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# Information On Management And Use Of The Radio Frequency Spectrum -- A Little-Understood Resource

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Federal Communications Commision
Office of Telecommunications Policy

*UNITED STATES*
*GENERAL ACCOUNTING OFFICE*

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LOGISTICS AND COMMUNICATIONS DIVISION

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Chairman, Federal Communications Commission
Director, Office of Telecommunications Policy

This is our report, "Information on Management and Use of the Radio Frequency Spectrum--a Little-Understood Resource."

We are sending copies of this report to interested congressional committees and, at his request, to Senator Charles H. Percy.

F. J. Shafer

Fred J. Shafer
Director

# Contents

## ABBREVIATIONS

| | |
|---|---|
| A.T.&T. | American Telephone & Telegraph Co. |
| DOD | Department of Defense |
| EMC | electromagnetic compatibility |
| EPA | Environmental Protection Agency |
| ERMAC | Electromagnetic Radiation Management Advisory Council |
| FAA | Federal Aviation Administration |
| FCC | Federal Communications Commission |
| FMAC | Frequency Management Advisory Council |
| GAO | General Accounting Office |
| HEW | Department of Health, Education, and Welfare |
| IRAC | Interdepartment Radio Advisory Committee |
| ITU | International Telecommunication Union |
| OT | Office of Telecommunications |
| OTP | Office of Telecommunications Policy |
| RF | radio frequency |

GENERAL ACCOUNTING OFFICE
REPORT TO THE CHAIRMAN
FEDERAL COMMUNICATIONS COMMISSION
AND THE DIRECTOR, OFFICE OF TELE-
COMMUNICATIONS POLICY

INFORMATION ON MANAGEMENT AND USE
OF THE RADIO FREQUENCY SPECTRUM--
A LITTLE-UNDERSTOOD RESOURCE
B-159895

## D I G E S T

### WHY THE STUDY WAS MADE

The radio frequency spectrum is the range of radio frequencies used to transmit information from one place to another without connecting wires.

The radio frequency spectrum is one of the least understood of natural resources.

This study was made because over $90 billion has been invested in the United States for spectrum dependent electronics equipment. About 55 percent of this represents the Federal Government's investment.

Though well known to some specialists, the value and importance of the spectrum--and the need for its prudent management--is not known well or understood by the public or even the preponderance of those who use it. The spectrum serves (1) government, (2) industry, and (3) private individuals for

--national defense,
--law enforcement,
--education,
--entertainment,
--safety of travel,
--management of resources,
--business, and
--other purposes.

Goods and services valued at more than $32 billion a year have been attributed to use of the spectrum for

--television and radio broadcasting,
--air and sea navigation,
--communications,
--meteorology,
--astronomy,
--mapping, and
--space exploration.

Past studies have concluded that the United States is not making the most effective use of this valuable natural resource. (See app. I.)

National boundaries are meaningless to the spectrum. International and national agreements and regulations are required for its effective and efficient use.

There are limitations to this use. (See ch. 2.)

### FINDINGS AND CONCLUSIONS

Demands for spectrum services are increasing more rapidly than technology can find space in the available range of usable frequencies.

In the past, technology has found ways to use ever higher frequencies and thus relieve congestion in the lower frequency ranges.

Today there are indications that the practical limits of the usable spectrum are being reached. (See p. 22.)

There is intense congestion in some

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parts of the spectrum while some other parts are lightly used. (See p. 29.) The problem may be further compounded unless more extensive use is made of other means of communication, such as wire, cable, or waveguides, in lieu of radio, when such means can be used.

This problem may become even more severe as a result of increased use of satellites, each of whose signals may cover 42 percent of the earth's surface. (See p. 22.)

There is also a proliferation of radio navigation or locator systems, some duplicative, whose mounting costs must be borne by both the Government and the users. (See p. 25.)

More coordination and reconciliation of views between Federal agencies could help limit the number of navigation systems to the minimum consistent with Government and civil requirements. (See p. 28.)

Some economists have suggested that, if the spectrum were not free but could be sold or rented, market forces would result in uses of greatest value superseding those of lesser value. Thus conservation would be rewarded, while waste would be penalized. (See pp. 29 and 31.)

Increased regulation is suggested by some knowledgeable parties. More and improved regulation would require

--more data on equipment and its use,

--more stringent equipment standards,

--improved engineering, and

--stepped-up monitoring and enforcement.

Tough rules may offend many interests and would take resolve to enforce. However, they may become necessary to improve spectrum availability for future needs. (See p. 32.)

GAO has made no judgement on whether increased regulation, some form of spectrum charge, or combinations thereof would be best. Any one of these solutions would require legislation before it could be implemented. (See p. 33.)

The environmental effects of increasing exposure to radio energy have not been established. More research on this appears needed. (See p. 34.)

Availability of people skilled in spectrum management has not kept pace with increased demand and economic and technical complexities associated with expanded use of the spectrum. Increased spectrum managers would be needed to administer any of the new measures discussed above. (See p. 37.)

Although Government frequency managers do not foresee a spectrum crisis resembling our energy problems, the gathering problems of spectrum management suggest the need for increased attention to these matters. (See p. 40.)

The division of spectrum management between the Federal Communications Commission and the President has been in effect for 47 years. (See p. 41.) Certain problems could arise if frequency management were consolidated summarily either under the Commission or the Executive Office of the President. (See pp. 41 and 42.)

Growing competition for spectrum between the Government and civil sectors might lead to conflicts which would call for more authoritative arrangements than now prevail. (See p. 43.)

RECOMMENDATIONS

This report contains no recommendations.

AGENCY ACTIONS AND UNRESOLVED ISSUES

GAO sought the advice of agency officials at the Office of Telecommunications Policy and the Federal Communications Commission and placed their suggestions in this report. Formal comments were not obtained from the agencies.

The following subjects should be considered and acted upon by the Chairman, Federal Communications Commission, and the Director, Office of Telecommunications Policy.

--Need for a comprehensive review, by the Interdepartment Radio Advisory Committee, Spectrum Planning Subcommittee or other group, of spectrum use, particularly in the VHF and UHF bands, to determine the need for reallocation of spectrum and, if so, recommending alternatives leading to the most equitable allocation.

--Feasibility and potential benefits in instituting a spectrum charge or rental plan.

--Need for evaluating existing spectrum management arrangement for strengthening present arrangements or creating a single spectrum manager.

# CHAPTER 1

## VALUE OF THE RADIO FREQUENCY SPECTRUM

The radio frequency (RF) spectum is a vital natural resource which all nations share. The RF spectrum is the range of frequencies which may be used for the electrical transmission of information from one place to another without connecting wires. Different parts are used for television and broadcasting, air and sea navigation and communications, astronomy, detection of distant objects, distance measuring, mapping of terrain, and space research and exploration. It is also used for the telemetering of information from distant points, scientific and medical purposes, public safety, telephone, land transportation, industrial communications, remote control devices, amateur radio operators, and hobby and personal use (Citizens Radio). In the United States, this resource is used by the Government, industry, and private individuals.

Although difficult to determine because equipment is continually replaced or retired, according to 1973 estimates over $90 billion has been invested in the United States for spectrum-dependent equipment in current use. Of that amount, about 55 percent represents the investment by the Federal Government and 45 percent by the private sector.

As a resource, the value of the spectrum depends on many factors which cannot be readily measured. For example, its use in national defense, education, law enforcement, resource management, and safety of travel and in making business operations more efficient cannot be readily measured in monetary terms. However, it is possible to infer a very large value based upon the contribution to our gross national product which derives from its use.

According to a recent estimate, U.S. industry receives annually more than $32 billion from the sale, maintenance, or operation of spectrum-dependent equipment, as shown below.

| Revenue source | Sales (billions) |
|---|---|
| Sales of equipment and components, including expenditures for research and development | $19.900 |
| Radio and TV broadcasts | 4.065 |
| Cable TV services | .300 |
| Common carrier services | 5.190 |
| Service and repairs | 2.677 |
| Total | $32.132 |

Radio and communications have grown remarkably in the United States. In the past 20 years, annual radio equipment sales have grown 500 percent and radio licenses have increased over 1,000 percent. Communications has also outpaced all other industries in its percentage increase to our gross national product. Its contribution has grown about 530 percent compared with an all-industry average of some 325 percent. Although the value of the spectum is well known to the small frequency management community, its importance and the need for its prudent management may not be well known or understood by the public or even the preponderance of its users.

## CHAPTER 2

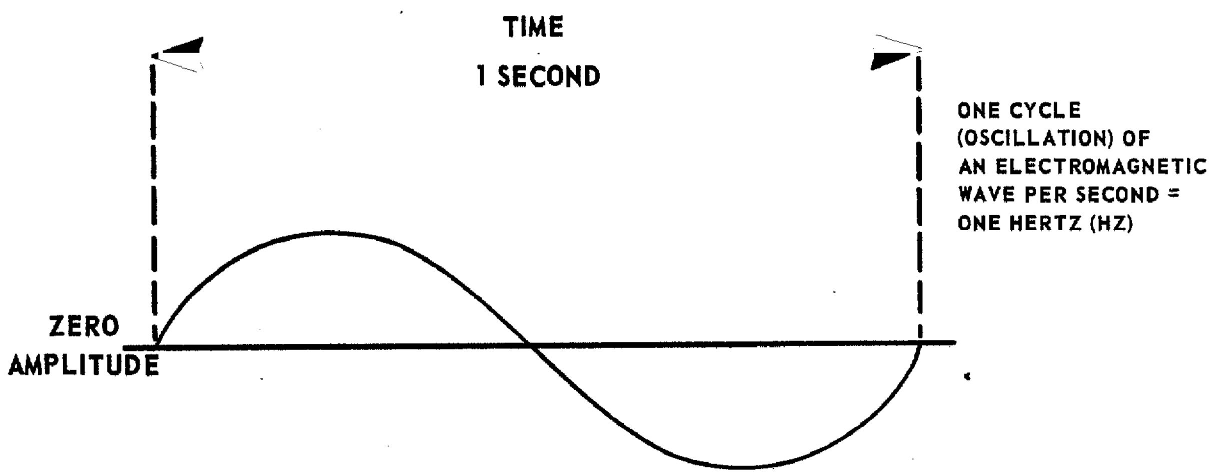
## TECHNICAL CHARACTERISTICS OF THE

## RADIO FREQUENCY SPECTRUM

The RF spectrum is one of the least understood of all our natural resources. The varied behavior of radio-wave propagation at different frequencies makes some parts of the spectrum suitable only for certain tasks. Although no two parts are exactly alike, there are common characteristics within internationally designated bands which permit their logical grouping. We will describe some of these characteristics, together with other factors, which affect frequency use. We believe some grasp of these matters is important to an understanding of how the United States is managing and using this resource.

