again evading the question, replied that in his opinion 'a station which was not notified or which did not observe the Regulations concerning the type of emissions, tolerance and frequency, could not benefit by the advantages that resulted from notification.' After the statement was made, no further discussion ensued. ....

The same hesitancy was apparent in the discussion of the sub-sub-committee of the Technical Committee that had been given the task of examining any juridical questions arising from the use of frequencies. At the third meeting of this sub-sub-committee the Japanese delegate asked whether a priority existed in favor of a station which was already using a frequency. After being requested by the chairman not to insist upon an answer, the Japanese delegate declared that, in his opinion, the sub-sub-committee was unanimously in agreement that there was absolutely no relation between 'notification' and 'priority.'

The same lack of clarity is evident in the following account of an article written in 1934 by a Mr. Schwill who was then Vice-Director of the Bureau.

'Mr. Schwill, ..... came to the definite conclusion that a frequency could not become the object of 'ownership.' Mr. Schwill qualified his conclusion by affirming that, in case of arbitration, an administration that had notified a frequency to the Bureau and used the frequency in conformity with the Convention and Regulations, could invoke those facts in its favor when requesting the right to continue to use the frequency without interference. This would be clearly, *Coddington, George Arthur, etc., pp. 189-190.*
in his opinion, 'a privileged position which one
could consider as a priority, but above all of the
order moral rather than juridic.' He then added the
following statement:

'The fact that the administrations scrupulously
observed the directions for the notification of
frequencies to the Bureau of the Union, and that they
attached the greatest importance to the correct
reproduction of all the details required, notably
the dates of notification, proves that the directives
are not devoid of all value.'

Mr. Schwill's concluding statement referred to
the known, but unpublished, fact that administrations,
even before the publishing of the Frequency List,
assumed that they had a claim to any frequency registered
with the Bureau. Even more important was the fact that
administrations recognized the right of other administrations
to operate radio stations on previously registered
frequencies, without being bothered by 'harmful interfer-
ence.' In cases where interference was experienced,
the date of registration was the determining factor in
deciding which station could continue to operate. This
practice increased when the Frequency List was first
published and even more so when the 'date of registration'
was included in the list. It is also a known fact that
the Bureau of the Union (later the General Secretariat)
has often been used as an intermediary in cases of
disputes over interference.***

The dilemma in which the international radio authorities found
themselves is apparent. In actual fact, national jurisdiction over
specific frequencies was being established as a consequence of the
Bureau's Frequency List, but there was at the same time great
anxiety to deny that such rights could be established.

THE CAIRO CONFERENCE

After the Madrid Conference, only one other radio conference
of any consequence was held prior to the termination of World War II;
the conference held at Cairo in 1938. The Cairo Conference was
concerned primarily with regulations and rate-making matters rather

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* Codding, George Arthur, etc., pp. 190-191.
than with frequency policy matters. The Conference did, however, take one important step concerning frequency matters by extending the frequency allocation table to 300 megacycles. Again, in order to satisfy differences between the desires of American and European nations, regional allocations were made for the added spectrum. Also, provision was made for another separate European Conference on broadcasting. However, before the resulting frequency allocations became effective, World War II erupted.

**The Atlantic City Conference**

During and immediately after World War II the demand for frequency spectrum increased greatly, just as it had in the years during and after World War I. Increased military activities generated new demands for established services; demands which were further compounded when new technology (e.g., radar) began to be used on a large scale. Civilian applications for new electronic devices were not far behind the military, and, coupled with the explosion of T.V. and radio, provided another important stimulus to demand. Similarly, a significant increment to demand was contributed by the greatly expanded air and sea travel of the time.

By the time the war ended, frequency spectrum was being used both more intensively and more extensively than ever before, and pressures existed which foretold an even greater use in the future. It is not surprising, thus, that shortly after hostilities ceased, plans were laid for the next I.T.U. conference. Indeed, in September of 1945, at the 3rd Inter-American Radio Conference, the United States announced that the next I.T.U. Conference would be held in the United States, probably in 1946.

Preparatory to the I.T.U. Conference, the United States suggested to the USSR that the latter invite the five major victorious powers to a prior policy conference. Accordingly, a meeting was convened in Moscow in September of 1946, with representatives of China, France, United Kingdom, USSR, and the United States, as well as the Bureau of the Union, attending.
At that conference agreement in principle was achieved on some important innovations in international frequency affairs. In particular, it was agreed that an elected board of technically qualified persons would in the future pass on the question of whether newly notified operations would interfere with already established uses. All frequency notifications to the Bureau were to be entered in the "Notifications" column of the Frequency List, but only those that the Board judged would not cause harmful interference were to be entered in the "Registration" column.

The effect of creating such a Board, of course, would be to enhance to an even greater extent the importance of the Frequency List, and further to strengthen the principle of right by prior notification. The participants at Moscow, however, were not prepared to accept the then existing Frequency List as the starting point. It was felt that the old list was out of date. Many frequencies registered were not being used and many frequencies were being used that were not registered. Moreover, the conference had decided that the allocation table would have to be substantially revised, and that a number of existing uses would have to be transferred to other frequencies. Both the U. S. and the U.S.S.R. submitted plans for the construction of a new frequency list, but the plans differed in one important respect. The Soviet plan provided for cancelling all filings for the period from 1941 until the new frequency board became effective. This implied that registrations and notifications prior to 1941 were to be recognized. The American plan was more sweeping and provided essentially for a completely new start. According to this plan, a conference would be convened that would collect from each nation a list of its requirements, and the conference would then "work out a frequency plan for all the world stations on a technical basis without regard necessarily for any particular frequency which any particular nation may have registered heretofore, but rather in order that the radio stations of the World could operate in the future without causing or suffering
harmful interference."* No resolution of this question was made at Moscow, and it was not until later that its importance was recognized.

Formally, the United States, during 1947, played host to three overlapping conferences dealing with telecommunications: The Atlantic City Radio Conference, the Atlantic City Telecommunications Conference, and the High Frequency Broadcasting Conference. The first of these, the Radio Conference, was called for the purpose of revising the Radio Regulations, and is of primary interest here. The Radio Conference devoted itself to two tasks; first, revising the allocation table; second, constructing a new international framework of frequency registration in line with the agreement reached at Moscow. Without undue conflict, a generally acceptable revision of the frequency allocation table was achieved. Agreement in the new plan for frequency registration, however, was not so easily achieved.

