Spectrum Management in the Global Village

William A. Luther

Federal Communications Commission

Washington, D.C. 20554

U.S.A.

e-mail: wluther@fcc.gov

Abstract: Spectrum management is examined, starting from a fundamental basis, drawing on principles, then advancing to current, accepted national and international practices and procedures in electromagnetic spectrum management that enable viable, global compatibility among the radio services. Attention is given to services that are both licensed {e.g., broadcast (sound and television), land mobile, maritime mobile, aeronautical mobile, mobile satellite, fixed satellite, etc.} and unlicensed (e.g., ultra-wideband, wireless local area networks, radio frequency identification, etc.). This paper relies on recent experiences at the Federal Communications Commission in the United States, indicating both the successful results obtained, and the failures which have consequently modified spectrum management philosophy.

Keywords: spectrum management, principles, regulations, compatibility, best practices

Introduction

"Global village" is an accurate appellation that applies to spectrum management. Electromagnetic energy knows no international boundary. Electromagnetic compatibility is a public trust for uses of the spectrum in every country, state, province, city, and village. It is more than incumbent upon a country to ensure that the duties of its telecommunications regulatory authority take into account other countries, their needs, and their responsibilities. It is for this reason that the International Telecommunication Union (ITU), the oldest agency of the United Nations, exists and is responsible for the regulation, standardization, and development of telecommunications worldwide, including international management of the radio frequency spectrum and satellite orbits. The ITU provides a forum in which its 189 Member States and almost 700 Sector Members can co-operate for the improvement and rational use of telecommunications to the village level.

The Six Principles Of Spectrum Management

There are six principles of spectrum management to be recommended for the global village. These will be discussed in some detail in this paper. They are:

1. Competition;
2. Maximum flexibility;
3. Public interest;
4. Constructive licensing and fee policies;
5. Administrative certainty with minimum delay; and
6. Taking national decisions in a global market context.

What Is Spectrum Management?

Spectrum management in the largest sense has a number of elements, and the degree to which a nation adopts these as part of its national infrastructure will vary depending on need. All of the elements may be understood by referring to Figure 1.

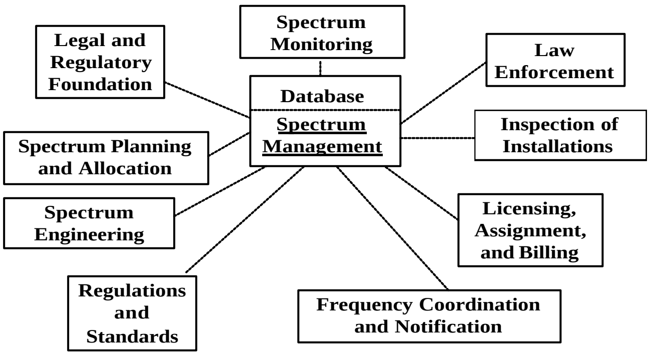

Figure 1. Spectrum Management

Legal and Regulatory Foundation

This first element in spectrum management must provide the basis in a nation's laws for the use and regulation of radiocommunications, and establish concepts, authorities, broad objectives, and responsibilities. The element should recognize that the spectrum is a resource available to all, and governance of it is always in the public interest.

Spectrum Planning and Allocation

Spectrum planning and allocation is the process of deciding distribution of radio frequency spectrum among different radio services on either an exclusive or shared basis. The international treaty governing global and regional spectrum allocations is known as the ITU Radio Regulations, updated every few years at a World Radiocommunication Conference (WRC). Based on a WRC's international frequency decisions, countries are able to establish a national frequency allocation table which allows for use of the spectrum by specific systems and licensees.

Spectrum Engineering

Spectrum management involves decisions pertaining to technology and engineering. Though social, economic, and political considerations enter into such decisions, many of the issues can be analyzed, and decisions made, based on engineering and technical factors.

Regulations and Standards

The ITU has established general rules and regulations regarding international spectrum allocation and spectrum management. Taking into account these treaty provisions, each Member State may create its own legislation with relevant rules and regulations to accommodate its national infrastructure.

Frequency Coordination and Notification

It is necessary to create a mechanism by which frequencies can be assigned to particular services and systems whereby the greatest number of users can be accommodated or the highest public interest is served. This is implemented through a frequency coordination process before giving an assignment to a station that might conflict internally or with that of another country. This is particularly crucial near national borders.

Licensing, Assignment, and Billing

Once a telecommunication authority has determined that a proposed system complies with the applicable regulations, authorization of frequency assignment(s) is granted. A fee for processing or for regulatory action may be levied concurrent with this activity, based on the regulatory provisions for the level of administrative service.

Inspection of Installations

Inspection is an effective means of regulating and ensuring more efficient use of the spectrum. Inspections may occur on a sampling basis for statistical reasons, or in some cases, e.g., broadcast stations, in all cases.