### FREQUENCY

Radio waves can vary in frequency from one wave (cycle) per second, called one hertz (Hz), to as much as $10^{25}$ Hz (10 followed by 24 zeros).




Multiples of radio frequencies are expressed as follows:

| | | |
|---|---|---|
| 1,000 Hz | = | 1 kilohertz (kHz) |
| 1,000,000 Hz | = | 1 megahertz (MHz) |
| 1,000,000,000 Hz | = | 1 gigahertz (GHz) |
| 1,000,000,000,000 Hz | = | 1 terahertz (THz) |

International radio regulations have designated RF bands as follows:

| Frequency range | Band designation | Abbreviation |
|---|---|---|
| 3 to 30 kHz | Very low frequency | VLF |
| 30 to 300 kHz | Low frequency | LF |
| 300 to 3,000 kHz | Medium frequency | MF |
| 3 to 30 MHz | High frequency | HF |
| 30 to 300 MHz | Very high frequency | VHF |
| 300 to 3,000 MHz | Ultrahigh frequency | UHF |
| 3 to 30 GHz | Superhigh frequency | SHF |
| 30 to 300 GHz | Extremely high frequency | EHF |
| 300 to 3,000 GHz (3 THz) | -- | -- |

These groupings are useful because there are different characteristics and uses for most bands. As you read down the chart each band is 10 times as wide as the preceding one. For example, the EHF band encompasses 10 times as much spectrum as the SHF band.

The RF spectrum is not elastic; that is, two radio signals of the same frequency and amplitude (signal strength) cannot occupy the same geographical space at the same time. Furthermore, certain tasks can be performed only by certain frequencies. Significantly, therefore, not all parts of the spectrum can be substituted for all other parts.

Most of the world's communications, in today's technology, operate at frequencies between 10 kHz (VLF) and 40 GHz (EHF). This study considered primariy this part of the spectrum. However, U.S. allocations of frequencies currently extend to 275 GHz.

Since the lower bands are small and crowded and since their transmissions carry long distances, there is an intensive international regulation of the use of bands below 30 MHz.

## BANDWIDTH

Simply stated, bandwidth is the amount of spectrum space (Hz, kHz, MHz, or GHz) needed to transmit information at the rate and with the quality required of the system used. The quest for bandwidth conservation or the ability to convey more information per kHz of spectrum is a constant preoccupation of system and equipment designers.

Some examples of typical bandwidths are:

--Morse code transmitted at the rate of 25 words per minute, using continuous wave telegraphy, requires 100 Hz.

--Sound broadcasting (AM) requires 8,000 Hz. (To minimize interference, AM broadcast channels are spaced at 10,000 Hz--10 kHz--intervals in the band from 535 to 1,605 kHz.)

--TV broadcasting requires 6,000,000 Hz. (TV channel 4, for example, occupies the band between 66 and 72 MHz.)

Confucius was prophetic when he said "a picture is worth a thousand words." TV uses about 750 times the bandwidth of sound broadcasting.

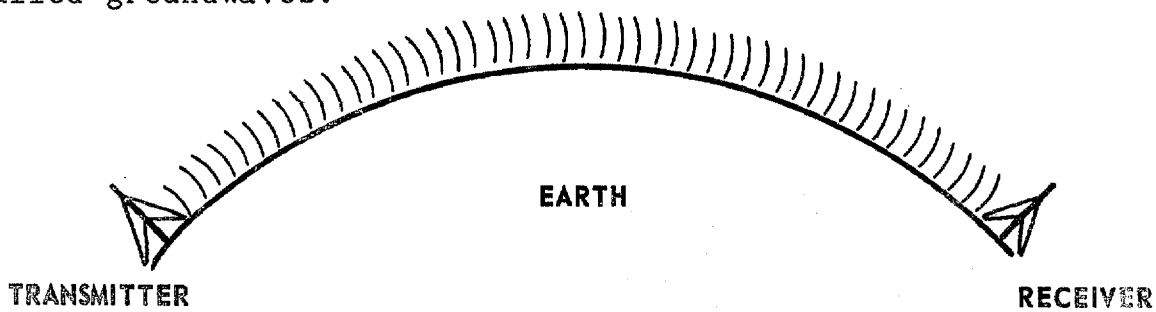
Bandwidth, obviously, is an important factor in spectrum planning and engineering. Its conservation is at the heart of spectral efficiency.

## RADIO-WAVE PROPAGATION

Propagation refers to the traveling of radio waves through a medium, such as our atmosphere. Radio waves travel at the speed of light but propagate in widely different ways, depending on the frequencies used for their transmission. To achieve effective communications, one must choose frequencies from the band whose propagation characteristics are best suited for the intended use.

### 10 to 3,000 kHz (3 MHz)

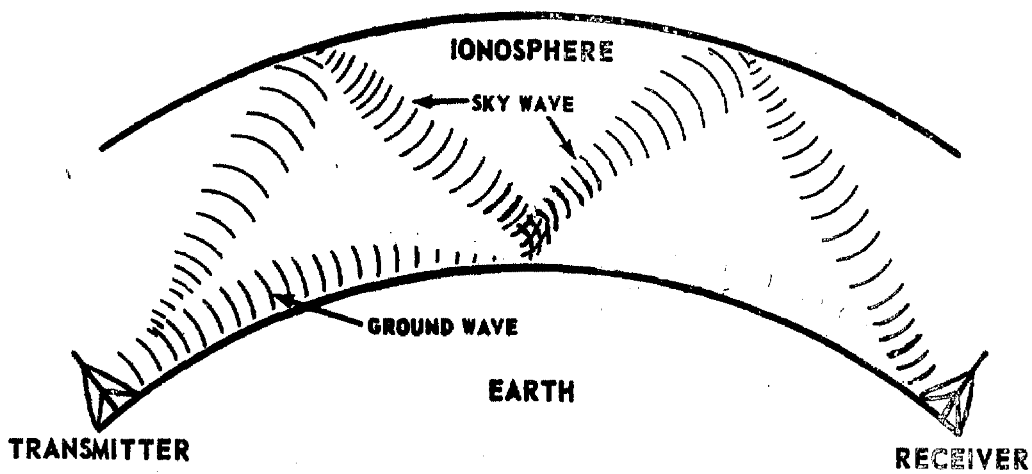
For VLF, LF, and MF radio waves (10 kHz to about 3 MHz), the most significant propagations travel along the ground, following the curvature of the earth in what are called groundwaves.




The lower frequency transmissions are very useful for certain types of communications (such as with submarines) or navigation but require high power for long-distance propagation. AM radio stations operate in this area of the spectrum (the MF band), the geographical area of coverage being constrained mainly by the power of the transmitter. This is why the Federal Communications Commission (FCC) limits the amount of power that AM stations may use. Also, because their signals tend to carry farther at night, many AM stations are permitted to broadcast only during daylight hours so as to avoid interference with distant stations.

3 to 30 MHz

From about 3 MHz to about 30 MHz (the HF band), a different characteristic of propagation becomes important because transmissions not only travel as groundwaves but also reflect from the various layers of the ionosphere. At high frequencies, the groundwave component of the signal tends to fade out at about 100 miles, but the wave reflected from the ionosphere (skywave) makes long-distance communication possible.




Skywave propagation makes it possible to transmit over long distances with much less power than would be required for groundwaves. For transmission to more distant points, radio waves may take two or more bounces between earth and ionosphere. Overseas radio telephone links, amateur radio, shortwave broadcasts, international aviation, and the maritime community represent the major use of this band (the HF band).

The four layers of the ionosphere each reflect or absorb radio energy differently depending upon the frequencies used, time of day, time of year, and period of the sunspot cycle. The highest layer, in the region from about 150 to 240 miles above earth, is the principal reflecting region for HF radio. Within this layer and in lower layers, rarefied air is ionized[1] by ultraviolet sunlight in ways which can either absorb or reflect radio energy. Thus, the reliability of skywave communications (at all frequencies below about 30 MHz) is sometimes poor in spite of our improved ability to forecast these ionospheric effects and occasional disturbances. This is one reason the international aviation and maritime communities could more effectively use very high frequencies via satellites.

30 to 10,000 MHz (10GHz)

Above 30 MHz (VHF and above), the groundwave component of a radio wave greatly diminishes and the skywaves, instead of being reflected by the ionoshpere, tend to pass through it. These tendencies are not abrupt but increase with increasingly high frequencies. Because of these characteristics, radio propagation at VHF tends to behave like light. In these circumstances, receivers (TVs, for example) must be nearly within line-of-sight distance from the transmitter. Due to the earth's curvature, these distances are limited to about 50 miles or so except when using very high antennas. This characteristic is very useful because it permits the reuse of such frequencies in many parts of the country so long as antenna heights and transmitter power are limited. Jet aircraft offer unique problems since their radio transmitting and receiving capabilities at high altitudes may exceed two hundred miles.

The advent of satellites has created an entire new dimension for frequency managers. A satellite's use of frequencies whose terrestrial propagation is of only local concern could become of very wide international concern. For example, satellites in geostationary orbit (22,300 miles over the equator) may have line-of-sight propagation paths which cover 42 percent of the earth's surface unless directed by narrowbeam (focusing) antennas.

