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Spectrum Management: Auctions

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Summary

Spectrum policy issues before Congress are characterized by economic, technological and regulatory complexity. An increasing number of public comments have criticized the effectiveness of spectrum management and policy in the United States. Questions regarding the role of auctions in spectrum management are of immediate concern because congressional authorization of the existing auction process expires in 2007. Proceeds from spectrum sales are presently attributed to general revenue in the U.S. Budget. The 108th Congress is expected to consider the passage of a Spectrum Relocation Fund (H.R. 1320, Representative Upton) that will use some auction proceeds to cover the expenses of federal agencies that are relocating to new frequencies in response to spectrum management decisions. Other bills that propose the establishment of trust funds are: H.R. 1396 (Representative Markey); S. 1854 (Senator Dodd) and H.R. 3370 (Representative Stupak).

Spectrum, a valuable resource governed by available technology, is regulated by the federal government with the primary objectives of maximizing its usefulness and efficiency, and to prevent interference among spectrum users. A key component of spectrum policy is the allocation of bands for specific uses and the assignment of frequencies within those bands. Auctions, a fairly recent innovation in frequency assignment, are regarded as a market-based mechanism for allocating spectrum. Other market-driven policies include licensing fees based on fair-market valuations of spectrum and flexibility in spectrum usage within assigned bandwidths.

Today, spectrum for commercial applications is typically auctioned to the highest bidder, but many commercial users have spectrum acquired before the present-day auction process was implemented. In these cases, the spectrum may have been received for free or through a lottery, to name some methods of distribution. Spectrum for public safety and federal government use is assigned, not auctioned. Thus, a limited amount of spectrum is available through the auction process for commercial use and development.

After years of debate over the idea of using auctions to assign spectrum licenses, Congress authorized the Federal Communications Commission (FCC) to establish an auction process to award spectrum licenses for certain wireless communications services (Omnibus Budget Reconciliation Act of 1993). In the Balanced Budget Act of 1997 and the Auction Reform Act of 2002, Congress established conditions regarding some auctions. Also before Congress is a proposal to clarify auction rules to be followed by the FCC (H.R. 4715, Representative Nussle).

This report will be updated.

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Spectrum policy covers both satellite and terrestrial (primarily antenna broadcast) transmissions. The issues discussed here refer principally to spectrum management for terrestrial technologies. International satellite frequencies are not allocated by the auction process.

Radio frequency spectrum is used for all forms of wireless communications including cellular telephony, paging, personal communications service, radio and television broadcast, telephone radio relay, aeronautical and maritime radio navigation, and satellite command and control. Wireless (radio frequency) spectrum is measured in cycles per second, or hertz (Hz).[1] Spectrum allocations are assigned within bands that are divided into bandwidths or channels with assigned frequencies.

Spectrum is a natural resource[2] with a combination of characteristics that differentiate it from other resources. For example, spectrum is:

- Finite. Today's technology can only operate on certain frequencies; commercially viable frequencies are a scarce commodity.
- Renewable. Airwaves used to broadcast any transmission can be reused after the broadcast is completed.
- Technology dependent. Most natural resources can be harvested manually, albeit inefficiently. Spectrum is in the atmosphere and is usable because technology has been developed to exploit the properties of electromagnetic waves for sound, data and video transmission.
- A national asset with international rule and regulations. For example, most domestic uses of spectrum are assigned bands of operation through the International Telecommunications Union, an agency of the United Nations; satellites for broadcasting are governed by international treaty.
- Administered. To avoid interference from competing broadcast transmissions, frequency assignments must be managed by recognized authorities.

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[1] Standard abbreviations for measuring frequencies include kHz — kilohertz or thousands of hertz; MHz — megahertz, or millions of hertz; and GHz — gigahertz, or billions of hertz.

[2] The Code of Federal Regulations defines natural resources as "land, fish, wildlife, biota, air, water, ground water, drinking water supplies and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States..." (15 CFR990, Section 990.30).