Law Enforcement

The benefits of spectrum management cannot be realized if the users fail to comply with the terms of authorization. The regulations should include provisions defining the enforcement action that may be taken if there is a finding of infringement. Based upon the severity of infringement, penalties could range from warnings, to fines, to revocation of license, to seizure of equipment, or even to incarceration.

Spectrum Monitoring

Spectrum monitoring serves as the eyes and ears of the spectrum management process. It is necessary in practice because in the real world, authorized use of the spectrum does not ensure that it is being used as intended. This may be due to the complexity of the equipment, interaction with other equipment, a malfunction of equipment, or deliberate misuse. Spectrum monitoring should be on a continuous basis if it is to be effective.

How Do We Achieve Spectrum Management?

In the spectrum management world, the rational, equitable, efficient and economical use of the radio frequency spectrum and satellite orbits is achieved by:

- Holding World and Regional Radiocommunication conferences to develop and adopt treaties covering the use of the spectrum;
- Establishing global radiocommunication recommendations on the technical characteristics and operational procedures for radio services and systems;
- Coordinating efforts to eliminate harmful interference between radio stations and networks;
- Maintaining a Master International Frequency Register which offers protection either through a Plan, or on an agreed basis for those appropriately registered; and
- Providing tools, information, and seminars to assist national radio frequency spectrum management.

Hottest Topics In Spectrum Management Today

Spectrum Economics

Currently in the U.S., only about 7 percent of the most valuable spectrum (i.e., < 3 GHz), and less in most other countries, is available for market allocation. Proposals to reallocate restricted spectrum more flexibly, and to modify auction approaches, while giving incumbents incentives to participate in "band restructuring," have been made. See section on Spectrum Policy Reform (infra).

Broadband

Broadband discussion is driven largely by the Internet and gaining faster access to it. Clearly, the Internet is one of the most important issues in global village infrastructure today. Convergence of voice, video, and data is also a major factor in seeking broaderband access. Fortunately, the first principle of spectrum management applies here as terrestrial radio broadband spectrum access competes with satellite delivery, wired television cable or fibre, wired telephone networks using DSL, and even access over power line mains.

Software-Defined Radios

As technology continues to advance in spectrum disciplines, software-defined radios offer new opportunities for access to, and use of the spectrum. This equipment can sense the spectrum environment and commensurately adjust power, frequency, and modulation type for optimum information (voice, video or data) transfer.

Terrestrial Sharing with Satellite Networks

New ideas for terrestrial systems are shaping sharing scenarios with existing satellite networks that employ the geostationary orbit (GSO). The GSO is used today by about two-hundred satellites in the fixed-satellite, mobile-satellite, broadcast-satellite and meteorological satellite services. All of the Earth station antennas point directly to the GSO, viz., point southerly in the northern hemisphere and point northerly in the southern hemisphere. It is possible to at least double use of spectrum by appropriately positioning terrestrial antennas behind fixed Earth station antennas, all of which are usually quite directive.

Ultra-wideband

Ultra-wideband (UWB) technology has been in limited use for many years by public service, research, and military agencies, primarily for imaging and radar. Today, consumer UWB devices are being developed for wireless communication, vehicular anti-collision radar, and other applications. Some specific uses for ultra-wideband technology are ground penetrating radars for public safety, archeological, civil engineering and earthquake applications; through-wall radar for public safety and construction purposes; high performance microphones; local area voice, video and data networks; security devices; vehicle collision avoidance and airbag sensors; fluid level detection; short-range communication; long-range military communication; and identification and location tags.

In the U.S., UWB operation has been authorized since February 2002 [1]. Furthermore, the U.S. UWB regulatory infrastructure was reaffirmed in February of 2003 while at the same time clarifying administrative details.

It is clear, because of their very low power output, the small size of the devices, and the consumer interest in better and faster communication services, that UWB devices will be ubiquitous and essentially uncontrolled in their usage. For these reasons the U.S. has determined, for its part, that these devices will be unlicensed in the usual regulatory sense, and operate on an unprotected (secondary) basis, but will have strict limitations on their marketing and use. Nevertheless, UWB applications are controversial as they develop because of the potential for causing harmful interference to almost any service in the spectrum. The most vulnerable service is that using the radionavigation satellite service (RNSS), i.e., GPS, GLONASS, and potentially, GALILEO. For this reason the protection offered to the RNSS is very stringent.