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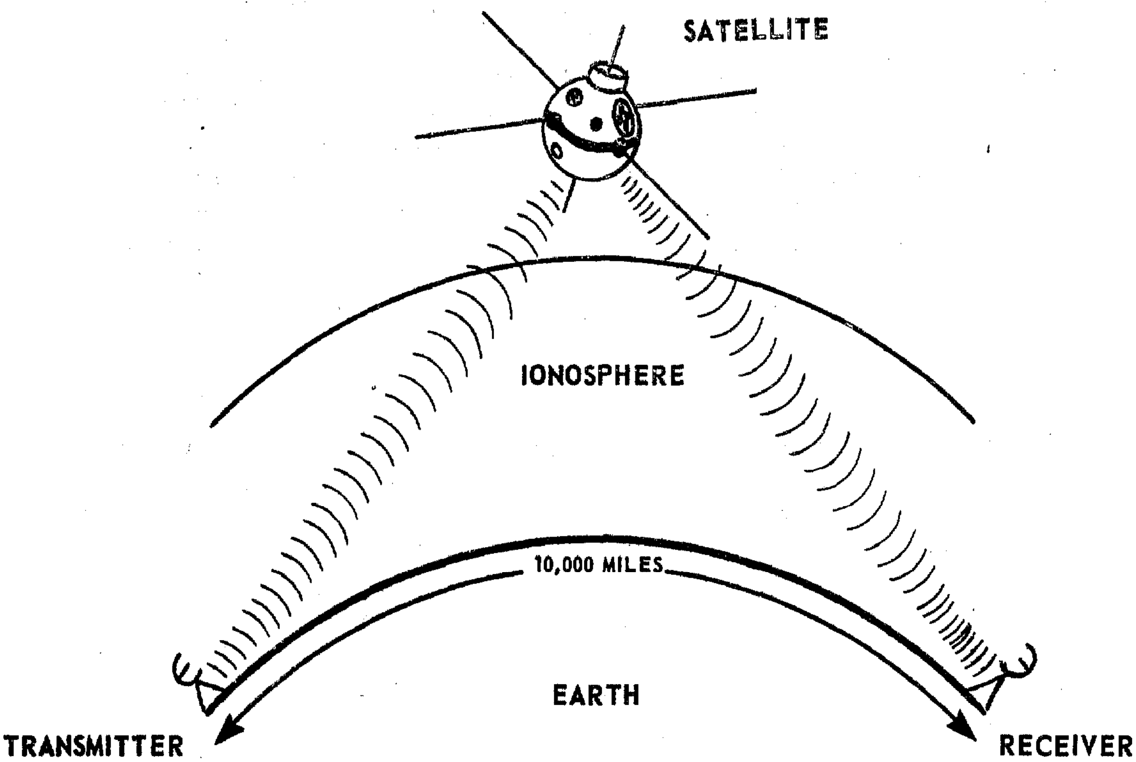
[1]The process by which electrically charged atoms or molecules gain or lose electrons.




A later chapter discusses some of the problems of satellite growth and its effect on spectrum use.

At frequencies above 1,000 MHz (called microwaves) radio propagation increasingly behaves like light (with increasingly higher frequency) and cannot pass around obstructions, such as mountains or buildings. Radiolocation (Radar) is widely used in several bands in the microwave region. Long-range search radars operate in the lower bands (about 1,350 MHz and to about 2,900 MHz). Shorter range, but highly precise, radars used for aircraft landings operate in the region of 9,000 MHz (9GHz). At such frequencies, radio energy can be very sharply focused by means of parabolic dishes or reflectors. Microwave radio relay, which spans our country for long-distance telephone service, operates in the lower SHF bands (4 and 6 GHz). These microwave stations, as most of us have seen, also use dishes or horns to transmit their beams to the next station. Satellite earth stations, most of which use very large dishes (to capture the weak, distant signals), operate in the 4 and 6 GHz region. As previously noted, their spectrum use creates unique problems.

10 GHz and above

At frequencies of 10 GHz and above, radio transmissions increasingly behave like light beams and are seriously attenuated (weakened) by weather phenomena, such as rain, heavy fog, and thermal layers in the air. These effects greatly limit the uses of radio in these higher frequencies. However, growing spectrum crowding in the bands below 10 GHz is challenging technology to find ways to overcome these limitations.

A range of frequencies which are least attenuated by the atmosphere is known as a window. One such window extends from about 10 MHz to 10,000 MHz (10 GHz). Another window exists at very much higher frequencies in parts of the infrared and optical region extending from 1 million to 1 billion MHz (1 THz to 1,000 THz). The technique, known as Light Amplification by Stimulated Emission of Radiation (Laser), uses this part of the spectrum. Although atmospheric absorption at these frequencies is high, the large bandwidths available and their pencillike beams may make lasers attractive for certain applications. They could be particularly useful if they could be transmitted within optical glass fibers or otherwise protected from the atmosphere.

ALLOCATION

As we have seen, radio propagation characteristics combined with ways in which we use the spectrum (international travel, satellites, etc.) have made it necessary to have both international and national agreements for frequency use. Such agreements allocate specific portions of the spectrum for designated radio services. As a result of the World Administrative Radio Conference on Space in 1971, all the spectrum extending from 10 kHz to 275 GHz has been allocated (apportioned) to some 41 discrete radio services (15 are now in satellite services). Typical radio services are: fixed (point to point), mobile, aeronautical mobile, maritime mobile, navigation, amateur, broadcasting (international, AM radio, FM radio, TV), radio astronomy, and radiolocation (Radar). These allocations are based broadly upon technical characteristics which make certain parts of the spectrum more useful for some purposes than others. Also, of the 275 GHz now allocated, in current technology we know how to use only the lower 15 percent.

The users of allocations in the United States are designated "Government," "non-Government," or "shared" (Government and non-Government). Currently in the usable radio spectrum (zero to 40 GHz), the Government allocation represents 26 percent of the total available, non-Government 30 percent, and shared 44 percent.

In making individual assignments from allocated bands, FCC and the Office of Telecommunications Policy (OTP) must consider several factors, such as propagation phenomena; bandwidth; transmitted power; type of transmission; type of antenna; locations; periodicity of use; and, increasingly, the crowded electromagnetic environment in which it will operate. Legal, economic, and social considerations affect decisions as well. Thus the management of the spectrum and assignments of its use are very complex tasks which affect nearly every segment of our population.

# CHAPTER 3

## INTERNATIONAL ORGANIZATION FOR SPECTRUM MANAGEMENT

The RF spectrum is oblivious to national boundaries. It is imperative that nations establish a common base to avoid chaos in their telecommunications. Such a base is found in the International Telecommunication Union (ITU).

### INTERNATIONAL TELECOMMUNICATION UNION

ITU is the oldest of the specialized agencies of the United Nations, created as a result of the invention of the telegraph. ITU officially began in 1865, when the first International Telegraph Convention was held to set up regulations for basic telegraph service, primarily among European countries. Currently ITU has 145 members, with its General Secretariat and other administrative bodies in Geneva, Switzerland.

The purpose of ITU is to facilitate improved efficiency and understanding in the worldwide use of telecommunications of all kinds, by

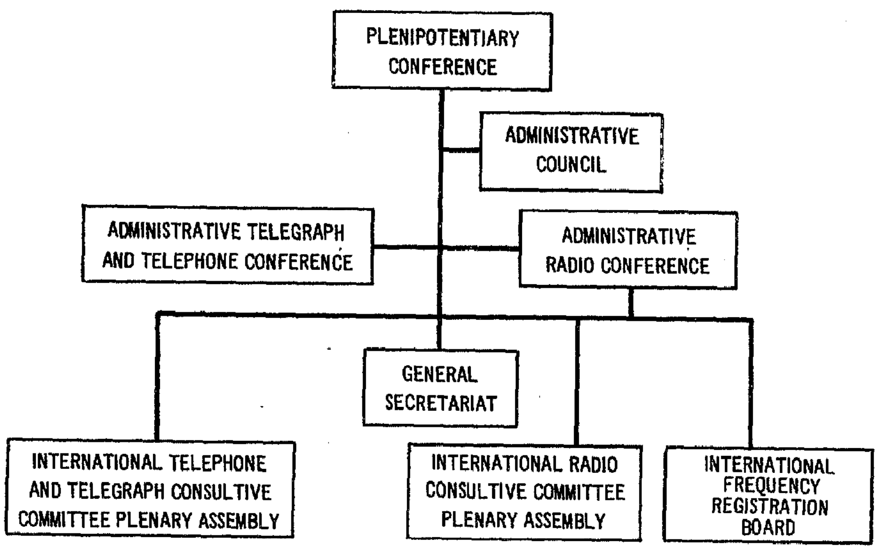
--maintaining and extending international cooperation,

--promoting the development of technical facilities and their most efficient operation, and

--harmonizing the actions of nations in attaining these common ends.

An organization chart of ITU follows.

**ORGANIZATION CHART OF THE INTERNATIONAL TELECOMMUNICATION UNION**



The Plenipotentiary Conference representatives, normally meeting every 5 to 7 years, determine the general structure and policies of ITU and revise agreements between ITU and other organizations as necessary. Within the United States, proposals on international policy are closely coordinated with all affected interests and parties by FCC and OTP. Final policy proposals are then submitted to the Secretary General of ITU, through the Department of State, some 6 or 8 months in advance of a Plenipotentiary Conference.

Specific telecommunications matters are normally submitted to an administrative conference, world or regional. For example, the concern of a World Administrative Radio Conference, commencing in April 1974, is maritime mobile telecommunications. U.S. preliminary views for this conference were developed by an ad hoc group of the Interdepartment Radio Advisory Committee (IRAC), consisting of representatives from FCC, OTP, several other Government agencies, and private industry.

U.S. preliminary views were circulated to affected interests, both at home and abroad.

Upon receipt of the national and international reactions and criticisms on the U.S. preliminary views, the final U.S. proposals were drafted, submitted to the public for comment, printed, and sent to ITU as official U.S. views. Pursuant to Executive Order No. 11556, OTP is responsible for coordinating the preparation of the U.S. positions, particularly those dealing with RF spectrum planning, allocation, and use. Because of the need for extensive coordination with the many diverse interests (industry, user groups, etc.), it may take several hundred persons 2 or 3 years to prepare for a single administrative conference.

ITU's two major international coordinating bodies, the International Radio Consultative Committee and the International Telegraph and Telephone Consultative Committee, study and issue recommendations to administrative conferences relative to technical and operational questions.

As frequency assignments are made by the different ITU members, they are recorded by the International Frequency Registration Board. The date, purpose, and technical characteristics of each assignment are provided to insure formal international recognition.