The Conferences readily agreed on the principle of a permanent registration board. Defining the functions of the board and deciding on its make-up, however, were somewhat more difficult problems. But what really proved the undoing of the whole idea was the difficulty of constructing an initial frequency list which the new board would presumably henceforth keep up.

Under the old scheme of registrations, the Bureau of the Union had no power to take action on a new registration that was submitted to it, even to the extent of notifying other members who might be affected. Under the new system the International Frequency Registration Board, or I.F.R.B., as it came to be known, was to play a much more active role. When a notice of frequency assignment was received by it, the Board was to circulate a copy

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of the notice to all countries who were members of the Union; determine whether the proposed assignment was in conformity with the allocation table and other provisions of the Convention and Radio Regulations; and judge the probability that the assignment would cause harmful interference. As suggested at the Moscow Conference, the Frequency List was to contain two columns -- a "Notification" column and a "Registration" column. The Board would have the right, in effect, to deny entry in the Registration column if it believed that harmful interference might result. A country could, however, assign and authorize the use of a frequency even though Registration was denied so long as no one raised objections. Presumably, if objections were subsequently raised, the findings of the Board would be an important consideration in any ensuing arbitration. The I.F.R.B. was also to be authorized to make special studies of frequency usage when requested to do so by a member nation, and to cancel frequency registrations when such registrations were not utilized (a) either for two years after initial notification or (b) after three years in cases where use had been made of a frequency for some period.

Membership on the I.F.R.B. was to be elective on a regional basis -- the World being divided into four regions. Region A, the Americas, was to have three seats; Region B, West Europe and Africa, was also given three seats; Region C, East Europe and North Asia, was to have two seats; and Region D, the rest of the World, was given three seats -- eleven seats in all.

Thus a Board was established and its functions defined without engendering fatal dissensions. But the establishment of the Board and the definition of its functions proved to be only a small part of the battle. The Atlantic City Radio Conference Plenary Assembly had also created an International Frequency List Committee. In practice, what that Committee set out to do was to prepare an entirely new frequency list. As prescribed by the United States the procedure to be followed in arriving at the new list was:

"(a) The Committee should first compile, on the basis of actual operations, a list of the 'circuit
requirements' of all of the nations of the world.

(b) The estimates should be made of the additional circuit requirements necessary to make possible the reactivation of circuits which were discontinued during the war and the institution of circuits for which plans have been made for operation by January 1, 1948.

(c) After the circuit requirements have been compiled, the number and approximate bandwidth of frequencies needed in order to meet circuit requirements should be determined, using as a basis for this work agreed engineering principles.

(d) A sharing plan should then be applied to the approximate bands of frequencies thus derived. For, as it was explained, 'Frequencies used for short distance circuits can generally be the same as those used for the longer circuits.'

(e) The final product could then be used to make specific individual frequency assignments within the bands allocated in the new allocation table.

The final result, in the words of the report, would be 'a completely new international frequency list which will, insofar as spectrum space is available, meet the circuit requirements of all countries, which will conform to the new allocation table, and which will be based upon sound engineering principles insuring the maximum utilization of the available spectrum space.'

In carrying out (c) above it was suggested that the committee apply the following "engineering principles."

"(a) Maximum use of frequencies shall be obtained by geographical duplication and time sharing.

(b) The minimum band or channel widths and tolerances appropriate to the type of communication and consistent with the state of the art shall be determined and applied.

(c) The minimum number of frequencies to provide satisfactory service shall be utilized.

(d) Frequency needs for radio circuits in countries or continental areas where wire line service is available shall be satisfied only if feasible when other requirements have been met.

(e) Circuit requirements submitted by each country shall be reviewed to insure correlation between countries operating both ends of the circuit.
(f) Frequency requirements for the shorter circuits shall in general be met by sharing with the longer circuits, using for daytime transmission the night time frequencies of the longer circuits.

(g) Frequency assignments solely as a guard against interference shall be eliminated since interference will be reduced by proper assignment on an engineering basis.

(h) Frequency space used for guard band purposes shall be reduced to a minumum."

The first serious signs of division of opinion developed in the Frequency List Committee over the question of whether to go directly to the "new" list, or to arrive at that juncture through an "interim" list. A minority, led by the U.S.S.R., France, Belgium, and Switzerland was in favor of interjecting an interim list while the majority, led by the U.S., the United Kingdom, and Canada, favored the direct route. When debate produced no compromise satisfactory to all delegates, the Committee Chairman called for a vote which was won handily by the proponents of the one-step method. The delegate of the U.S.S.R. then advised the Committee that the U.S.S.R. could not accept the decision.

It is worth noting that in the discussion of whether to go directly to the new list Bierlorussia raised the question of what was to happen to existing priority rights. In answer, "the United States delegate stated that if the list were completely engineered, it would not only provide for the operation of all existing services, but it would eliminate the harmful interference that had existed in the past; thus there would be no need for priority."*

When it became clear that it would be impossible for the Frequency List Committee to complete a new list in the course of the Conference, a Provisional Frequency Board was established to carry on the work after the Conference adjourned. Each member of the International Telecommunications Union was entitled to membership on the Provisional Frequency Board. Final responsibility for the new frequency list was given to the P.F.B., but part of the work of constructing the list was parceled out to other groups.

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*Coddington, George Arthur, etc., p. 259.
The scheduled High Frequency Broadcasting Conference was to generate the list for high frequency broadcasting; special regional conferences were to decide regional assignments; and special administrative conferences were to be called to decide aeronautical mobile and maritime mobile assignments. The Board adopted the following as ground rules:

"(1) The maximum use of frequencies shall be obtained by geographical duplication and time sharing as far as practicable.

(2) The minimum band- or channel-widths and tolerances appropriate to the type of communication, consistent with the state of the art, shall be applied.

(3) The minimum number of frequencies necessary to provide a service in accordance with sound engineering principles shall be utilized, taking into account the power of the transmitter and the directive properties of the antenna.

(4) International fixed circuit requirements submitted by each country shall be reviewed to ensure technical correlation between countries operating both ends of the circuit (with the exclusion of unilateral services of radio communication).

(5) Frequency assignments solely as a guard against interference shall be eliminated, since interference will be reduced by proper assignment on an engineering basis.

(6) Frequency space used for guard band purposes shall be reduced to a minimum consistent with the service required."

A full account of the fate of this U.S. sponsored scheme to "engineer" the spectrum is not called for here. Details of its conception have been described only in order to document the total lack of understanding exhibited by the plan as to the nature of the problem. As one would expect, carrying the idea into effect proved quite impossible.