The definition of an ultra-wideband transmitter is: An intentional radiator that, at any point in time, has a fractional bandwidth equal to or greater than 0.20, or has a UWB bandwidth equal to or greater than 500 MHz, regardless of the fractional bandwidth. UWB bandwidth is the frequency band bounded by the points that are 10 dB below the strongest radiated emission, based on the complete transmission system including the antenna. See Figure 2. The upper frequency boundary is designated f_H and the lower frequency boundary is designated f_L. The center frequency of a UWB emission is then defined as:

$$f_C = (f_H + f_L)/2 \quad (1)$$

The fractional bandwidth, f_F, of a UWB emission is defined as:

$$f_F = 2(f_H - f_L)/(f_H + f_L) \quad (2)$$

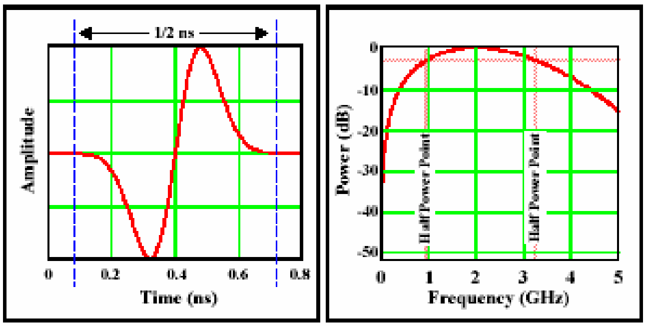

Figure 2. Typical UWB Monocycle Pulse in Time and Frequency Domains

Pulse widths of UWB signals may range from a few picoseconds to several nanoseconds, with the choice of time based on the UWB application. The pulse width establishes both the center frequency and energy distribution of the signal. For example, a 300 picosecond pulse has a center frequency of:

$$f_C(300\ ?s) = 1/time = (1/300 \times 10^{-12})\ \tilde{}\ \ 3.3\ \text{GHz} \quad (3)$$

For longer pulse duration, e.g., 600 ?s, the center frequency (apex of the spectrum) is about 1.7 GHz.

Four well known modulation schemes have been visualized for UWB systems, viz., on-off keying (OOK), pulse amplitude modulation (PAM), binary phase shift keying (BPSK), and pulse position modulation (PPM).

National Spectrum Management Handbook

The International Telecommunication Union is in the process of preparing a new Handbook on National Spectrum Management scheduled to be completed in 2003. The Handbook is designed to give guidance and recommendations to the world's spectrum managers that, if followed, would mean a range of convergence to more simple approaches to spectrum management and greater compatibility among the many services. Convergence among services and technologies would lead to greater economies of scale and certainly, greater compatibility. To illustrate the value of the Handbook, the chapters that will be included are:

Chapter 1 – Spectrum Management Fundamentals

Chapter 2 – Spectrum Planning

Chapter 3 – Frequency Assignment and Licensing

Chapter 4 – Spectrum Monitoring, Spectrum Inspection and Investigation

Chapter 5 – Spectrum Engineering Techniques

Chapter 6 – Spectrum Economics

Chapter 7 – Automation for Spectrum Management Activities

Chapter 8 – Spectrum Efficiency

Chapter 9 – Spectrum Management Information Available on the ITU-R Website

Annex 1 – Spectrum Management Training

Annex 2 – Spectrum Best Practices

Spectrum Management Best Practices

The standards world is converging on a set of Best Practices for use in spectrum management. The draft set has been considered by the International Telecommunication Union (ITU) Radiocommunication Study Group 1 (Spectrum Management) and improvements, intended to make the set more universal and practical on a national basis, have been incorporated. These Practices will have been approved in final version by the international group of the ITU at its meeting in France in April 2003. The Handbook on National Spectrum Management will be published in paper and electronic form by the ITU later this year in English, French, and Spanish languages.

Best Practices

Following is the set of national spectrum management Best Practices as it currently exists. Because this set has been iterated several times at international meetings of spectrum managers, it may be considered definitive:

1. Establishing and maintaining a national spectrum management entity responsible for managing the radio spectrum in the public interest;
2. Promoting transparent, fair, economically efficient, and effective spectrum management policies;
3. Maintaining a stable decision-making process that permits consideration of the public interest in managing the radio frequency spectrum;
4. Providing in special cases, where adequately justified, for exceptions to spectrum management decisions;
5. Having a process to seek reclama for spectrum management decisions;
6. Minimizing regulations to the extent practicable;
7. Encouraging radiocommunication liberalization policies;
8. Assuring open and fair competition in the marketplaces for equipment and services, and removing any barriers that arise to open and fair competition;
9. Harmonizing, as far as practicable, effective domestic and international spectrum policies, including of radio frequency use and, for space services, for any associated orbital position in the geostationary-satellite orbit or for any associated characteristics of satellites in other orbits;
10. Allocating frequencies and making assignment for flexible use to the extent practicable to allow for the evolution of services and technologies;
11. Working in collaboration with regional and other international colleagues to develop simplified regulatory practices;
12. Encouraging free circulation and global roaming of mobile terminal and radiocommunication equipment;
13. Using internationally recommended data formats and data elements for exchange of data and coordination purposes, e.g., as in the Radiocommunication Data Dictionary [2] and in the Radio Regulations Appendix 4 [3];