## RELATED INTERNATIONAL ORGANIZATIONS

Besides ITU, there are other international organizations concerned with use of the RF spectrum, such as the International Civil Aviation Organization and the Intergovernmental Maritime Consultative Organization, which have observer status in ITU activities (only governments obtain ITU membership). International coordination is still handled through ITU and/or the Department of State, as appropriate.

# CHAPTER 4

## NATIONAL ORGANIZATION FOR SPECTRUM MANAGEMENT

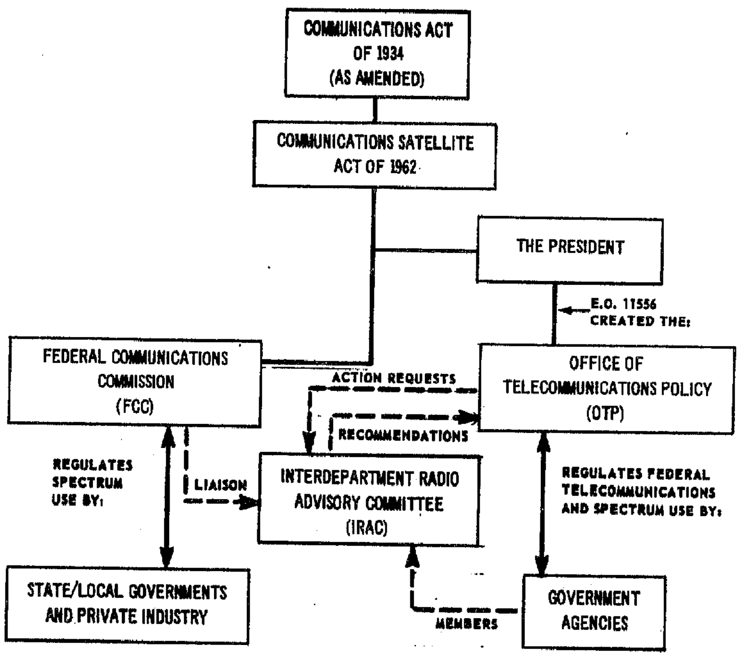
The management of RF spectrum within the United States is the responsibility of FCC and the President. This responsibility includes formulating and implementing national policies to insure the most efficient use of the spectrum.

Under the Communications Act of 1934, as amended, responsibility for regulating non-Federal Government interstate and foreign telecommunications is vested in FCC. The act specifically exempts radio stations belonging to, and operated by, the U.S. Government and provides that these stations shall be regulated by the President.

With the advent of space communications, it became necessary to provide for regulating commercial communication-satellite systems. Under the Communications Satellite Act of 1962, the regulatory authority for the U.S. part of these international systems is vested in FCC. This act also assigns responsibility to the President to help attain coordination and efficient use of the spectrum, both domestically and overseas.

Following is a diagram of the U.S. frequency management authority and a synopsis of the organization of FCC and that portion of the Executive Office of the President dealing with telecommunications policy; namely, OTP.

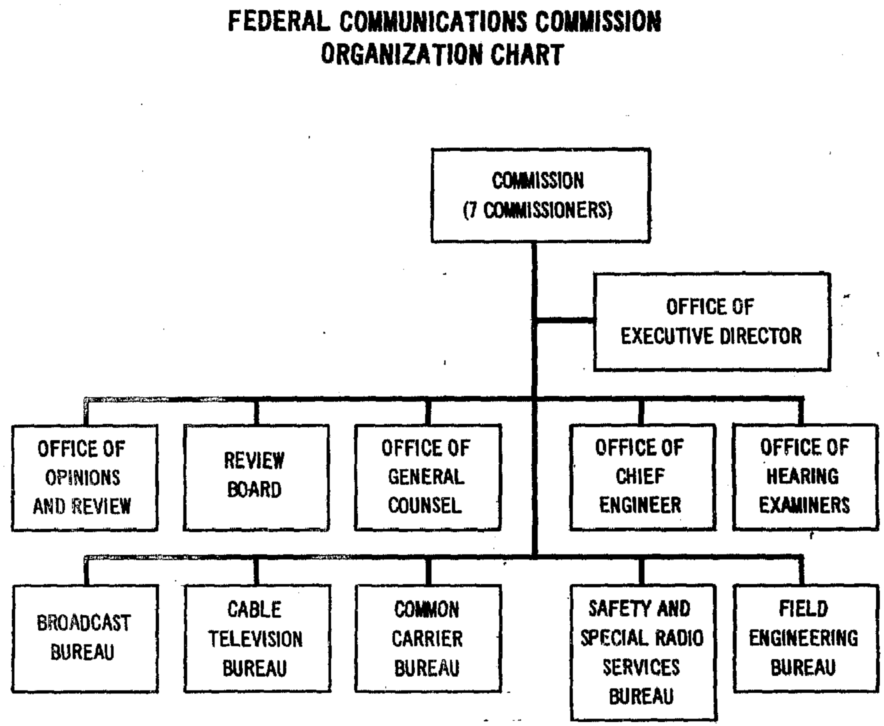
U.S. FREQUENCY MANAGEMENT AUTHORITY



FEDERAL COMMUNICATIONS COMMISSION

FCC was established in 1934 as an independent Government agency, with direct responsibility to the Congress. It is headed by seven commissioners, appointed by the President and confirmed by the Senate for 7-year terms. One commissioner is designated by the President to serve as chairman.

FCC is divided into five bureaus, each responsible for a specific segment of FCC's functions. In addition, FCC has five offices and a review board and is organized as follows:




The five bureaus and their principal spectrum functions follow.

Broadcast Bureau

1. Grants permits for station construction; authorizes frequencies; and licenses operation of AM and FM radio, UHF and VHF TV, educational TV, translator stations, and all other broadcast services.

2. Establishes rules and regulations for operation of broadcast stations. These include technical matters, such as hours of operation, power limits, frequency tolerances, use of call signs and distance separations between stations using the same or adjacent channels to prevent interference (in TV, called "taboos").

3. Negotiates international broadcasting agreements.

4. Assigns frequencies and makes engineering analyses of possible interference potential of new stations.

Cable Television Bureau

1. Approves applications for contruction of and certifies new cable television systems.

2. Develops policy and rulemaking for cable TV service, which includes technical, social, and antimonopoly matters.

3. Licenses stations in the Community Antenna Relay Service (a group of private microwave facilities used to relay TV and other signals to the cable systems).

Common Carrier Bureau

1. Issues permits for construction of and licenses operation of common carrier radio facilities, such as microwave, satellite, coastal stations, and paging services. This also includes interstate radio communications.

Safety and Special Radio Services Bureau

1. Licenses radio stations and operators designated for specialized services, such as aviation, marine, public safety, industrial, land mobile, amateur, and citizens band. (This is the largest regulated group in FCC, with over 1.7 million transmitters of various types.)

2. Establishes rules and technical standards for designing and operating safety and special radio equipment.

Field Engineering Bureau

1. Monitors radio transmissions to enforce the FCC rules and regulations and issues violation notices.

2. Tests and licenses radio operators and technicians.

3. Inspects facilities for performance and technical compliance.

The Office of Chief Engineer serves as the focal point on frequency allocation and treaty matters and functions as the engineering adviser to the commissioners and the FCC staff.

Office of Chief Engineer

1. Develops and coordinates engineering aspects of communications regulations.

2. Develops technical standards for electronic equipment and accepts/approves this equipment.

3. Formulates and recommends policies on frequency management and coordinates use of specific frequencies with OTP.

4. Formulates and recommends the allocation of blocks or bands of frequencies to the various radio services.

5. Participates in technical aspects of international communications activities.

Within the Office of Chief Engineer, two groups are active in the frequency spectrum area.

Frequency Allocation and Treaty Division

1. Designated as the FCC liaison representative to IRAC and works with OTP, IRAC, and executive agencies on spectrum matters.

2. Responsible for planning and maintaining a centralized frequency assignment data base for FCC

that records all non-Government frequency assignments usage, etc., in the United States.

3. Tasked with allocation and reallocation of spectrum for national and international use in concert with OTP.

4. Tasked with obtaining industry and public views on spectrum matters to be presented as U.S. positions in international radio conferences.

5. Responsible for assigning all call signs, both Government and non-Government.

6. Is the focal point for notifying the International Frequency Registration Board on all U.S. frequency assignments, Government and non-Government, which have international implications.

7. Responsible for resolving with OTP all Government versus non-Government interference problems.

8. Responsible for handling all international interference problems.

Spectrum Management Task Force

1. Responsible for planning and implementing the National Spectrum Management Program to realize the maximum practicable use of the radio spectrum for land mobile users.

2. Responsible for setting up and initially operating a regional spectrum management center in Chicago (Chicago Plan). Eight to ten regional centers are planned, depending on the success of the Chicago Plan.

As can be seen, frequency management in FCC is widely dispersed. We have described this in some detail because some experts have contended that improved spectrum management would result if it were placed under a single FCC manager.

OFFICE OF TELECOMMUNICATIONS POLICY

To carry out his telecommunications responsibilities, the President, under his Reorganization Plan No. 1 of 1970, established OTP (formerly the Office of Telecommunications Management).

Subsequently, on September 4, 1970, by issuance of Executive Order No. 11556, the President's responsibilities were redelegated to the Director of OTP, and include the following spectrum-related functions.

--Serves as the President's principal adviser on telecommunications.

--Develops U.S. positions for international conferences.

--Develops policies and practices for Federal Government use of the spectrum.

--Develops, in cooperation with FCC, long-range planning for better spectrum use.

--Amends, modifies, and revokes frequency assignments for Federal Government radio stations.

--Authorizes foreign government radio stations at the seat of government.

Within OTP, the Assistant Director for Frequency Management is responsible for frequency management of the Federal Government sector of the spectrum. He has four professional staff members and two consultants directly supporting his office.

OTP receives support from the Office of Telecommunications (OT), IRAC, Frequency Management Advisory Council (FMAC), and Electromagnetic Radiation Management Advisory Council (ERMAC). (See p. 20.)