The development and implementation of better wireless communications technologies is critical for maximizing the efficiency of spectrum resources. Spectrum management policies ideally should take into account the impact of new technology, or — since it is difficult to predict the development paths of new technologies — allow for flexibility and accommodation in spectrum allocation. Although flexibility may be desirable in policy-making, most existing wireless technologies are inflexibly constructed to work on a limited range of specific frequencies. Relocation from one part of the spectrum to another can require costly equipment changes. Therefore, reallocation of spectrum to new uses is often expensive as well as technically and administratively difficult. Additionally, some uses of spectrum are governed by international regulations.

Spectrum policy originated in the need to manage frequency assignments. Auctions are a market-driven solution to allocating frequencies. Auctions, also, are a recent innovation in spectrum management and policy. The auction process assigns a monetary value to spectrum. The Federal Communications Commission (FCC) manages all non-federal spectrum, including that used by state and local governments. Among other responsibilities, the FCC supervises spectrum auctions. The National Telecommunications and Information Administration (NTIA) manages all spectrum used by the federal government, including the Department of Defense (DOD). The NTIA — part of the Department of Commerce — also serves as the principal adviser to the executive branch on domestic and international telecommunications issues. The NTIA and the FCC work together to coordinate spectrum policy.

Many economic models for providing the "highest and best use" for spectrum exist and have been tried, both in the United States and worldwide. Spectrum for what is widely described as "prime" frequencies (300 MHz - 3000 MHz) is judged by many to be the most commercially desirable and is widely sought after at auction by competing interests.[3] Several lucrative auctions have added billions to the federal treasury, applied to general revenue. Various proposals have been introduced in recent years that would use auction proceeds for purposes such as funding public safety telecommunications needs; paying for defense; covering the costs of relocating federal agencies now occupying prime frequencies to less commercially desirable spectrum; and financing social needs, such as education. There is no single, or simple, answer that resolves all the questions of economics, fairness, security, and global competitiveness.

Spectrum Management and the 108th Congress

A pressing issue in spectrum policy reform regards spectrum auctions. The FCC's auction authority expires at the end of 2007. To ensure continuity, by that time Congress must pass legislation either to extend the existing authorization or to modify the laws governing spectrum auctions. The issue is bipartite: both the manner

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[3] Federal Communications Commission, Office of Plans and Policy, OPP Working Paper Series No. 38, "A Proposal for a Rapid Transition to Market Allocation of Spectrum," November 2002 [http://hraunfoss.fcc.gov/edocs_public/attachmatch/DOC-228552A1.pdf]. Viewed June 28, 2004.

of spectrum allocation (auction or other method) and the use of the proceeds are of importance and interest to Congress. The 108th Congress is considering several legislative issues related to spectrum management, including the use of special funds to direct auction proceeds for specific purposes and an amendment to the Communications Act of 1934 that would alter the FCC's rules for using auctions.

Regarding special funds, H.R. 1320 (Representative Upton) and its companion bill, S. 865 (Senator McCain), would establish a trust fund for reimbursing the costs of moving federal users to new spectrum frequencies. H.R. 1396 (Representative Markey) would allot $5 million from spectrum auction proceeds to reimburse federal users for the cost of moving to other frequencies and place the balance in a Digital Dividends Trust Fund for diverse purposes. S. 1854 (Senator Dodd) would create a Digital Opportunity Investment Trust that would use 30% of certain spectrum revenue through 2020 to foster programs for "innovative telecommunications and information technologies." H.R. 3370 (Representative Stupak) would create a Public Safety Communications Trust Fund to fund the implementation of modernization and interoperability.[4] Among the points these bills have in common is that they specify certain frequencies for auction, precluding other methods of allocation. The implied assumption in all these proposals for trust funds is that auctions generate desirable levels of measurable revenue in a short time frame.

The Communications Act of 1934 (as amended) gives the FCC the authority to decide when auctions are necessary and generally grants the FCC the authority to use auctions when "mutually exclusive applications are accepted for filing for any initial license."[5] H.R. 4175 (Representative Nussle) targets the perceived intention of the FCC to avoid the above-quoted requirement in the case of Nextel Communications. The FCC is expected to okay a spectrum swap that would give Nextel new spectrum at 1.9 GHz as compensation for lost spectrum and the costs of relocating from frequencies at 800 MHz, a move intended to alleviate interference to public safety channels in the 800 MHz band.[6] This move has been decried by many, especially rival carriers such as Verizon Wireless, as a spectrum "windfall" for Nextel.