14. Using project management procedures to monitor and control lengthy radiocommunication system implementation;

15. Using auctions for the assignment of commercial terrestrial and domestic satellite service licenses;

16. Adopting decisions that are technologically neutral and which allow for evolution to new services;

17. Facilitating timely introduction of appropriate new services and technology while protecting existing services from radio frequency interference including, when appropriate, the provision of a mechanism to allow compensation for systems that must redeploy to accommodate new spectrum uses;

18. Fostering backwards compatibility of new equipment and services, whenever practicable;

19. Promoting spectrum sharing using available techniques (frequency, temporal, spatial, and modulation - - coding and processing), including using interference mitigation techniques and economic incentives, to the extent practicable;

20. Using enforcement mechanisms, as appropriate, under relevant judicial processes;

21. Utilizing regional and international standards whenever possible in lieu of specific national standards; and

22. Relying on voluntary industry standards in lieu of government mandates, to the extent practicable.

Spectrum Policy Reform

Europe and the United States

It is understood both in Europe by the European Union, and in the U.S. by the FCC and the U.S. Department of Commerce that spectrum policy is not perfect and must be adjusted from time-to-time to accommodate changing circumstances, i.e., technology, the market, and new services.

A consensus is forming that the current process of allocating radio spectrum by administrative decision-making is in serious need of reform. In a recent press conference, the Chairman of the Federal Communications Commission said, "Put simply, our Nation's [U.S.] approach to spectrum allocation is seriously fractured… ." Billions of dollars of cumulative loss to the U.S. economy have been attributed to inefficient spectrum allocations under the current system of administrative allocation. It has been estimated that the lost consumer welfare from a 10-year delay in cellular service in the U.S. is at $86 billion [4]. Another economist estimated lost consumer welfare at about $34 billion [5]. The solution, according to most economists, is to replace the current administrative allocation process with a spectrum market.

Spectrum Policy Task Force

In a recent study, the FCC's Spectrum Policy Task Force found that (1) spectrum access is a much more significant problem than spectrum scarcity and, (2) that technology is allowing systems to be much more tolerant to interference than in the past [6]. The Task Force consequently recommended that the FCC migrate from its current "command and control" model to a more market-oriented model with more emphasis on time sharing and allowing unlicensed devices to operate in common frequency bands. To respond to rising consumer demands, consideration should be given to permitting low-power users, possessing smart radios, to operate just above the ambient noise floor but below the levels of signals used by others, levels that change as a function of geography. This latter approach requires a quantification of acceptable levels of interference, a quantification that is being studied with expectation of future practical application.

Conclusions

The world must approach spectrum management as one village! Electromagnetic energy knows no international boundary. The world's strength is its diversity. Though we are of different tribes and tongues, we must remember that we are the same people. Telecommunications tie us to the past, connect us in the present, and link us for the future. It is not enough that we learn to live together. We must visualize and learn together to appreciate other means and ways. Harmonization of spectrum management will help in providing mankind with a means to work together more effectively as the globe continues to become smaller. People have come to Istanbul for this Symposium from all over the world, bringing new energy, new dreams, and new ideas. Each person at the Symposium has a story to tell. Every story enriches and invigorates us. Let us carry the stories and apply them as we all need.

References

[1] First Report and Order, "*In the matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems*," ET Docket 98-153, Federal Communications Commission 02-48, adopted February 14, 2002.

[2] Recommendation ITU-R SM.1413, "*Radiocommunication Data Dictionary for notification and coordination purposes*," International Telecommunication Union, Geneva, Switzerland.

[3] Appendix 4, Radio Regulations, "*Consolidated list and table of characteristics for use in the application of the procedures of coordination, notification and recording of frequency assignments and Plan modifications*, International Telecommunication Union, Geneva, Switzerland, ISBN: 92-61-09351-5.

[4] Charles Jackson, Tracey Kelly, and Jeffrey Rohlfs, "*Estimate of the Loss to the United States Caused by the FCC's Delay in Licensing Cellular Telecommunications*," National Economic Research Associates, 1991.

[5] Jerry Hausman, "*Valuing the Effect of Regulation on New Services in Telecommunications*," Brookings Papers on Economic Activity: Microeconomics: 1-38, 1997.

[6] Spectrum Policy Task Force Report, ET Docket No. 02-125, Federal Communications Commission, Washington, D.C., November 2002.

Biographical Notes

The author holds BSEE and MSEE degrees from Drexel University, Philadelphia. He has worked at the FCC for 43 years as a field engineer, inspector, investigator, Engineering Division Chief, International Advisor, and Chief of International Radiococommunication Policy. He has fifty-eight publications.

Endnote

The views expressed in this paper are those of the author and do not necessarily reflect the views of the Federal Communications Commission.