When the participating nations reported their needs to the P.F.B., the total bandwidth requested exceeded the available spectrum many times over. The Board began its work in January, 1946, and for the next two years made a valiant effort to execute a new "engineered" list through a series of regional and international conferences. Such a list was never attained, however.
From the outset the Soviet Bloc objected to discarding the old "Berne List," the frequency registration list kept by the Bureau of the Union. The Soviets argued for using the Berne List, as it stood at the time World War II broke out, as a starting point for the construction of a new list. Their motives were simple. Before World War II they had taken advantage of the priority scheme that prevailed by methodically notifying the Bureau that they were using frequencies at regular intervals all the way up and down the spectrum. As a result, under the Berne List they were "entitled" to a very large amount of bandwidth. That position of preeminence in bandwidth was being threatened by the U. S. sponsored scheme. As the U. S. delegate to the Provisional Frequency Board put it:

"It also became clear after much consideration and discussion that, because of the phenomenal growth in the use of radio communication in the past decade, never again could the world return to a condition where priority of notification to the Bureau of the Union would constitute a proper claim for the exclusive use of a frequency. In short, it was realized that in order to permit an equitable use of the available radio spectrum space by all nations of the world, distribution of frequencies must be made on the basis of actual needs of each country, as opposed to notifications made years ago when there were enough frequencies for all and when operating practices were notoriously wasteful of spectrum space."

The Soviet interpreted this as an "attempt by a definite group of countries, first of which is the U.S.A., to satisfy their own inordinately inflated requirements by discriminating against those of the U.S.S.R., the Ukrainian S.S.R., the Belorussian S.S.R., as well as those of a number of other countries, and thus gain a dominating position in radio communications."*

In the fall of 1949 the Soviets announced that the attempt to construct a new frequency list was a failure and that their delegation was going home. Early in 1950 the Chinese delegation followed suit. By February of 1950 it became clear that further attempts would be fruitless, and the P.F.E. ceased work. At the Extraordinary Administrative Radio Conference, Geneva, 1951, some

of the lists and plans that had evolved out of the attempt to construct a new list were adopted, but for most of the spectrum established utilizations were perpetuated -- nations continued to use whatever frequencies they had been using, for whatever purposes they had been using them.

With the dissolution of the Provisional Frequency Board, the International Frequency Registration Board, as originally planned, took over the assignment function in the ITU, but without the benefit of an "engineered" list. At the request of the 1951 Geneva Conference the I.F.R.B. constructed a list of frequencies, now called the Master Frequency Record. Except for those bands and services for which plans had been accepted by the Conference, the Master Frequency Record simply listed claims to and uses of the spectrum. The Master Frequency Record did contain columns ostensibly to designate the class of title a nation had in a frequency; but for the unplanned frequencies, no entries were made in the registration column, implying that no nation had a first-class title to any frequency in that domain. Entries were limited to the notification column.

More recently, at the 1959 Geneva Radio Conference, a plan was adopted to gradually transfer the entries in the Master Frequency Record to a new list, the Master Frequency Register, where entry in the latter was to be limited to frequencies that the I.F.R.B. verified were being used. Even then, however, the entries for the unplanned bands were not to be made in the registration column, but in another new column created for that purpose. It is still the hope of some that an engineered list can thus be gradually evolved.

**HISTORICAL DEVELOPMENT OF JURISDICTION**

The history of international frequency affairs, summarized above, covers three periods. The first period begins with the invention of radio at the turn of the century, and ends with the 1927 Washington Conference. The second begins with the Washington Conference and ends with the Atlantic City Conference of 1947. The third covers the years from the Atlantic City Conference to the present. The basis used to define national jurisdiction over radiation differed for each of these periods. Because frequency spectrum was practically a free
good, the problem of delineating jurisdiction over it was not serious in the early period. Each nation individually, and the International Radio-Telegraph Union collectively, proceeded on the basis of national "sovereignty" -- meaning that each nation had the right to authorize any transmissions it chose. National jurisdiction comprehended the right to license transmission at any frequency and such authority was co-terminus with geographic boundaries, but did not extend to the prohibition of transmission from other nations. In other words, each nation had emission control, but no admission control.

The readiness with which this concept was accepted is no doubt to be explained by the illusion it engendered that nations thereby established a sovereignty over frequency rights on a par with that which they exercised over land -- each nation thought that it was securing control over all of the spectrum without sharing with its neighbors.

As radio uses developed, however, the flaw in this reasoning became apparent. No nation could authorze transmission and protect them from interference originating in other nations, since the latter could always grant similar (but conflicting) rights to their citizens. If land rights were to be defined in this way, nation A could authorize me to build a house on "my" land, but since nation A would have no jurisdiction over the citizens of nation B, it could not stop my counterpart in nation B from building on the same piece of land. The result would be interference and conflict in the use of that land.

By 1927, when the Washington Conference convened, this practice had resulted in serious practical problems which the participants were anxious to solve -- conflicting authorizations to use frequency spectrum were resulting in "harmful" interference. It was believed that limitations had to be placed on the use of frequencies. The solution which came to be accepted, more by osmosis than by calculated choice, was that priority was established on the basis of notification. Thus, despite the protestations cited in the above historical summary, the Berne List did give jurisdiction over specific frequencies to particular nations to the exclusion of other nations. In brief, title to
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frequencies was established by this list. Whatever its shortcomings, this contrivance had the practical advantage of reducing interference by limiting the use of individual frequencies. The scarcity of frequency spectrum, and the absurdity of pretending that every nation could authorize the use of every frequency, was recognized. Acceptance of the principle of "priority" itself represented a crude kind of exchange between the parties involved. Parties to the acceptance of the principle "exchanged" the right to authorize emission at certain frequencies in return for the right to authorize emission on other frequencies free of interference from without. Thus, they gave up some emission jurisdiction in exchange for jurisdiction over admission.

Despite this advantage, ITU member nations never formally acknowledged what was an accomplished fact, namely that rights accrued to those nations which first notified the Bureau of their intention to use a frequency. Resistance to assigning formal status to the priority system stemmed from a desire on the part of the participants to have their cake and eat it too. Each nation wanted clear title to the frequencies it used, but did not want permanently to forego its claims to frequencies which other countries had acquired—a consequence that was likely to follow from formal recognition of the principle of priority.