Placing spectrum auction decisions within the broader context of a national spectrum policy, the focus shifts to planning and oversight. Arguably, the controversy over Nextel might have been avoided if the FCC had formulated a coherent spectrum policy for public safety. Congress may consider reviewing the roles of the FCC and NTIA in implementing spectrum policy. The General Accounting Office (GAO) in a study released in 2002,[7] was critical of FCC and NTIA spectrum management policies. Among its recommendations was a suggestion that the NTIA and FCC prepare reports for Congress on developing a national spectrum policy. The GAO report contends that the United States is lacking a

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[4] For more details, see CRS Report RS21508, *Spectrum Management: Special Funds*.

[5] Communications Act of 1934, 47 U.S.C. 309 (j) (1).

[6] For more details, see CRS Report RL32408, *Spectrum Policy: Public Safety and Wireless Communications Interference*.

[7] *Better Coordination and Enhanced Accountability Needed to Improve Spectrum Management*, GAO-02-906, September 30, 2002

cohesive policy, with negative consequences both domestically and in international negotiations. A follow-on report from the GAO, released in early 2003,[8] recommended that Congress consider establishing an independent commission to evaluate the need for spectrum management reform. These reports were prepared at the request of Senators Burns, Hollings, Inouye and Kerry.

A report released by the Republican Main Street Partnership[9] has advocated the participation of the Department of Homeland Security in spectrum negotiations. The report noted the importance of spectrum because it is integral to the communications of homeland security response. It called for the creation of a spectrum-management function within DHS and stressed the need to "review and establish a clear picture of the frequency spectrum needs of the Department" and other agencies, including state and local agencies, with which DHS will be operating.

Spectrum Auctions

Because two or more signal transmissions over the same frequency in the same location at the same time could cause interference (a distortion of the signals), the FCC, over many years, has developed and refined a system of exclusive licenses for users of specific frequencies.[10] Traditionally, the FCC granted licenses using a process known as "comparative hearings" and later using lotteries. After years of debate over the idea of using competitive bidding (i.e., auctions) to assign spectrum licenses, the Omnibus Budget Reconciliation Act of 1993 (47 U.S.C. 927) added Section 309(j) to the Communications Act, authorizing the FCC to use auctions to award spectrum licenses for certain wireless communications services. Additional provisions concerning auctions were included in the Balanced Budget Act of 1997, discussed below. The main category of services for which licenses may be auctioned are called Commercial Mobile Radio Services (CMRS) which include Personal Communications Service (PCS), cellular, and most Specialized Mobile Radio (SMR) and Mobile Satellite Services (MSS). With some exceptions, CMRS providers are regulated as common carriers to ensure regulatory parity among similar services that will compete against one another for subscribers. The FCC has the authority to conduct auctions only when applications are mutually exclusive (i.e., two licensees in the same frequency band would be unable to operate without causing interference with each other) and services are primarily subscription-based.[11] The FCC does not have authority to reclaim licenses awarded prior to the decision to permit auctions.

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[8] *Comprehensive Review of U.S. Spectrum Management with Broad Stakeholder Involvement Is Needed*, GAO-03-277, January 31, 2003.

[9] *A Republican Approach to the Department of Homeland Security; recommendations for the first 100 days*, Republican Main Street Partnership, released December 10, 2002.

[10] Technically, two signals will interfere with each other even if they are not at the same exact frequency, but are close in frequency. To avoid harmful interference, the frequencies must have frequencies that are sufficiently different, known as a "minimum separation."

[11] Licenses are issued for the use of frequencies within bands of spectrum. In general, a greater bandwidth can carry more information than a smaller bandwidth.