OFFICE OF TELECOMMUNICATIONS

Pursuant to Executive Order No. 11556, this office was established on September 20, 1970, by the Secretary of Commerce and operates under Department Organization Order 30-5A. Its purpose is to provide analysis, engineering, and technical services (including economic and technical research) to the Director of OTP, including support of his responsibilities for frequency management. Currently, it has about 40 people involved in frequency support to OTP, including the IRAC Secretariat noted below.

In addition to maintaining its headquarters in the Department of Commerce, OT maintains the Institute for Telecommunication Science in Boulder, Colorado (where most of the research programs are conducted), and the Secretariat for IRAC in Washington, D.C.

## INTERDEPARTMENT RADIO ADVISORY COMMITTEE

IRAC was established in June 1922 to find means for making the most effective use of radio by the Government.

In earlier years, IRAC reported directly to the President. However, it now reports to OTP's Assistant Director for Frequency Management, who is also its chairman.

IRAC comprises representatives from 16 governmental departments or agencies, with a liaison representative from FCC. Its functions are to assist the Director of OTP in assigning frequencies to the U.S. Government radio stations and in developing and executing policies, programs, procedures, and technical criteria pertaining to the use of the RF spectrum.

IRAC has three permanent subcommittees--the Frequency Assignment Subcommittee, the Spectrum Planning Subcommittee, and the Technical Subcommittee--all are chaired by officials of OTP. In addition, there is the IRAC Secretariat and the International Notification Group.

## FREQUENCY MANAGEMENT ADVISORY COUNCIL

FMAC was established in June 1965, originally to voice the private sector's views on the Government's frequency management. FMAC comprises respected scientists and engineers, chiefly from the academic and industrial communities, who advise OTP.

OTP Order No. 2, dated December 31, 1972, enlarged the scope of FMAC's activities to include

--reviewing, as appropriate, recommendations of IRAC;

--reviewing the progress of electromagnetic compatibility programs; and

--developing proposed U.S. positions on spectrum matters with respect to ITU conferences.

## ELECTROMAGNETIC RADIATION MANAGEMENT ADVISORY COUNCIL

ERMAC was established on December 11, 1968, to advise and recommend to the Director of OTP constructive measures for investigating possible harmful side effects of radiation arising from intensive radio use. ERMAC comprises experts from various fields, including electronics and biomedical sciences.

## CHAPTER 5

## TECHNOLOGY

Up to the present time, technology seems to have stayed ahead of, or contributed to, solutions to serious spectrum congestion and interference. For example, transocean voice cables introduced in the midfifties provided much needed relief from spectrum crowding in the HF radio band used for fixed point-to-point overseas calls and messages. The first such cable, known as TAT-1, provided only 36 two-way voice channels, whereas TAT-6, scheduled for service in 1976, will carry nearly 4,000 two-way voice channels.

In another instance, improved transmitter and receiver designs have permitted channel splitting of VHF aeronautical radios, reducing the bandwidth (spectrum space) per voice channel from 100 kHz to 50 kHz. Effective in January 1976, when other nations are ready, another changeover will be made to 25 kHz spacing. These changes will have quadrupled the number of channels available for air-to-ground and air-to-air communications. However, these improvements have barely kept pace with the growth of aviation. The Federal Aviation Administration (FAA) projects a virtual doubling of aviation operations during fiscal years 1972-83.

Channel splitting has also provided more channels in the crowded land mobile bands (fire, police, taxi, etc.), but OTP has stated that this technique has about reached its practical limit.

Technology in fixed communications (those which operate at permanent locations) is advancing in still other ways which free it from spectrum dependency. The largest coaxial cable systems in current use carry 32,400 voice channels. The American Telephone and Telegraph Company (A.T.&T.) plans service in 1974 of a new coaxial cable which will carry 108,000 voice channels between two U.S. cities. A.T.&T. says that, about the same time, it will start field tests of a transmission system, known as millimeter waveguide,[1] which will provide about 230,000 two-way voice channels.

For the distant future, A.T.&T. scientists envision cables made of hair-thin glass fibers, each capable of carrying a wide variety of signals--voice, data,

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[1]A transmission line consisting of a conducting tube within which electromagnetic waves are propagated.

television--transmitted by laser beams. Such beams have the potential to carry a million times more messages than the entire range of frequencies we now use for communications. Someday these fibers might replace the copper wires which enter our offices and homes. These developments, of course, do not use the spectrum in the ordinary sense. Since their transmissions do not propagate into space, there is little or no potential for interference with or from other systems.

Despite these developments which reduce or eliminate spectrum dependency, there is evidence that technology is now creating demands for spectrum use faster than it is creating methods to meet those demands, principally because we have about reached the practical limits for which we can use ever higher frequencies to relieve congestion in the lower bands. Atmospheric absorption and attenuation of radio energy by rainfall at frequencies above 10 GHz seriously limits our use of such frequencies.

One area, in particular, which is creating new strains upon spectrum engineers and managers is the proliferation of space activities for a growing list of purposes (communications, meteorology, oceanography, defense, etc.). Although they offer vast and new benefits to man, these systems all use considerable spectrum space in ways which, by their nature, pose very difficult interference problems, known as electromagnetic compatibility (EMC) problems. Being latecomers for use of the spectrum, most frequencies allocated (internationally and nationally) for space applications must be shared with terrestrial uses.

Earth stations (including those aboard ships or aircraft) must use highly sensitive receivers, which make them vulnerable to interference. At the same time, they must employ very high powered transmitters which may be a prime source of interference to others. Finally, although the spacecraft operate in frequency bands which, on earth, are limited to short, line-of-sight distances, from geostationary orbit (22,300 miles over the equator) their signals can cover 42 percent of the earth's surface (and could potentially interfere with other radio systems in a large area).

However, the cause for immediate concern is not with the spacecraft but with the number and location of earth terminals and their potential interference with one another and with the widespread and growing number of terrestrial radio use, particularly land microwave links, most of which tend to converge upon the larger cities they are designed to serve.

For example, it required more than 1-1/2 years to select and clear an earth terminal site in West Virginia and involved more than 20 potential interference problems with microwave systems. There are additional problems from FAA's air traffic and military radars at or near airports serving our cities. These radars radiate undesirable secondary signals which can interfere with the reception of satellite signals. Technical corrections are costly, degrade radar performance, and may not completely suppress the interference. Finally, engineers are not certain what additional problems may occur with a large number of microwave, radar, and earth stations operating in the same environment.

The fixed communications services are also growing rapidly in our economy. Typically these include: TV broadcast (predominantly fixed), the telephone and telegraph industry, the energy industry (communications-supporting pipelines, power grids, etc.), and other industrial users. Planners for these systems are free to choose between radio systems (broadcast, microwave, or satellites) and nonradio systems (wires, cables, submarine cables, or waveguides). Their choice is usually based on cost.

Microwave congestion in or near urban areas is demanding more complex and costly engineering. For example, industry sources told us that about 6 months of coordination and computer-assisted engineering were required to select routes, tower locations, frequencies, and equipment characteristics for new microwave systems before they file license and construction applications with FCC. As of the end of 1972, FCC reported it held a backlog of some 7,260 microwave applications whose processing time, on the average, added another 6 months. Both the backlogs and the processing times have been steadily increasing.

Use of non-spectrum-dependent means of fixed communications, such as wires or cables, would conserve spectrum for use in the mobile services for which radio alone must be used. Wire or cable systems are often more costly than microwave radio systems and hence, when the choice is available, the microwave systems are usually chosen. OTP has restricted the Government's use of HF radio in domestic point-to-point service. It is also Government policy to lease communications services and facilities within the United States, other things being equal, rather than build its own. However, A.T.&T. said that about 60 percent of its long-distance facilities depend upon microwave radio. For reasons of reliability, both A.T.&T.

and Government policies favor a 50-50 split in overseas communications between cables and satellites.

It seems possible that unrestricted growth of radio in the fixed services may, in the end, stifle itself because of the increasing difficulties and costs of avoiding harmful interference in the increasingly crowded spectrum environment in or near our cities. If this development continues, new and very important radio uses might be penalized or denied by reason of spectrum already filled by established fixed services.

Another cause for future concern may arise as other nations develop a proliferation of satellites for their own purposes. The International Telecommunications Satellite Organization (INTELSAT) agreement provided some constraint. The participants have agreed not to launch or use their own satellites for international communications in ways which would cause interference problems or financial harm to INTELSAT.

No such international constraints apply to domestic or military communications satellites or to satellites used for other than communications. RCA Chairman Robert Sarnoff recently called upon ITU to take bold and imaginative steps to avert "an electronic free-for-all of worldwide dimension." He was referring to the trend toward unrestrained international communications competition with many nations wanting their own cable and satellite systems without regard for other nations' plans. Mr. Sarnoff added "Unfortunately, there is no master plan for the proper use of the great new power to communicate."

# CHAPTER 6

## PROLIFERATION OF NAVIGATION SYSTEMS

We observed a proliferation of radio navigation or locator systems, some involving the use of satellites. Most navigation systems have the same objectives although the needs for accuracy of positioning vary widely between users.

The field of radio navigation and locator systems is technically complex; affects many diverse interests (chiefly those in the maritime and aviation communities); and involves large governmental and public investments, some long standing and others developing. All navigation systems have, as their purpose, the determination of one's position and the course and distance to another position. Although there are similarities among some systems and certain systems are used by both ships and aircraft, needs for accuracy differ widely both within and between the maritime and aviation communities. In general, greater accuracy imposes higher costs and the pleasure boat or small aircraft cannot afford the range and accuracy that a supertanker or an airliner can.

Notwithstanding such differences and the need for special systems for particular classes of users, there is impressive evidence of a proliferation of systems, some duplicative, whose mounting costs must be borne by both Government and users. Such proliferation also uses extensive RF spectrum which, as previously discussed, is becoming ever more crowded. As an official of OTP recently observed, there is a pressing need for a National Radio Navigation Program. That official has estimated that one-time savings of hundreds of millions of dollars and recurring annual savings of somewhat lesser amounts would be possible from development of and adherence to such a program. He was referring to savings that may be possible by eliminating duplication and the selection of the proper mix of systems needed by military and civil users for both ships and aircraft.