THE REPUDIATION OF PRIORITIES

With the U.S. in the vanguard, a determined effort was made following World War II to discard the priorities that had been acquired on the basis of notification, and to substitute in their stead a so-called "engineered spectrum." This involved the proposal to create an international body similar to the FCC, to assign and allocate frequencies, with the ITU being the international counterpart of the FCC. The pressure to sweep away the old claims, along with the system that had generated them, emanated from two sources. First, those nations that had not staked claims in the early years by notifying the Bureau of their intention to use frequencies realized that they had missed the boat. This was the
real source of complaints about the inequity of a system that assigned rights on the basis of whoever happened to develop radio technology first. The less "radio developed" countries resented the fact that the more developed countries had already divided up much of the pie among themselves. They were supported in this view by the United States.

Second, the great shifts in demand for spectrum that had occurred as a result of new technology, higher incomes, and changes in tastes, could not be accommodated under the old priority system. This system contained no provisions for transfers of priority from one service to another or from one nation to another, even where the parties involved would have been agreeable to an exchange. There was no way in which a nation, or even a group of nations, that wanted to start a new radio operation could buy spectrum rights from those who had acquired them under the notification system.

Because the old priorities had never been formally recognized, the idea of denying their existence and beginning anew seemed an attractive way to relieve these pressures. It appeared that by beginning anew justice would be served so far as the backward nations were concerned, and that at the same time a more sensible use of the spectrum could be effected. As it turned out, however, the struggle to construct a new list—i.e., to engineer the spectrum—ended in failure and the ITU was left with no explicit rule for determining what nations would have jurisdiction over what frequencies.

The notion of priority established on the basis of first use or first notification was not easy to obliterate, and although the principle suffered a trauma from which it has not yet fully recovered, it survived. Today, as a result, where a nation knows that interference would occur, it does not generally authorize transmission on frequencies already registered in the name of some other nation. Moreover, there is no doubt that in resolving disputes over the use of a frequency the date of notification or of first use is given weight.
ON ENGINEERING THE SPECTRUM

The experience of the late 1950's when an attempt was made to engineer the spectrum, reflects a serious misunderstanding of the nature of the international frequency problem, and many of the serious misconceptions that led us into difficulty at that time continue to enjoy respectability today.

One of our most serious mistakes in this attempt was to suppose that we could deny established radiation rights to certain countries, whether those rights had ever been formally recognized or not. Nations cannot be expected passively to consent to a redistribution of wealth that affects them adversely.

This naivete was compounded by assuming that the entire question of determining radiation rights is a "technical" one that can somehow be solved by appropriately engineering the spectrum. A more insidious fallacy than this would be hard to find in the annals of frequency affairs. It was this fallacy that led the U.S. to assure the rest of the world that everyone's demands could be fitted into the spectrum. It was this fallacy also that led the U.S. to invite the rest of the world to submit their "needs" to the Provisional Frequency Board as a basis for constructing a new list. The latter procedure is on a par with deciding how to allocate land or any other resource by simply asking everyone how much of the resource they need. One could hardly expect the answers to conform to what was actually available, yet the U.S. petulantly accused other nations of violating the spirit of the whole effort by submitting requests for frequency spectrum which exceeded their "true needs."

The pitfalls awaiting those who persist in this engineering approach are still not widely appreciated. A recent report on international frequency management, for example, states: "Prior occupancy and use, rather than technical criteria (such as a more efficient mode of propagation that would eliminate the interference), continue to govern disputes over interference."

The ITU has not fulfilled what might be considered its basic
mission, the prevention of international interference, because it has failed to progress beyond the service allocations toward a "fully engineered" spectrum.

The earlier system of priority through notification encouraged claim-staking and was quite obviously not conducive to the theoretical maximum utilization of the radio spectrum (in terms of the use of all frequencies, at all times, and in all places), clearly the ideal toward which a fully engineered spectrum is directed."

Statements of this type illustrate the perils involved in viewing the problem as a technical one. In the space of a few pages the above report assigns two contradictory objectives to international frequency management: (1) to minimize interference; and (2) to maximize use of the spectrum, literally meaning to insure that none is idle. Aside from the fact that these goals are in direct conflict, taken literally neither seems very attractive. The way to minimize interference is to prohibit all but one individual from radiating. The way to maximize utilization is to let everyone radiate. Perhaps the most generous interpretation that can be given to the proposal is to say that the statements were not meant to be taken literally. If they cannot be taken literally, however, they have no real meaning. In any event, they are very misleading and are essentially useless as guides to practical policy.

The proper objective of international frequency management is to ensure that radiation rights are used efficiently. We want neither minimum interference nor maximum usage, but just the amount of interference that will result in efficient usage. In addition, this almost certainly will not mean "use of all frequencies at all times, and in all places," any more than the efficient use of land.

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P. O. Proehl, Communication Satellites and International Frequency Management, RM-2941-NASA, the RAND Corporation, November 1961, pp. 29, 30, 33-34. (Emphasis supplied.)
requires the use of all land, at all times, in all places. Some frequencies simply will not be worth using because their use currently is uneconomic, just as there is always some land that it is not economic to bring into production. Moreover, in an efficiently operating market for frequencies we would expect some very valuable frequencies to be held out of use, just as vacant lots are held out of use in a city. Withholding frequencies can perform a useful function, namely, preventing uneconomic investment in specialized equipment that is destined to shrink in value when the pertinent frequency later becomes more valuable in an alternative use. In other words, it is desirable to have a system that takes into account future as well as current uses in settling the question of spectrum utilization, and paradoxically this is likely to mean that segments of spectrum which are very valuable are held idle.

The present domestic system is not designed to take alternative future uses adequately into account and, as a result, uneconomic investment is induced. Equipment is designed and built to operate at certain frequencies. Later those frequencies became valuable in some alternative application, but transfer of the frequencies to the new uses means discarding the equipment. Therefore the cost of using the frequencies in the alternative application is higher than it would have been if the frequency had been held idle. This phenomenon has come to be recognized as a problem not only in government, but also in the electronic and radio industries generally.

What needs to be emphasized, however, is not the specific shortcomings of statements such as the foregoing, but the resulting misunderstanding and policy blunder that follows once one accepts the "technical" point of departure. This does not mean that scientists and engineers are disqualified as experts in the radio frequency business, any more than they are disqualified in building dams simply because dams should be erected on the basis of economic criteria.* What it does mean is that ultimately economic

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*Obviously, a technically perfect dam is worthless if there is no economic value to its output. It is economically inefficient if the value of its output is less than the value of the resources that go into it.
criteria must serve as the measure of sensible behavior in the use of any resource.