Auction Rules. The Communications Act of 1934 directs the FCC to develop a competitive bidding methodology.[12] The FCC initially developed rules for each auction separately (with some common elements), but after several years of trial and error, it has developed a set of general auction rules and procedures. While there may be special requirements for specific auctions, the following rules generally apply. As a screening mechanism, all auctions require bidders to submit applications and up-front payments prior to the auction. Most auctions are conducted in simultaneous multiple-round bidding in which the FCC accepts bids on a large set of related licenses simultaneously, using electronic communications. Bidders can bid in consecutive rounds on any license offered until all bidding has stopped on all licenses. Even though licenses must be renewed periodically, it is generally understood that license winners will be able to keep the license perpetually, as long as they comply with FCC rules.[13]

For some auctions, the FCC gives special bidding credits to smaller companies, called entrepreneurs, defined as having annual gross revenues of less than $125 million and total assets of less than $500 million. In the first year or so of auctions, the FCC originally also gave special provisions to women-owned, minority-owned, and rural telephone companies (called designated entities). After a 1995 Supreme Court decision determined that government affirmative action policies must pass a "strict scrutiny" test to demonstrate past discrimination, the FCC removed minority-owned and women-owned groups from its list of businesses qualifying for bidding credits as designated entities.[14] Many industry observers have expressed concern that some of the small businesses participating in auctions actually represent larger companies. Larger companies reportedly lament the limitations of the designated entity rule in auctions and have lobbied the FCC to eliminate it.[15]

Service Rules. The FCC also develops service rules for each new service for which a license will be used. Licenses are granted according to the amount of spectrum and the geographic area of coverage. The FCC's plan for the amount of spectrum per license, the number of licenses, and the conditions for use of the designated spectrum, known as the "band plan," is developed for each new wireless service. Licenses can cover small areas, large regions, or the entire nation. Terms used for coverage areas include basic trading areas (BTAs) which correspond roughly to metropolitan areas; major trading areas (MTAs), which are combinations of BTAs dividing the United States into 51 geographic regions of similar levels of commercial activity; and regions, which are combinations of MTAs. Metropolitan statistical areas (MSAs), rural service areas (RSAs), economic areas (EAs), and major economic areas (MEAs) — defined by the Department of Commerce for economic

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[12] Communications Act of 1934, 47 U.S.C. 309 (j) (3).

[13] The FCC provides information on auctions at [http://wireless.fcc.gov/auctions/]. Viewed June 17, 2004.

[14] Adarand Constructors Inc., petitioner v. Federico Pena, Secretary of Transportation, et al. Docket No. 93-1841, decided June 1995.

[15] Communications Daily, "FCC Expected to Reject Changing Auction Rules," page 3, June 18, 2004.

forecasts — are also used by the FCC to describe areas of coverage for some spectrum auctions.

The FCC has also modified some wireless service rules to help new spectrum licensees maximize the value from their licenses. Changes include allowing licensees to partition licenses for greater efficiency, sharing regions among licensees, and expediting the relocation of incumbent microwave licensees from the spectrum purchased in the PCS auctions.

NextWave. The auction of one of the blocks of spectrum allocated for PCS, known as the C-block, presented legal problems for the FCC. In the original C-block auction, also called the entrepreneur's auction, the FCC gave bidding credits to small businesses to help them compete with larger entities in the auction. Winning bidders only had to pay 10% down and the remainder could be paid over ten years at below-market interest rates. At auction in 1996, broadband C- block licenses were sold for bids totaling $10.2 billion. By mid-1997, however, many of the license winners (most notably NextWave Telecom Inc.) had defaulted. In September 1997, the FCC offered a set of options for C-block licensees to restructure their debt (that offer was modified in March 1998). Some licensees opted to maintain their bankrupt status, however, preventing the C-block spectrum from being re-auctioned. Based on its interpretation of a series of decisions in 1999 and 2000 by a U.S. Court of Appeals, the FCC cancelled the licenses that had not been paid for and re-auctioned that spectrum. The auction (Auction 35) for the defaulted licenses was completed January 26, 2001, and booked $16.86 billion in projected revenue for the general treasury.[16]