The development of and adherence to such a program will not be easy. The field of radio navigation affects many different Government agencies, each with its own interests, investments, plans, and constituencies. Some of those more heavily involved are: Army, Air Force, Navy, FAA, Coast Guard, and Maritime Administration. On the civil side several powerful and vocal international interests are also affected, notably the Inter-Governmental Maritime Consultative Organization and the International Civil

Aviation Organization. Added to these are many special interest U.S. groups representing particular segments of both users and equipment suppliers.

Radio navigation systems are generally described in two categories; long-range and short-range systems. Typical of long-range systems in current use by the United States are Long-Range Navigation (Loran) systems "A" and "C", "Transit," "Omega" (recent). Except for Transit, these systems operate in the lower frequency bands (VLF, LF and MF). Users of these systems include most of the maritime community (including the world's navies) and aircraft flying over oceans (including military). Typical short-range systems include VHF omnidirectional ranging (VOR), Tactical Air Navigation (TACAN), instrument landing systems (ILS), various interim and proposed microwave landing systems, radars (air route, air terminal, and precision landing), and a growing assortment of land vehicle locator systems. These systems are predominantly used by aviation and operate in the VHF band and above.

A new class of navigation systems, such as the Navy Transit system, is made possible by satellites. Satellites can combine the advantages of long range by reason of their altitudes and accuracy by reason of their line-of-sight propagation. Hence, satellite systems have the unique technical potential for satisfying both the range and the accuracy requirements for nearly all users. Theoretically, users could tailor the complexity of their receivers to the accuracies they require and could pay for the equipment accordingly. However, current satellite navigation systems, including the receivers, are too costly for most users except when long range and high accuracy is required, such as by the military.

The principal difficulty in the radio navigation field is that, as newer and better systems come into being, older systems, even though costly for Government to maintain, cannot be closed down without economic loss to a large population of users. Loran A is a good example. It was originally installed many years ago to meet military requirements. In the near future, military use will terminate in favor of Omega. Meanwhile, many fishing and other marine interest, including pleasure craft, have acquired Loran A receivers and use the system extensively. The Coast Guard has estimated that between 12,000 and 25,000 recreational vessels carry Loran A. We were informed that much use of the Loran A is also made by foreign-flag vessels. Some Loran A receivers cost as little as $1,000.

The Government's current, direct-operating cost of the Loran A system is about $6 million a year.

FAA's operating and investment costs are partially paid through taxes on those who fly or operate aircraft. The maritime community is not similarly taxed to defray Coast Guard costs. Civil users of military-operated systems, though thought to be small in number, also do not contribute to their upkeep. Possibly some mechanism of user charges for navigation would have merit. Users would be paying their fair share, and if properly devised, such charges might provide the economic incentives for users to switch to newer systems. However, it would be difficult to identify who owns receivers and to collect from them. Moreover, if the United States were to levy user charges, other nations might decide to do likewise, which could lead to many complications. In any event, implementing legislation would probably be required.

The Navy's Transit system has been in service since 1964 but has features which limit its usefulness. Because its five satellites are in low earth orbit, position fixes are possible only at intervals of every 1-1/2 to 2 hours. This rules out Transit in its present configuration for use by aircraft or by ships other than on the high seas. Also, the complex calculations involved with Transit require a computer which, until very recently, has made equipment costly; from $30,000 and up. A Navy-sponsored development has recently demonstrated a receiver combination which, it is claimed, can be produced for under $10,000.

To improve its capability to service the submarine fleet, the Navy plans to upgrade Transit. Meanwhile, the Department of Defense (DOD) is undertaking the development of an advanced defense navigation satellite system. The objective is to obtain a secure system with worldwide continuous coverage providing high accuracy for both geographic and altitude fixes and accurate velocity data. This is the Navigation Satellite Using Time and Ranging - Global Positioning System (NAVSTAR-GPS).

Although it would be premature to select one system largely on the basis of unproved performance and uncertain costs, the longer such experimentation and developments are prolonged, the higher the risk that the Government cannot close down these systems by reasons of growing user investments. For example, DOD has assured at least one large equipment manufacturer (in comtemplation of foreign sales) that the Transit system will be in operation at least until 1980 and that the system will not be altered so as to make user equipment obsolete. In this respect, Transit, like Loran A, may be perpetuated by a large user population long after it has fulfilled its original purpose. Very recently the Coast Guard announced the phaseout of Loran A in favor of Loran C, allowing most users 5 years to changeover.

An area requiring more detailed review by GAO is interagency coordination and reconciliation of views to achieve the minimum number of navigation systems consistent with Government and civil requirements.

## CHAPTER 7

## SPECTRUM FOR SALE OR RENT

Although the RF spectrum is regulated both internationally and nationally, it is a resource which has always been considered free. Because it is a free resource, it has been argued that there are no inherent economic incentives for its conservation nor are there clear economic penalties for its waste or pollution. In recent years some economists have suggested that, if the spectrum were to be sold or rented, market forces would give rise to uses of greatest value superseding those of less or marginal worth. At the same time, they submit that a free money exchange for the resource would permit its deregulation rather than more intense regulation which seems necessary in present circumstances.

Others no doubt feel that, since the spectrum is finite and demands on it are expanding, regulation in the national interest should be increased or strengthened.

This chapter explores aspects of payment for spectrum use and increased regulation but does not evaluate the case for either reduced or increased regulation.

Chapter 5 described how technology was creating demands for spectrum use faster than it was finding ways to use it more efficiently. Therefore, we attempted to identify ways in which existing regulatory processes were trying to achieve effectiveness and efficiency. By "effective use" we mean employing the resource equitably among claimants having valid needs. By "efficient use" we mean using the minimum amount of spectrum (bandwidth, power, area of coverage, etc.) which technology requires for the use intended.

There is evidence, and some past studies have concluded,[1] that we are not making the most effective or efficient use of our spectrum resource. A major example of ineffectiveness or inequality of spectrum allocation has resulted from the growth of two-way radio in the land mobile bands used in public safety (fire, police, ambulance, etc.), industrial (public utilities, forestry, press), and land transportation (taxis, railroads, truck, etc.). By mid-1971 more than 4 million transmitters in these services were operating in some 43 MHz of spectrum space while only 25 percent of some 420 MHz allocated for UHF TV was being used.

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[1]See app. I.

Temporary relief for land mobile users was arranged by FCC when licenses were granted in August 1971 to permit their sharing one or two of the seven lowest channels of the UHF TV band (TV channels 14 to 20) in the 10 largest U.S. cities. Additional relief is in prospect from the reallocation of UHF TV channels 70 through 83, of which some 40 MHz will be available for private land mobile use.

Indications of ineffectiveness and congestion can be found in other parts of the spectrum, such as those noted in chapter 5, involving aeronautical radio and microwave radio relay plus several Government bands, particularly those used in space applications.

But the more pressing problem appears to be the inequalities of spectrum allocations in the VHF and UHF bands below 1,000 MHz. The Spectrum Planning Subcommittee of IRAC (with FCC participation) is tasked to study this problem. Early in 1974 when our study was completed, the Subcommittee's studies had not yielded results adequate for evaluation. In view of the problems in the VHF and UHF bands, the results and effectiveness of the Subcommittee's studies should be the subject of more detailed review by the Director OTP, and the Chairman, FCC.

On the positive side, the Federal Government, under OTP's guidance, has relinquished large portions of the super and extremely high frequency bands which had been previously allocated exclusively for Government use.

| Spectrum from zero to 40 GHz | 1969 | 1973 |
|---|---|---|
| Exclusive Federal Government | 42% | 26% |
| Exclusive non-Federal Government | 34 | 30 |
| Shared | 24 | 44 |
| Total | 100 | 100 |

OTP is continuing its efforts to share more of the spectrum previously allocated exclusively for Government use.

With respect to the efficiency of spectrum use, congestion problems in the aeronautical and land mobile bands induced successive steps of channel splitting to obtain relief. Congestion itself is some incentive for conservation or better efficiency. Unfortunately, however, countervailing influences--principally economics--generally dominate. Research and development leading to less use or more productivity per MHz of the spectrum is expensive and rarely benefits the sponsor but more likely benefits someone else who may then use the spectrum saved.

TV broadcast currently uses 408 MHz, or 44 percent of the highly valued portion of the spectrum from 30 to 960 MHz. We were informed, for example, that today's technology would make it possible to use about half the 6 MHz of spectrum which is now allocated for each TV channel. We were told that this could be done without degradation of picture or sound quality while also permitting a reduction in the geographical distances (called taboos) between adjacent or identical channel reuse. The latter would allow many more stations in the TV bands. The problem, however, is that the change would require new TV receivers of considerably different design.

By 1971 more than 95 percent of the nation's homes had TV sets and more than half of the 190 million receivers built up to the time were still in service, representing a public investment in excess of $16 billion.

Such large and growing public investments, of course, frustrate spectrum planners in their search for conservation. While deferring considerations which could threaten the public investment, FCC is considering stricter equipment standards which would make future TV receivers less susceptible to adjacent channel and other interference. This would allow relaxation of the taboos and permit more VHF TV broadcast stations.

The radio spectrum management community is well aware of the inefficiencies in spectrum allocation and use. OTP has concluded that regulatory pressures alone have not brought about effective and efficient use of the spectrum. Additional measures are needed.

One new measure being considered by OTP involves an experiment in spectrum charge or rental. As noted earlier, some economists have argued that spectrum charge not only would promote more effective use of the resource but also would provide economic incentives for its conservation or efficiency of use while economically penalizing users who waste or pollute the spectrum. In short, system planners would be forced to consider the trade-offs between lower cost equipment which might be spectrally wasteful with higher cost equipment which would use less spectrum. Such a scheme would also, of course, provide added economic incentives for the use of wire or cables in lieu of radio in the fixed services.

Spectrum charge would be based broadly upon radio propagation characteristics which make some parts of the spectrum more suitable for certain uses than others and specifically upon (1) bandwidth (spectrum occupancy), (2) area of coverage (denial of use by others), and (3) periodicity of use. Such a formula would differ markedly from license fees currently charged by FCC, which bear little relationship to spectrum occupancy.