THE POLICY ISSUE

Our discussion of the history of international frequency affairs has by now made the crux of the international frequency problem apparent. If every nation exercises the right to authorize transmission on every radio frequency, the radio spectrum will be used very badly. Some means must be found to limit the number of nations having the right to authorize transmission on individual frequencies.

Initially, there were two approaches we could have taken in trying to resolve these difficulties. One was to accept the principle that individual nations would have both admission and emission control for all the spectrum. This is a parallel to what we do for other types of resources. The suggestion of the Russian delegate that nations pay for the use of the airwaves of other nations is a case in point. That suggestion implied recognition that each nation possessed both admission and emission jurisdiction for the entire spectrum contiguous with its geographic borders.

The other approach was to create an international agency like the ITU to settle international questions of frequency usage. The latter was the course actually adopted. That choice, however, left unsettled an important question, namely, that of the role of the international agency. Was the ITU simply a forum where national jurisdiction was adjudicated or was the ITU itself to retain jurisdiction over rights and manage and control their use? Was the ITU to preside over the disbursement of frequencies to nations, or was it the International Ministry for Frequency Spectrum? Though that question has not been an explicit issue, it underlies the controversy over the priority system and the attempt after WW II to revamp priorities.

The most important long run international frequency policy question facing the United States concerns the question of what role we should advocate and support for the ITU. Should the United States promote centralized international management with the ITU as an
international FCC, or should we foster and lend status to decentralization and the devolution of national jurisdiction? The analysis which follows is directed to that question.

CONTIGUOUS JURISDICTION

The suggestion of the Russian delegate at London in 1912 that nations be charged when they use the airwaves of other countries is at one extreme of the possible levels of decentralization. What this attitude implies is control by each nation of admission as well as emission rights, and not just for some frequencies, but for the entire spectrum. Let A and B in Figure 6 represent two countries. Within its borders each nation would have the right to authorize whatever emission it chose, but neither would have the right at any frequency to authorize emissions (at significant powers) across the border.

Thus each nation could deny or permit admission at any frequency as it chose. We shall refer to this type of jurisdiction as "contiguous jurisdiction."

No doubt the attitude of the Russian delegate was regarded in 1912 (as it would be in many circles today) as mercenary and obstructionist. His view, however, offered some definite advantages over the course we actually took with the ITU.

(1) Contiguous jurisdiction would have resolved the question of who (what nations) would capture the value of the newly discovered resources with far less dissension than we have experienced. Since each nation would have had admission and emission control coterminous with its geographic boundaries, each would have enjoyed some part of their value, and there would have been no occasion for the objection leveled at the priority system that the share of value a nation has received is a function of the rate at which it developed the use of radio. Even the incentive to claim-staking that characterized the priority system would have been eliminated.

(2) The evolution of clearly defined rights would have been fostered -- rights for which the nations of the world gradually would have developed more and more respect. By covering the admission as
well as the emission side the specification of rights would have been made symmetrically complete.

(3) The suggestion that nations pay for using other nation's "airwaves," implied the development of a truly international market for frequencies, a market that would have enabled use of individual frequencies to adjust to where their value was greatest. Suppose Nation A wanted to authorize emission that transgressed the geographic borders of B. Whoever wanted this authority in A (e.g., A.T.&T.) would presumably be willing to pay for it, and so long as any suitable frequency had less value within B than to the potential user in A, nation B would find it in its interest to sell admission rights of the type desired. In brief, nations could have been induced to auction off some of their frequencies to the highest bidder, even though the highest bidder might be in some other country.

It is important in this context to distinguish between exchanges or sales of (government) dominion over a frequency and exchanges of the right to use a frequency. What is important from an efficiency point of view is only that potential users have the opportunity to acquire rights to use frequencies by bidding for them. It is much more difficult to induce a nation to give up sovereignty over spectrum than to induce it to permit an outside party (as the highest bidder) to use that spectrum, subject to whatever laws and conditions the sovereign nation chooses to impose.

British, French, or U.S. corporations and citizens often hold title to land in foreign countries or hold oil or mineral rights there; there is no reason why they could not also hold frequency rights there. Indeed, it is not uncommon for corporations to hold frequency rights in other countries now, but the market for acquiring them is not as well developed as it would have been had contiguous jurisdiction been established from the start. Even sovereign nations could make mutually agreeable exchanges involving rights to use frequencies without altering the pattern of dominion.

Within the formal framework of the ITU the emphasis in the past has been on exchanging dominion itself, and the possibilities for providing an environment conductive to exchanging only rights to use
have been neglected. Some exchanges of dominion have been effected under the auspices of the ITU. In the course of the post-war reform effort attempts were made to effect such exchanges. Nations that were asked to give up frequencies they had been using were sometimes offered others in exchange. Reconciliation of use to changes in demand through this route, however, are the exception rather than the rule and the process is a clumsy one at best.

NON-CONTIGUOUS JURISDICTION

Insofar as nations have acquired jurisdiction under the ITU, they have done so as a result of the priority system, where instead of acquiring authority over admission and emission for all of the frequency spectrum, they have acquired control only for specific frequencies. Generally, under the priority system jurisdiction was not coterminous with geographic boundaries. If we return to Figure 6, nation A would have jurisdiction over frequencies a, b, c, ..., e in the entire geographic area occupied by A and B, while nation B would have similar rights for a set of frequencies m, n, o, ..., t. This form of jurisdiction we shall refer to as "non-contiguous jurisdiction." Under contiguous jurisdiction frequency rights are defined so as to coincide with geographic boundaries. Under non-contiguous jurisdiction spatial boundaries to rights to not necessarily coincide with geographic boundaries.

The evolution of non-contiguous jurisdiction raises problems that would not be encountered in the case of contiguous jurisdiction. One source of difficulty is the conflict that ensues over how the value of the spectrum is divided. Under contiguous jurisdiction each nation's share of the value is determined by the value of rights (both emission and admission) within its geographic boundaries. That basis of settlement coincides with accepted practice for the discovery of other new resources like oil fields or minerals, generally. As a result political acceptance is relatively easy to achieve. Under non-contiguous jurisdiction, however, there is no such generally acceptable basis for dividing the value of spectrum.
Historically, of course, the sharing question has been decided largely on the basis of notification to the Bureau of the ITU. In order to capture the value of a frequency a nation has had to acquire priority rights to its use. Capturing the value of a frequency has thus been tied to using it.