On June 22, 2001, the United States Court of Appeals for the District of Columbia found that the FCC did not have the legal right to take back NextWave's licenses and that 216 of the licenses (worth $15.85 billion) still belong to NextWave rather than reauction winners such as Verizon Wireless.[17] The U.S. Supreme Court agreed to hear the case, essentially weighing NextWave's right to protection under bankruptcy laws against the FCC's right to allocate spectrum. On January 27, 2003, the Supreme Court ruled in favor of NextWave, agreeing with the earlier Court of Appeals decision that the FCC did not have the authority to recover the licenses.[18] Subsequently, NextWave agreed to return some of the disputed spectrum to the FCC for re-auction in January 2005.[19]

Recent Congressional Actions Regarding Spectrum Auctions

Congress uses its oversight authority of the FCC to correct the agency's course or to steer it in new directions. Two notable laws that deal with spectrum policy and

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[16] Summarized in Associated Press Online, "Feds Ordered to Return Wireless Licenses," January 28, 2003.

[17] 254 Federal Report, 3d Series, page 130.

[18] U.S. Supreme Court, Docket No. 01-653 at [http://www.supremecourtus.gov/docket/01-653.htm]. (Viewed June 28, 2004.)

[19] See FCC Report No. AUC-03-58 (Auction No. 58), "Broadband PCS Spectrum Auction Scheduled for January 12, 2005," available at [http://wireless.fcc.gov/auctions/].

auctions are the Balanced Budget Act of 1997 and the Auction Reform Act of 2002. The Balanced Budget Act also directs FCC actions concerning the transition to digital televison, an event with significant impact on spectrum management.

The Balanced Budget Act of 1997. The Balanced Budget Act of 1997 (47 U.S.C. 153) contained several spectrum management provisions. It amended Section 309(j) of the Communications Act to expand and broaden the FCC's auction authority and to modify other aspects of spectrum management. Whereas previous statutes gave the FCC the authority to conduct auctions, the Balanced Budget Act *required* the FCC to use auctions to award ownership in mutually exclusive applications for most types of spectrum licenses. It directed the FCC to experiment with combinatorial bidding (i.e., allowing bidders to place single bids on groups of licenses simultaneously), and to establish minimum opening bids and reasonable reserve prices in future auctions unless the FCC determined that it was not in the public interest. This amendment also extended the FCC's auction authority to September 30, 2007. Furthermore, the act directed the FCC to allocate spectrum for "flexible use," which means defining new services broadly so that services can change as the telecommunications technology evolves.

Exempted from auctions are licenses or construction permits for: "(A) public safety radio services, including private internal radio services used by state and local governments and non-government entities and including emergency road services provided by not-for-profit organizations, that —

(i) are used to protect the safety of life, health , or property; and
(ii) are not made commercially available to the public;

(B) digital television service given to existing terrestrial broadcast licensees to replace their analog television service licenses; or
(C) noncommercial educational broadcast stations and public broadcast stations."

Examples of services exempted from auctions include utilities, railroads, metropolitan transit systems, pipelines, private ambulances, volunteer fire departments, and not-for-profit emergency road services.

The act directed the FCC to auction 120 MHz of spectrum, most of which had already been transferred by NTIA from federal to non-federal and to allocate another 55 MHz located below 3 GHz for auction not later than September 2002.[20] These deadlines were subsequently amended by the Auction Reform Act of 2002.

Auctions of Spectrum Used for Television Broadcasting. The Balanced Budget Act of 1997 required the FCC to conduct auctions for 78 MHz of the analog television spectrum planned to be reclaimed from television broadcasters at the completion of the transition to digital television. These channels occupy spectrum in the 700 MHz range. For administrative purpose, the FCC divided the spectrum into "Upper 700 MHz" and "Lower 700 MHz"bands. Congress instructed the FCC to hold auctions for the 700 MHz frequencies not later than 2002. The

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[20] Demand for this spectrum is discussed in CRS Report RS20993, *Wireless Technology and Spectrum Demand: Third Generation (3G) and Beyond.*

spectrum was to have been auctioned in 2002 but not reclaimed from broadcasters until at least 2006. The act directed the FCC to grant extensions to stations — allowing them to keep the spectrum — in television markets where any one of the following three conditions exist: (1) if one or more of the television stations affiliated with the four national networks are not broadcasting a digital television signal, (2) if digital-to-analog converter technology is not generally available in the market of the licensee, or (3) if at least 15% of the television households in the market served by the station do not subscribe to a digital "multi-channel video programming distributor" (e.g., cable or satellite services) and do not have a digital television set or converter. Until these conditions are met, broadcasters are not required to surrender the spectrum.[21] Concerning allocation and assignment of frequencies for public safety services, the act directed the FCC to reallocate 24 MHz between TV channels 60-69 (in the Upper 700 MHz band) for public safety services and to auction the other 36 MHz in that band for commercial use.