Spectrum rental could create problems no less difficult than those it would try to solve. Many values of spectrum use are difficult to measure in economic terms. How can one quantify the values of missile defense or safety of life? Also, when one pays for rights to a resource, he reasonably expects protection from infringement. Suppose, for example, he rents a frequency for a microwave link from his business to a point 25 miles distant and later someone erects a 20-story building some miles away but directly in the path of his microwave, blocking its operation. To whom could the spectrum renter look for redress? In other parts of the spectrum, nature itself creates anomalies, such as sunspots, aurora, lightning, or rainfall, which can interfere. It may be possible, of course, to provide for such eventualities in the rental contracts and thereby minimize litigation.

An experiment being considered by OTP would involve charges for the 2,700 to 3,700 MHz band which is allocated chiefly for radar and which is used principally by the Federal Government. Hence, users in the public sector should not be involved. This experiment would involve principally FAA, the Department of Commerce, and DOD and would not be complicated by certain technical and operational problems which would be encountered in other bands.

The fiscal implications or administrative and technical practicalities of such an experiment should be explored if we are to make the most effective and efficient use of our increasingly valuable spectrum resource.

An alternative to spectrum charge would be increased regulation. This course would compel users to furnish more data on equipment and its usage and would require more stringent equipment standards, improved engineering and EMC analysis, and stepped up monitoring and enforcement. Our report on "Fundamental Changes Needed to Achieve Effective Enforcement of Radio Communications Regulations" (B-159895, Nov. 3, 1972) cited deficiencies and laxity in present monitoring and enforcement practices. Such measures not only would increase the costs to users but also would require a substantial increase in the resources devoted to spectrum management in both the Federal and civil (FCC) sectors. Finally, tough rules may offend many interests and would take resolve to administer. For example, abuses in the Citizens Radio (such as unlicensed operation and gross violation of regulations) suggest that FCC might require confiscatory authority over those who refuse to conform.

In either case, spectrum charge or increased regulation (or some combination thereof) would require legislation to implement.

## CHAPTER 8

## SPECTRUM POLLUTION--A BIOLOGICAL HAZARD

Management of spectrum allocation presents one type of problem. But attention may also be needed to determine the effects upon our environment from exposure to increasing levels of RF energy.

The United States is experiencing an extraordinary growth of radiating and potentially radiating equipment, such as transmitters, radars, televisions, and microwave ovens. For example, by the end of fiscal year 1971, FCC had authorized over 8.8 million transmitters for use in the United States. This is more than three times the number authorized through fiscal year 1961. There is growing concern among some scientists that the continued increases of radiating equipment may be leading to spectrum pollution of our environment, particularly in areas of intensive radio use.

Because manmade radiation is relatively new, knowledge of its possible biological hazards is limited and not fully verified. Scientists have established that microwave and other radiating equipment operating at certain frequencies and higher power levels generate heat causing intense burning. In other cases, exposure may induce cataract formation. U.S. scientists have not determined the extent and importance of subtle changes which may occur from long-term exposure at lower intensities. Nevertheless this has been a matter of concern to a number of Federal and non-Federal Government agencies.

Controversy exists among scientists over the significance of low-level radiation effects. Soviet and other Eastern European scientists have published numerous research papers on the effects to the nervous system of low-level exposure. Some U.S. scientists believe these papers are inconclusive because they are summary in nature and difficult to interpret.

In the United States the maximum recommended power level for continuous human exposure to radio energy (at frequencies above 10 MHz) is 10 milliwatts per square centimeter. The U.S.S.R. has set a figure of 10 microwatts per square centimeter, a standard 1,000 times more stringent than ours. However, differences in what United States and Soviet scientists interpret as effects and safety hazards may account for some of this variance.

Legislation had led to the prescribing of safety standards on certain radiating equipment. For example, as a result of the "Radiation Control for Health and Safety Act of 1968" (Public Law 90-602), a mandatory performance standard was set on microwave ovens which prescribes the maximum allowable radiation leakage. Also, under the "Occupational Safety and Health Act of 1970," an occupational safety standard has been set for radiation in the bands from 10 MHz to 100 GHz. This standard sets the power levels of radiation referred to above.

At present, our major radiation effects research programs are conducted by DOD; the Department of Health, Education, and Welfare (HEW); and the Environmental Protection Agency (EPA). Total Government expenditures in this area were approximately $5.5 million for fiscal year 1973.

In December 1971, ERMAC (see ch. 4 for description) proposed a program to the Director of OTP, recommending that cognizant Government agencies coordinate efforts to survey, test, and research for the control of electromagnetic pollution. The program's intent is (1) to evaluate the significance of long-term, low-level RF radiation in the environment and (2) to investigate the possible biological hazards. The proposed expenditure for a 5-year program (FYs 1974-78) ranges from $10 to $15 million annually (two or three times the present level) with an overall 5-year estimate of $63,435,000. DOD, HEW, and EPA would provide over 80 percent of this proposed funding, as follows:

| | |
|---|---|
| DOD | $25,100,000 |
| HEW | 15,175,000 |
| EPA | 12,910,000 |
| | $53,185,000 |

OTP is responsible for coordinating overall research efforts of the participating agencies to eliminate unintended duplication. ERMAC advises and assits OTP in this effort. For intergovernmental coordination, a Side Effects Working Group has been formed within the IRAC Technical Subcommittee (chaired by an OTP representive). OTP has taken the initial steps in emphasizing the need for action and defining what needs to be done.

Several problems which may hinder the success of the ERMAC program are:

--It is not now visible at a high level within the agencies (not a line item in agency budgets).

--The lack of expertise in this new field may result in slow progress.

--The basic research money is less than the amount recommended by OTP-ERMAC.

--Industry seems to be reluctant to put money into this area.

This matter should be the subject for more detailed review by GAO at some future time.

## CHAPTER 9

## WILL PERSONNEL RESOURCES BE ADEQUATE

## FOR FUTURE SPECTRUM MANAGEMENT?

As was noted, communications growth has outpaced all other industries for the past 20 years. We have also seen how spectrum crowding in some bands, particularly in areas of intensive radio use, threatens to stifle future communications growth unless new or improved measures can be found to achieve more effective and efficient use of the spectrum. Chapter 6 discussed the possibility of user charges for navigation systems, and chapter 7 described a new measure being considered, namely, a charge for spectrum use. As another alternative, intensified spectrum regulation may be necessary. Finally, some combination of these measures may be needed. In any case, increased spectrum management resources would be needed to administer such measures.

We briefly examined the Government's spectrum management personnel resources in both Federal and civil sectors with the following results.

### THE FEDERAL SECTOR

The numbers of people and their technical competency were declining in the agencies examined. For example, figures for DOD (excluding a few overseas personnel) show:

| | 1967 | 1973 | Percent change |
|---|---|---|---|
| Army | 50 | 27 | -46 |
| Air Force | 36 | [a]24 | -33 |
| Navy | 58 | [b]25 | -57 |

[a]Ten spaces to be added in FY 1974.

[b]Five spaces of recent retirees unfilled at time of our inquiry.

In addition, two of the services have reduced the grade levels of their senior frequency managers. This could discourage talented young officers from seeking a career in frequency management.

Beyond obtaining the above figures for DOD, we did not make a manpower analysis of all personnel involved with the spectrum in the Federal Government (as discussed later, we did some analysis in FCC). However, we received a number of unconfirmed allusions to an erosion of competence and the numbers of people in the frequency management community.

An example of potential concern is U.S. participation in an international frequency conference to be held in 1979 to consider major reallocations of spectrum designed to meet international and national needs well into the next century. We understand that U.S. dominance of past major conferences, although not unchallenged, has been a leading factor in promoting U.S. economic and Government interests at home and abroad. Decisions reached at these conferences bind the participating nations for many years. An official of OTP stated that few U.S. representatives attending the 1979 conference will have had experience in international negotiations. The lack of experienced representatives may jeopardize U.S. interests.

According to OTP, an in-depth EMC analysis is needed to determine the potential interference which may result from the simultaneous operation of some 30 prospective and existing space, airborne, shipborne, and terrestrial systems in 5 discrete bands. Implementation of these systems will involve expenditures in the hundreds of millions of dollars, and it is important to analyze and predict potential interference before such large expenditures are incurred if changes and added costs are to be minimized. Despite such need, we were advised that OT, which supports OTP in such matters, had sufficient qualified staff to address only 2 of the 30 systems in 1973. A serious interference problem arising in any 1 of these 30 systems might be costly to resolve, if not identified before major funds are committed.

## THE CIVIL SECTOR

FCC regulates non-Federal Government (industry, local government, and private) use of the spectrum. Frequency management within FCC is divided among the five bureaus (Broadcast, Cable TV, Common Carrier, Field Engineering, and Safety and Special Radio Services). In addition, the Office of the Chief of Engineers performs important frequency management functions, including liaison with IRAC and its subcommittees.

Both DOD and OTP conduct extensive EMC analysis to predict interference which might result from the operations of new or planned equipment in areas of intensive radio use. OTP's Circular 11, effective January 1, 1973, is designed to withhold budgetary approvals of any Federal agency for research and development or procurement of equipment before assured spectrum availability. FCC makes the users of spectrum responsible for any EMC analysis which might be required. For the sophisticated users, such as the telephone and telegraph industry, it is obviously in their self-interest to choose equipment, routes, and frequencies which will avoid interference to or from other systems. In fact, these industries probably would not make their investments on the basis of someone else's engineering. Conversely, the unsophisticated user must depend either on equipment suppliers or on companies in the engineering services business to advise what equipment and frequencies should be used. Though requiring the users to make their own EMC analysis seems to have worked reasonably well, the increased sharing of the spectrum between Government and civil users may force FCC, in the future, to develop its own EMC analysis capability. FCC's current resources could not likely support such efforts.

FCC's Common Carrier Bureau is attempting to process microwave license applications manually to verify complex engineering detail which industry often prepares with the aid of computers. Such a method, in the face of mounting backlogs in applications, suggests that the FCC have a computer capability for engineering verification no less capable than that of the industries it serves.

According to FCC officials, there is a pressing need for a centralized data base to be used by all bureaus. FCC has obtained a new computer system for its Spectrum Management Task Force in Chicago, but its data base is presently limited to land mobile licenses in the Chicago area.

FCC is designing a program to collect data on all microwave systems, which would consist of an on-line computer accessible to all carriers.