The development of non-contiguous jurisdiction has a second disadvantage relative to contiguous jurisdiction; it lacks a built-in mechanism for inducing nations to sell rights to use frequencies. Efficient utilization of the frequency spectrum requires that a potential user be able to acquire spectrum rights from current holders whenever their value is greater to him than to them. As we noted, sales would spontaneously develop under contiguous jurisdiction, but there is no such ready-made market under noncontiguous jurisdiction.

Both of these disadvantages of noncontiguous jurisdiction have indeed raised problems under the priority system. As indicated earlier, the question of how the value of this newly discovered resource would be divided has been resolved largely on the basis of who first notifies the bureau -- the only way a nation could share in the prize was to use the spectrum. When some of the nations discovered after WW II that they had missed the boat because they had not begun using the spectrum early enough, trouble followed.

From the viewpoint of future policy, it is important to recognize that sharing in value is not inevitably linked to use. For that reason we have carefully distinguished between sharing the value of frequencies and using those frequencies. Initially, jurisdiction might have been auctioned off to the highest bidder, and the proceeds divided on any of a number of bases -- population, per capita income, lottery, etc. A nation might end up using none of the spectrum, but still share in its value, just as the prospector who makes a strike can capture the value of his claim with operating the mine himself.

The question of how to divide the proceeds of such a sale among nations is identically the question of how to divide the value of the pie. It is a question of what is "just" or "right" in an ethical sense, not something one can decide on the basis of analysis. As a
practical political matter it is a question of what would achieve a
workable consensus of the nations involved. The important point is
that each nation need not be given its share in kind, i.e., other
means of compensation, e.g., money, are acceptable substitutes. The
implications for future United States policy are worth emphasizing.
Real possibilities exist for making monetary or other payments to
nations who would prefer those to sharing in the use of spectrum.

FREQUENCY ALLOCATIONS

To this point, our treatment of international frequency affairs
has dealt only peripherally with the allocative functions performed
by the International Telecommunications Union. In that respect it
misrepresents the activities of the ITU, for most of the energy of
member countries focuses on construction of the International Table
of Frequency Allocations. The Table of Frequency Allocations speci-
fies what frequencies shall be used by what classes of service. The
practice of designating the specific segments of spectrum that various
services will use dates back to the Berlin Convention of 1906, and
has grown in scope and importance ever since. The 1959 Convention
designates the use of frequencies by services from 10 kc/s to
40,000 mc/s. The list of services designated includes:

1. Amateur
2. Broadcasting
3. Fixed
4. Fixed Aeronautical
5. Scatter-Tropospheric
6. Mobile
7. Mobile (Distress and Calling)
8. Mobile Except Aeronautical Mobile
9. Mobile Except Aeronautical Mobile (R)
10. Land Mobile
11. Aeronautical Mobile
12. Aeronautical Route
13. Aeronautical Off Route
14. Aeronautical Radionavigation
15. Maritime Mobile
16. Maritime Coast
17. Maritime Ships
18. Maritime Radionavigation
19. Industrial, Scientific, Medical
   (Requires no protection and does not protect allocated services.)
20. Radioastronomy
21. Radiolocation
22. Radionavigation
23. Standard Frequency
24. Earth-Space and Space
   (For research purposes.)
25. Meteorological Aids

To a degree, allocation of frequencies by the ITU is comparable to zoning for land use. For allocative purposes, the world is divided into three regions. In each of these regions the usable spectrum is apportioned among a list of services. Specific categories of service like fixed, broadcasting, etc., are the counterpart of specific land use categories like commercial, industrial, etc. Allocations thus determine the kinds of service (or services) that will use various portions of the spectrum. From one point of view, allocations confine each service to particular regions of the spectrum. From the opposite point of view, they supply each service with particular regions of the spectrum.

Today, the Table of Frequency Allocations is the primary medium through which the ITU can control and manage the frequency spectrum. For that reason, the question of whether the United States will promote centralized international management or foster decentralization in large measure comes down to the question of what position we will take in regard to the allocative functions of the ITU. Should be endeavor to strengthen and rely on those allocative functions, or should we strive for more autonomy in frequency affairs? There are a variety of steps and degrees to which we
could move in the latter direction. By making more extensive use of footnotes to the allocation table, we could except ourselves from more of the provisions thereof. We could extend the use of regional agreements and allocations, and press for more and smaller regions so that allocations can be tailored more to the taste of individual countries. More generally, we can for much of the spectrum encourage recognition of dominion by individual nations over admission and emission control contiguous with their borders. Where the priority system has led to non-contiguous jurisdiction, there is little we can do but encourage formal recognition of that fact. Certainly we should discourage any grand attempts like the post-World War II one to redistribute jurisdiction already lodged in individual nations.

Whether we want to move toward more autonomy and decentralization depends on the relative advantages thereof, and raises the question of what benefits international allocations confer.

**THE PURVIEW OF THE ITU**

One largely neglected subject that demands attention in deciding about the role of the ITU is that of the extent to which there really is a multilateral international problem in any case.

As radio technology has progressively taken advantage of higher and higher frequencies, the International Telecommunications Union has extended its jurisdiction, and in particular its allocations, to include roughly whatever spectrum was technically usable. For the most part the spectrum incorporated in the early days -- up to the Madrid Conference of 1932 when the allocation table was extended to 28.0 megacycles -- clearly raised **intercontinental** interference problems. At those frequencies, especially between 3.0 and 30.0 megacycles, or what is referred to as the High Frequency band, signals carry very long distances around the earth through reflection from the ionosphere.

Above 30.0 megacycles (and present ITU allocations extent to 40,000 megacycles) the story is different. In general, for frequencies above 30.0 megacycles, interference can occur at the surface
of the earth only if the interfering source is very close to the affected station. The reason is simply that radio waves tend to travel in straight lines, while the earth's surface is curved. For receivers using frequencies above 30 megacycles, interference at distances much beyond the line of sight (30 miles or so) is not a serious problem. Thus despite their elongated antennas T.V. broadcasters have a very limited reception area. Indeed, all the post-war tumult over a new frequency registration list really involved only frequencies below 30.0 megacycles. The Provisional Frequency Board was commissioned to construct a list only for the portion of the spectrum between .15 megacycle (150 kilocycles) and 27.5 megacycles.