Auction Reform Act of 2002. Concerns about spectrum management, including spectrum used for public safety, prompted the introduction of H.R. 4560, the Auction Reform Act of 2002, on April 24, 2002. The purpose of the bill was to eliminate deadlines for auctions of Upper and Lower 700 MHz frequencies originally scheduled by the FCC for June 19, 2002. Shepherded through the House by Members Dingell and Tauzin, the bill was introduced in the Senate in May, and compromise legislation became P.L. 107-195 on June 19, 2002. Specifically, the law stopped auctions in the Upper 700 MHz band that might have impacted efforts to increase the amount of spectrum available for public safety use, while requiring that some auctions in the Lower 700 MHz band take place. The broad language of the law gives the FCC discretion in setting auction dates for all auctionable spectrum by eliminating deadlines established by the Balanced Budget Act of 1997. The Auction Reform Act also required the FCC to submit a report to Congress, by June 19, 2003. The report must specify when the FCC intends to reschedule Upper 700 MHz auctions halted by the act and to describe the progress made in the transition to digital televison and in the allocation of additional spectrum for advanced mobile services. Auctions in these areas must be justified by the information in the report.

Spectrum Value

Spectrum value depends on many factors, such as the amount of spectrum, its frequencies (since signal transmission characteristics vary along different parts of the spectrum), the geographic area covered, the services permitted by FCC rules, the availability of equipment that can operate at those frequencies, the demand for services that do not interfere with other bands, the amount of alternative spectrum already available for similar services, the number of incumbents presently occupying the spectrum, and whether incumbents will remain in that spectrum or be relocated to other spectrum. Spectrum value may be greater if adjacent bands can be aggregated to form larger blocks and if the given spectrum is not encumbered by other licensees using the same frequencies. Giving bidders time to review the auction rules and

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[21] See CRS Report RS21570, *Spectrum Management: Public Safety and the Transition to Digital Television.*

services rules, examine technical opportunities and constraints, prepare marketing plans, and arrange financing helps in obtaining full value at auction.

The Congressional Budget Office (CBO) annually scores the anticipated receipts from planned spectrum auctions, and includes the revenue estimate in its annual report, *The Budget and Economic Outlook*. The January 2004 report[22] estimates receipts from the sale of spectrum at $15 billion over the period 2005 through 2009, with most of the revenue booked in 2006-2008. The revenue expected from the auctions is used as offsetting receipts to other federal expenditures. In accordance with the Budget Enforcement Act of 1990, auction proceeds cannot be used for funding other programs.

To date, the FCC has garnered over $14 billion from completed auctions, most of which has been deposited in the U.S. Treasury as general revenue to the federal government. (The FCC keeps a small portion of auction proceeds to cover the expenses of the auctions.) This total does not include approximately $10 billion for contested licenses in the C and F Blocks awarded to NextWave and others in 1996 — money which has never been received.

Auctions as a means of allocating spectrum are considered a success by many observers because of the federal revenue generated, as well as for the speed with which licenses auctioned have gone to the companies that value them the most and are most likely to put them to use. Moreover, many prefer letting businesses determine whether to invest in a new service rather than relying on the government to decide who receives a spectrum license. The FCC has concluded that auctioning of spectrum licenses has contributed to the rapid deployment of new wireless technologies, increased competition in the marketplace, and encouraged participation by small businesses.[23] Many other countries have adopted the use of auctions to assign commercial licenses to use spectrum bands.