As one indicator of FCC's workload in frequency management, we compared the number of personnel assigned with the number of radio licenses issued for 1968 and 1972. Only Washington-based people were counted.

| FCC bureau | Number of personnel 1968 | 1972 | Increase | Number of licenses issued 1968 | 1972 | Increase |
|---|---|---|---|---|---|---|
| Broadcast | 247 | 266 | 7.7% | 23,125 | 27,670 | 19.7% |
| Cable TV | 22 | 32 | 45.5 | [a]61 | 508 | 568.9 |
| Common Carrier | 138 | [b]117 | -15.2 | 13,376 | 22,315 | 66.8 |
| Field Engineering | 72 | 78 | 8.3 | 3,135,697 | 3,648,267 | 16.3 |
| Safety and Special Radio Services | 139 | 148 | 2.9 | 1,723,098 | 1,779,931 | 3.3 |

[a]Cable TV was in its infancy in 1968.

[b]Excluding 50 assigned to A.T.&T. rate case.

We did not make an in-depth determination whether the increased ratio of licenses to staff resulted from increased productivity of the staff, a reduction in the quality of the engineering review of license applications, or inordinate delays in license processing.

The Common Carrier Bureau of FCC was experiencing problems. At the time of our study, processing times for microwave construction permits and licenses were running 7-1/2 months behind. Industry sources we contacted could not estimate their dollar costs from such delays, but they said that the delays did increase their risks since they usually must decide upon and order equipment well in advance of filing for licenses.

Although Government frequency managers do not foresee a spectrum crisis, resembling our energy problems, the gathering problems in spectrum management indicate the need for increased public and official attention.

## CHAPTER 10

## FUTURE PROBLEMS IN SPECTRUM MANAGEMENT

In the earliest days of radio in the United States, civil use and experimentation caused interference to military and Coast Guard radio operations. To minimize such interference, the Congress, in the Radio Act of 1912, provided that certain frequencies[1] belong exclusively to the Government. The same act also authorized the President to control all radio emissions in time of war.

This philosophy was continued and expanded upon in the Radio Act of 1927. This act created the Federal Radio Commission with the power to authorize frequencies and issue licenses for radio stations for civil use but exempted radio stations owned and operated by the Federal Government. The responsibility to regulate frequencies and radio use by the Government was given to the President. The act also authorized the President to preempt the use of any communications, if necessary, in time of war or threat of war. The Communications Act of 1934, which created FCC, contained these same general provisions.

The concepts of the Government having its own frequencies and the President's communications-related war emergency powers have been in effect since 1912, and the division of frequency management between the President and the Federal Radio Commission (now FCC) has been in effect since 1927.

The final report by the President's Task Force on Communications Policy, December 7, 1968, alleged inherent inefficiencies in the division of spectrum management between FCC and the Office of Telecommunications Management (now OTP). The report recommended that spectrum management be consolidated in the Office of the President. Conversely, there have been other proposals, such as a bill recently introduced in the Senate, which would transfer all OTP's functions--including spectrum management--to FCC and abolish OTP.

The question of how and where frequency management should be performed is a matter for the Congress to consider and resolve. Some of the more significant factors and

[1]By 1912 we knew how to use frequencies only from 150 to 1,000 kHz, which is about one-eighth that needed for one TV channel.

observations which we believe should have a bearing on this matter follow.

In chapter 1 we said that about 55 percent of the total U.S. investment in radio and radar belongs to the Federal Government and 45 percent belongs to industry, local government, and the public. Conflicts of interest could arise from the executive branch (Office of the President or another executive agency or department) being the major user as well as the purveyor of all spectrum.

There might be some reluctance on the part of the executive branch to rule against itself if, for example, defense or air traffic safety needs were competing with commercial broadcast or common carrier needs. Conversely, if FCC were to manage all spectrum, it would be in the position of adjudicating issues between itself, as the agent of Government users, and the industry which it regulates. Such a relationship could impair the appearance, if not the fact, of impartiality in FCC's regulatory processes. It may be that the communications industry, on the one hand, would strongly resist executive branch management of all spectrum as inimical to its interests while Federal agencies would equally resist its management by FCC.

There are significant differences between the policies and methods which can appropriately be used for frequency management in the Federal sector as opposed to those which may be used for the civil sector. Some important Government uses of the spectrum are highly classified, notably many used by the intelligence community and those used in certain weapons systems. Some Government uses also require urgent frequency actions such as those which occurred when troops were called in during the Washington disturbances of 1968. Such matters could not countenance either the public scrutiny or the delays which characterize FCC's hearing processes. The Government frequency sector is highly structured and disciplined and therefore susceptible to planning ahead with high confidence in comparison with the civil sector. Decisions in the Government sector, although not always easy, can nevertheless be authoritative. By contrast, the civil sector is unstructured and subject to the pressures of many diverse user and special-interest groups. Planning is much less certain and decisions must usually await the arduous process of public hearings and quasijudicial procedures.

It appears that, if a single frequency "czar" were established, he would have to divide his own resources and management methods along lines paralleling present arrangements or risk serious penalties to either or both communities. The vast majority of matters and actions affecting both the Federal and civil sectors are resolved in the daily coordination between the FCC and IRAC and its subcommittees. These arrangements seem to have worked reasonably well. We found no instances when an issue had not been resolved at or below the FCC Chairman-OTP Director level.

Nevertheless, as the use of the spectrum increases, competition for this finite resource will increase. Public and private needs versus those of Government could progressively find themselves in conflict. If this happens, then a more authoritative arrangement for resolving these conflicts will be needed than the cooperative interaction now prevailing between FCC and OTP.

## CHAPTER 11

## SCOPE OF STUDY

We made our study in Washington, D.C., at the Office of Telecommunications Policy, Executive Office of the President; Office of Federal Communications Commission; Office of Telecommunications, Department of Commerce; Office of the Assistant Secretary of Defense (Telecommunications), Department of Defense; and the Federal Aviation Administration and U.S. Coast Guard, Department of Transportation. We also made this study at Army, Navy, and Air Force installations in the Washington, D.C., and Norfolk, Virginia, areas.

We (1) studied legislations, regulations, policies, procedures, and practices pertaining to Federal use and management of the radio frequency spectrum, (2) reviewed records and documents and interviewed agency officials at the various headquarters and selected Army, Navy, and Air Force field installations, (3) obtained the views of communications industry representatives in relevant areas, and (4) sought the advice of cognizant agency officials; however, we did not obtain formal comments from the agencies.

APPENDIX I

## SPECTRUM MANAGEMENT STUDIES

| | |
|---|---|
| 1952 | "Radio Spectrum Conservation"<br>Joint Technical Advisory Committee<br>Institute of Electrical and Electronic Engineers |
| 1964 | "Radio Spectrum Utilization"<br>IEEE and Electronic Industries Association (EIA) |
| 1966 | "A Report of Frequency Management Within the Executive Branch of Government"<br>Office of Telecommunications Management (OTM) |
| 1966 | "Electromagnetic Spectrum Utilization--The Silent Crisis"<br>Commerce Technical Advisory Board |
| 1967 | "Final Report of the Advisory Committee for Land Mobile Radio Services"<br>Federal Communications Commission |
| 1968 | "Spectrum Engineering--Key to Progress"<br>IEEE and EIA<br>(A 4-year study) |
| 1968 | "Final Report," President's Task Force on Communications Policy; Eugene V. Rostow, Chairman |
| 1969 | "The Radio Frequency Spectrum--United States Use and Management"<br>OTM |
| 1973 | "The Radio Frequency Spectrum--United States Use and Management"<br>Office of Telecommunications Policy |

# PRINCIPAL OFFICIALS OF MAJOR FEDERAL AGENCIES RESPONSIBLE FOR ADMINISTRATION OF ACTIVITIES DISCUSSED IN THIS STUDY

| | Tenure of office | |
|---|---|---|
| | From | To |
| **DEPARTMENT OF COMMERCE** | | |
| SECRETARY OF COMMERCE: | | |
| Frederick B. Dent | Mar. 1973 | Present |
| ASSISTANT SECRETARY OF COMMERCE FOR SCIENCE AND TECHNOLOGY: | | |
| Betsy Ancker-Johnson | May 1973 | Present |
| **DEPARTMENT OF DEFENSE** | | |
| SECRETARY OF DEFENSE: | | |
| James R. Schlesinger | July 1973 | Present |
| OFFICE OF DIRECTOR, TELECOMMUNICATIONS AND COMMAND AND CONTROL SYSTEMS (note a): | | |
| Thomas C. Reed | Feb. 1974 | Present |
| David L. Solomon (acting) | Sept. 1973 | Feb. 1974 |
| Eberhardt Rechtin | Feb. 1972 | Sept. 1973 |
| **DEPARTMENT OF TRANSPORTATION** | | |
| SECRETARY OF TRANSPORTATION: | | |
| Claude S. Brinegar | Feb. 1973 | Present |
| COMMANDANT, U.S. COAST GUARD: | | |
| Adm. Owen W. Siler | June 1974 | Present |
| Adm. Chester R. Bender | Apr. 1970 | June 1974 |
| ADMINISTRATOR, FEDERAL AVIATION ADMINISTRATION: | | |
| Alexander P. Butterfield | Mar. 1973 | Present |
| **FEDERAL COMMUNICATIONS COMMISSION** | | |
| CHAIRMAN: | | |
| Richard E. Wiley | Mar. 1974 | Present |
| Dean Burch | Oct. 1969 | Mar. 1974 |

| | Tenure of office From | To |
|---|---|---|
| CHIEF ENGINEER: | | |
| Raymond E. Spence, Jr. | Apr. 1971 | Present |

OFFICE OF TELECOMMUNICATIONS POLICY

| | From | To |
|---|---|---|
| DIRECTOR: | | |
| Clay T. Whitehead | Sept. 1970 | Present |
| ASSISTANT DIRECTOR, FREQUENCY MANAGEMENT: | | |
| Wilfrid Dean, Jr. | [b]Dec. 1967 | Present |

[a]Before February 1974, this office was Assistant Secretary of Defense (Telecommunications).

[b]Tenure includes time with the Office of Telecommunications Management, predecessor to OTP.

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