In practice this means that stations in the United States, for example, using frequencies above 30.0 mc/s cannot interfere with other stations anywhere in the world excepting Canada, Mexico, and possibly one or two Carribean off-shore islands. Moreover, even in those cases, the transmitters would have to be very close to our borders, and the receivers close to theirs. About the only place there would be a practical problem is where contiguous cities lie at the borders, e.g., Windsor and Detroit, or Jaurez and El Paso. In brief, not only is there no multilateral problem, even the bilateral problem is a very limited one.

Two qualifications are necessary to this generalization. First tropospheric and ionospheric scatter systems do use frequencies above 30.0 megacycles and transmit energy over distances up to several hundred miles. However, the amount of energy returned to earth with scatter systems is very small, hence it is lost in the general noise level for all but the most sensitive receivers. Also, the demand for frequencies for this purpose is very small, and only a trivial quantity of spectrum is devoted to it.

Second, the line of sight is extended if the transmitter or receiver is airborne. This is a more serious problem than scatter systems. At altitudes of 60,000 feet the line of sight is extended to distances of the order of 300 miles. In the near future satellites will operate at altitudes of thousands of miles. However, such satellites will be like the scatter system in that the energy returned
from the satellite will be so small it will not interfere with other services unless the latter have very sensitive receivers with antennas pointed directly at the satellite. In the distant future satellites technically could broadcast over areas as large as 1/3 of the globe, but the cost of putting payload into space being what it is, it is very unlikely that such satellites will be economic. The case of the airbreathing aircraft communicating at altitudes high enough to extend line of sight to several hundred miles is an exception of some practical importance, but it is hard to see how it could be important enough to justify progressively extending the jurisdiction of the ITU throughout the entire frequency spectrum and making allocations to all of the services.

If interference is largely a local phenomena at frequencies above 30.1 megacycles, it seems reasonable to ask what is gained from having the ITU decide all the allocations for all services in that part of the spectrum. There is no obvious virtue in Italy being consulted on the use of frequencies within the U.S. that affect no other nation, nor does there seem to be any good reason why the U.S. should be called upon to settle the parallel question for Italy. The ITU is globally multi-lateral, which means that localized questions that come within its purview must be sanctioned by a number of largely disinterested parties. Taking local issues to such a forum invites delays and disputes, and diverts attention from issues which really do affect a large number of ITU members. Moreover, from the United States' point of view, we surrender control of our own fate in

*The use of communication satellites to broadcast directly into home receivers (rather than as point to point relays) loses much of its appeal on objective analysis. If stations are to have any local fare, broadcast satellites will not be substitutes for local transmitters. If local transmitters are necessary in any case, they might just as well be used for broadcasts and network shows relayed point to point. While on the subject it is worth noting that such satellites would be inefficient in using spectrum rather than efficient. They would consume an assigned frequency throughout the entire geographic area in which they broadcast, while an alternative network of terrestrial T.V. stations would not use frequency in areas where it did not pay to broadcast. The fact that only one assignment is required for a broadcast satellite does not mean that less spectrum is being used. The paper work may be reduced for the FCC, but the "one" piece of spectrum used is even more valuable than the sum of the value the little pieces which would be used instead.
frequency matters to nations who are not likely to have our interests at heart; nations who at best are likely to be indifferent.

**ALLOCATIONS AND INTERFERENCE**

Earlier we noted a similarity between frequency allocations and zoning. That parallel, however, can easily be overplayed. In the zoning case, because the land is already owned, most of the conditions for its use are defined in law and are independent of zoning action. In particular, when a piece of land is zoned for industry, the question of who has the right to build (or authorize building) a plant there is already known. The ITU often makes frequency allocations, however, when the question of what nation has jurisdiction and the question of what individual (or individuals) has use rights are still up in the air. Sometimes neither question is settled by the allocation. Thus, if the frequencies between 525 kc/s and 1,000 kc/s are allocated to broadcasting in the European Region; that allocation does not solve the question of which nations will have jurisdiction over particular frequencies, nor which individuals will have the right to use them. Within that bend the allocation has done nothing to resolve the basic problem of restricting authorizations to broadcast. If each European nation still insists that it has the right to authorize broadcasts on every frequency between 525 kc/s and 1,000 kc/s, some other means, e.g., the priority system, must be found to effect restrictions on emissions.

In other cases, allocations convey use rights to individuals directly without ever conferring jurisdiction on nations. Generally, when allocations are made to mobile services that are international in character, any private user who operates such a service is entitled to share the use of the frequencies allocated anywhere in the world. Thus, whereas a broadcaster must get express consent from his government in the form of an assignment before he can use a frequency, an international air transport firm can acquire the right to use a frequency or frequencies anywhere in the world simply by virtue of an ITU allocation. Given the way such allocations are shared, the only restriction on the number of users of a particular allocation is the
number of mobile stations of the type concerned that are in operation.

The only way allocations limit emissions hence reduce interference is through circumscribing the supply of spectrum available to particular services. Each class of users is allotted a specified amount of spectrum, and that class is insulated from competition from other classes of users for the allotted bandwidth. For services in which the demand for frequencies is small relative to the supply allocated by the ITU, no restrictions on entry may be required. New users may be indulged without serious consequences, as they are generally for international mobile services. For services in which the demand is large relative to the supply allocated, however, entry restrictions will be necessary. Boardcasting is perhaps the best example.

ALLOCATIONS AND MOBILE SYSTEMS

As we have noted, the first radio communications systems were international mobile systems -- radio-telegraph from ship to ship and between ships and shore. The inception of a system of international allocations and the viability of that system is probably best explained in terms of the advantages it offers to operations of international mobile equipment. In the beginning it was the maritime industry; since then air transport has become of primary importance. International air and sea transport concerns have exercised an important voice in the affairs of the ITU, and today a very large amount of spectrum is allocated on a global basis to their use.

Systems can be mobile with respect to the transmitter, to the receiver, or to both. In practice, the important international cases are aircraft and ships, which are mobile in both respects. Communication satellites and other space systems may become important mobile systems in the future.

Mobile systems are distinctive because the geographic area in which they wish to communicate moves about as they move. As a single
ship or aircraft progresses around the world, it will want to communicate with diverse stations along the way, including perhaps other mobile stations, e.g., other ships.

Generally, mobile units can share frequencies timewise. In part this is because a given mobile unit usually will not want to transmit or receive continuously, but it is also in part a result of mobility per se. As an aircraft that has been communicating with a ground station passes out of range, a new aircraft can take its place. Thus, a given frequency in a given area can be shared in the time dimension by successive mobile units. To effect such sharing, however, systems installed in different aircraft must be capable of operating at the same frequencies.