Technology

Several technological advances could affect the outcome and prospects for spectrum auctions and how the spectrum is managed. The usable spectrum for communications purposes is currently considered to be below 300 GHz. Higher frequencies present limitations such as a greater absorption of signals by the atmosphere, and difficulties in high frequency reception. As the technology for radio transmission and reception improves, higher frequencies will likely become available for use. Technology improvements may, in turn, spur increased consumer demand for spectrum.

Some of the problems with high-frequency signal transmission and signal interference at all frequencies are being solved by engineering techniques which

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[22] *The Budget and Economic Outlook: Fiscal Years 2004 - 2014*, Table 3-8. CBO does not break down the amounts in terms of individual auctions, but only provides the aggregate estimated revenue.

[23] FCC 97-353, *FCC Report to Congress on Spectrum Auctions*, WT Docket No. 97-150, released October 9, 1997.

could make better use of the spectrum, thus reducing some of the spectrum demand. These include methods of digital signal compression, which increases the carrying capacity of currently used bands, error detection and correction which maintain the signal integrity even in high levels of noise, and other digital techniques such as frequency hopping, in which the transmitted signal avoids frequencies that are already being used. The use of fiber optic cables (which carry signals over wires rather than propagating through the air, and therefore do not require frequency allocations) can provide enormous capacity and alleviate some of the demand for spectrum.

Conclusion

Spectrum is a natural resource with its own unique set of characteristics. Most assigned spectrum was allocated prior to the adoption of the auction process. The amount of spectrum available for new uses, given current technology, is limited; the amount available for commercial use and development is smaller still.

Auctions are the primary mechanism used for implementing market-based spectrum allocation policies in the United States. Many have questioned whether auction policy should be supplemented more aggressively with other market-driven solutions such as licensing fees and whether the existing auction process and administration can be improved.[24]

Spectrum management is an exercise in reconciling divergent interests. Over time, developments in technology may significantly increase the amount of useable spectrum and consequently the ease with which a policy of equitable allocation and use can be crafted. For the immediate future, Congress may choose to debate and act on questions such as reforming spectrum management and allocation mechanisms. Some observers insist that a fully-developed policy should take into account issues such as international competitiveness, the communications needs of public safety agencies and the military, the role of wireless technology in economic growth, and the encouragement of new technologies that make spectrum use more efficient and more beneficial to society as a whole. The stated objective of most policy reformers is a coherent national policy that provides the proper balance for existing applications while at the same time providing opportunities for future growth and development.

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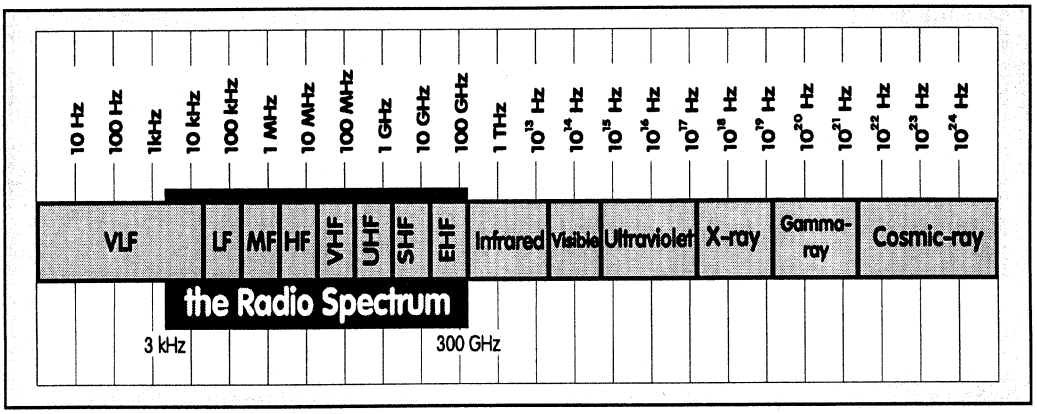
[24] The GAO, among others, analyzes auction policies and documents alternative mechanisms in its report, *Comprehensive Review of U.S. Spectrum Management with Broad Stakeholder Involvement Is Needed*, GAO-03-277, January 31, 2003.