It is very convenient (i.e., less costly) for a given mobile unit to be able to use the same frequency everywhere. A mobile unit that is not authorized to use the same frequency (or same band of frequencies) throughout the area in which it operates, must accommodate an assortment of frequencies. Otherwise it will interfere with other services or be interfered with itself. The broader and more heterogeneous the spectrum of frequencies over which it receives and transmits, the heavier and more costly its radio equipment will be. Thus, equipment cost considerations call for using a limited number of frequencies in communicating with a given mobile unit, while time-sharing suggests standardizing frequencies so that different mobile units can use the same bands. In other words, uniform frequency allocations covering extensive geographic areas are something that mobile operators would be willing to pay a high price for.

In large part this explains their interest (or that of their trade organizations like the International Air Transport Association) in the affairs of the ITU.

It is in the context of separating international mobile systems from each other and from other systems that allocations are usually thought to be essential to controlling interference. If there were nothing except fixed systems or intra-national mobile systems, it is hard to imagine what role an international allocation table would
play. There would still be the problem of what nations would have jurisdiction and the problem of what individuals would acquire use rights, but neither of these would seem to call for allocating spectrum among alternative services. In inferring that allocations are necessary, however, it is usually assumed that without them the international mobile services would be scattered all over the spectrum and thus would cause serious interference. That assumption is certainly questionable. Even if contiguous jurisdiction had been accepted from the beginning so that each nation individually had emission and admission control for all of the spectrum, and no international allocation system had ever been established, the costs that would have been imposed on operators, and the desire on the part of nations to avoid interference would have provided a strong incentive to both to use uniform frequencies around the world for mobile services. It might very well have been true that international mobile services received less spectrum than has been allotted to them under the present system, but that is not necessarily bad. Given the way the allocation table is generated, it is very likely that such services have been supplied more spectrum than is efficient anyhow.

In the past the United States has exercised a powerful voice in international frequency affairs. We have been able to elicit allocations from the ITU favorable to certain users, especially, the maritime industry and the commercial airlines, even though we have had to pay a price for this in terms of domestic freedom to use frequencies as we choose. Whether we can continue to get favorable allocations in the future depends on our ability to maintain an influential position. The allocation table is a two-edged sword. It can be employed to deny us the right to use frequencies in ways we would like. More important, it can be used to deny other nations around the world the right to negotiate with us for the use of frequencies in their locales even though they might be willing to do so. If we are unsuccessful in our efforts to get allocations for space activities through the ITU as currently planned, we will be effectively stopped from negotiating with individual nations to grant such rights. That is the danger inherent in relying on and strengthening the management function of the ITU.
Non-management Functions of the IMU

Outside the area of controlling and managing the use of frequency spectrum, there are a number of functions of the IMU that could very well be strengthened. One of these is the evolution of clear definitions of the jurisdiction of individual nations. In international frequency affairs, individual nations stand in the same relation to the rest of the world as the individual user does to other users in the domestic market. If we are to minimize conflict, jurisdiction must be well-defined. Each nation must know exactly what it has the right to authorize and what it does not, and other nations must be able to recognize those rights. Moreover, we would like rights to be defined comprehensively, so that none that are valuable are overlooked to cause disputes later. In fact, we would like to have jurisdiction defined so that if new uses for spectrum are found or new portions of the spectrum become useable later, the question of jurisdiction is automatically resolved as it is when a new oil well is found. We would also like to have jurisdiction defined so that users have complete freedom to vary their inputs so long as their output does not infringe on the rights of others. This will enable them to combine equipment so as to produce any given service at lowest cost. Finally, jurisdiction should be defined so that the rights nations authorize are readily transferable, even if the buyer is a foreign firm or nation.

These desirable qualities can be realized by defining national jurisdiction along the lines discussed for individual rights in the preceding chapter. An individual nation would have the right to authorize emission at specific frequencies within a prescribed geographic area. At those particular frequencies that same nation would have the right to deny admission to outsiders at powers above some minimum level. The area might or might not coincide with geographic boundaries. If every frequency in every geographic area is thus awarded to one nation or another, jurisdiction will be as comprehensive as we know how to make it. Such rights will also be readily transferable.

In contrast to the domestic arrangement, defining jurisdiction in terms of output is no innovation in the international sphere. It is essentially what has come to be accepted under the priority system.
This is largely traceable to the provision in the Washington Convention that led to the priority system, whereby nations were permitted to authorize the use of any frequency so long as that use did not interfere with an established service. The affect was to define jurisdiction in terms of output rather than input, and the institutional framework that was developed to handle violations was based on output. It was only when a station was interfered with that it instituted proceedings in official channels to have the interfering source desist. The latter procedure was what gave a nation admission jurisdiction.

A good example of the way we could further the definition of rights is provided by the sharing criteria proposed in Docket No. 13522, of the Federal Communications Commission dealing with the Allocation of Frequency Bands for Space Communications. Sharing criteria are specified there in terms of radiated power, i.e., in terms of output. One useful function the ITU could perform is to spell out in a similar fashion even more specifically the rights of individual nations in various areas and at various frequencies. The ITU could also help by serving as the official agency for keeping up to date a record of what nations had established what rights.

Finally, the ITU could be strengthened as a world court with the function of adjudicating disputes between nations. Compliance is a serious problem in international frequency affairs. To say that Nation A has rights in certain frequencies in certain areas implies that other nations somehow constrain their behaviour (or more accurately perhaps the behaviour of their subjects) in recognition of A's rights, e.g., B refrains from authorizing emissions in areas and at frequencies over which A has dominion. But how are A's rights, whatever they may be, protected from intrusions emanating from B?

In certain respects there is no satisfactory answer to that question. There is no international enforcement agency, nor any prospect that one will come into being in the foreseeable future. The ITU does not have such powers, and even if its status were enhanced, it is hard to imagine individual nations either endowing it with police powers or providing the resources necessary to carry them into effect. Insofar as nations
have adhered to ITU sponsored agreements in the past, they have done so voluntarily. They have been willing to comply because they realize that non-compliance on any significant scale would make each worse off. That realization induces the group as a whole to bring pressure and sanctions to bear on individual members who are disposed to stray. Despite these pressures conformance has been less universal than one might hope.

An international frequency court can make an important contribution to enforcement as an institution for clarifying rights and peacefully resolving disputes. As rights become more clearly defined and time passes, violations will come to be regarded as more and more serious offenses, just as are violations of geographic boundaries.