Appendix: Spectrum Technology Basics

Electromagnetic radiation is the propagation of energy that travels through space in the form of waves. The most familiar form is light, called the visible spectrum. The radio frequency spectrum is the portion of electromagnetic spectrum that carries radio waves. Figure 1 shows the radio spectrum as part of the measured electromagnetic spectrum. Wavelength is the distance a wave takes to complete one cycle. Frequency is the number of waves traveling by a given point per unit of time, in cycles per second, or hertz (Hz).[25] The relationship between frequency (*f*) and

Figure 1: The Electromagnetic Spectrum



wavelength (λ) is depicted in Figure 2. Bandwidth is a measure of how fast data are transmitted or received whether through wires, air or space. Signals are transmitted over a range of frequencies which determines the bandwidth of the signal. Thus a system that operates on frequencies between 150 and 200 MHz has a bandwidth of 50 MHz.[26] In general, the greater the bandwidth, the more information that can be transmitted.

An important distinction in spectrum technology is the difference between narrowband and broadband. Narrowband signals have a smaller bandwidth (on the order of kHz) and are used for limited services such as paging and low-speed data transmission. Broadband signals have a large bandwidth (on the order of MHz) and can support many advanced telecommunications services such as high-speed data and video transmission. The precise dividing line between broadband and narrowband is not always clear, and changes as technology evolves.

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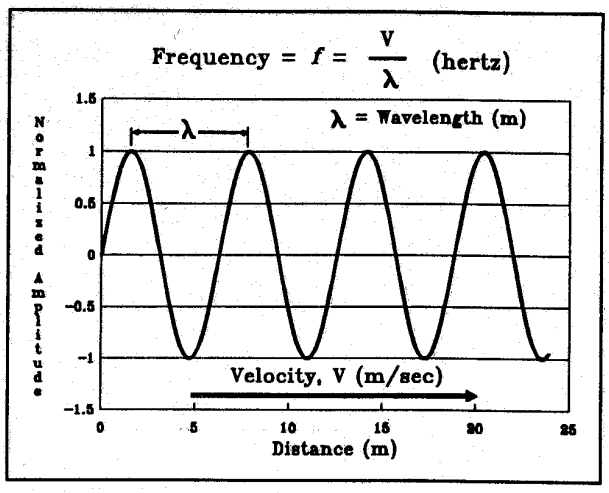
[25] Radiofrequency is usually measured in kilohertz (kHz), which is thousands of hertz, megahertz (MHz) which is millions of hertz, and gigahertz (GHz) which is billions of hertz.

[26] Bandwidth is also measured in bits per second (bps) instead of cycles per second. especially in digital systems.

Two other important terms are analog signals and digital signals, depicted in Figure 3. In analog signal transmissions, information (sound, video, or data) travels in a continuous wave whose strength and frequency vary directly with a changing physical quantity at the source (i.e., the signal is directly analogous to the source). In digital signals, information is converted to ones and zeros which are formatted and sent as electrical impulses. Advantages of using digital signals include greater accuracy, reduction in noise (unwanted signals) and a greater capacity for sending information. Analog signals have the advantage of greater fidelity to the source, although that advantage can be made very small by increasing the rate at which signals are digitized. Digital signals are acknowledged to be superior to analog signals for the majority of applications.

Figure 2: Frequency vs. Wavelength



Electromagnetic waves have many characteristics that govern how spectrum can be used in telecommunications systems. For example, antennas are used for transmitting and receiving signals, and can be designed to transmit in all directions or can be directed toward specific receivers. Receiving antennas are typically aligned with the transmitting antenna to maximize signal reception, but unintended signals can still interfere with the reception of the information sent. To avoid signal interference from stray signals, more than one radio signal usually cannot be transmitted in the same frequency range, at the same time, in the same area. Another characteristic is that the spectrum, unlike other natural resources, is not destroyed by use. As soon as one user stops transmitting signals over a portion of the spectrum, another can immediately re-use it. The spectrum is scarce, however, because at any given time and place, one use of a frequency precludes its use for any other purpose.

Figure 3: Schematic Comparing Analog vs. Digital Signals