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INTRODUCTION TO INTERNATIONAL RADIO REGULATIONS

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INTRODUCTION TO INTERNATIONAL RADIO REGULATIONS
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PREFACE

One of the main missions of the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy, founded in 1964, is to foster the growth of advanced studies and scientific research in developing countries. To this end, the Centre organizes a number of schools and workshops in a variety of physical and mathematical disciplines.

Since unpublished material presented at the meetings might prove to be of interest also to scientists who did not take part in the schools and workshops, the Centre has decided to make it available through a new publication series entitled ICTP Lecture Notes. It is hoped that this formally structured pedagogical material on advanced topics will be helpful to young students and seasoned researchers alike.

The Centre is grateful to all lecturers and editors who kindly authorize the ICTP to publish their notes in this series.

Since the initiative is new, comments and suggestions are most welcome and greatly appreciated. Information regarding this series can be obtained from the Publications Section or by e-mail to "`pub_off@ictp.trieste.it`". The series is published in-house and is also made available on-line via the ICTP web site: "`http://www.ictp.trieste.it/~pub_off/lectures/`".

K. R. Sreenivasan

Katepalli R. Sreenivasan, Director
Abdus Salam Honorary Professor

Introduction

It is a pleasure for me to introduce these notes, which contain an overview of basic problems of the International Radio Regulations. Access to the existing information infrastructure, and to that of the future Information Society, depends critically on radio, especially in poor, remote and sparsely populated regions with under-developed telecommunication infrastructure. How the spectrum of radio frequencies is regulated has profound impact on the society, its security, prosperity, and culture. The radio regulations represent a very important framework for an adequate use of radio and should be known by all of those working in the field.

The author of these notes Professor Ryszard (*Richard*) Struzak, Co-Director of the series of schools on Radio Use at the Abdus Salam International Centre for Theoretical Physics (ICTP), is very well qualified to present the issue having been Vice-Chair of the Radio Regulations Board of International Telecommunication Union (ITU), a specialized agency of the United Nations (UN). He is also former Co-Chair of the Spectrum Management/ Utilization Working Group of International Union of Radio Science (URSI). Prof. Struzak served as a consultant to the UN, ITU, World Bank and governmental and private sector entities in a number of countries, and as Editor-in-Chief and Chair of Advisory Editorial Board of Global Communications. Earlier, he headed the technical department at the ITU International Radio Consultative Committee (CCIR) for more than nine years. Prior to joining the ITU, he served as university professor and head of national R&D laboratories on electromagnetic compatibility (EMC) and antennas in Poland. He has co-founded the International Wroclaw EMC Symposium and served for many years as its officer, the Symposium Chair and Program Chair. An Academician of the International Telecommunication Academy and IEEE Fellow, he was honoured by two international awards, the ITU Silver Medal, and numerous national awards and decorations. He received BSc, MSc, PhD, DSc, and the rank of full University Professor for life.

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Introduction to International Radio Regulations

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Abstract

These notes introduce the ITU Radio Regulations and related UN and WTO agreements that specify how terrestrial and satellite radio should be used in all countries over the planet. Access to the existing information infrastructure, and to that of the future Information Society, depends critically on these regulations. The paper also discusses few problems related to the use of the radio frequencies and satellite orbits. The notes are extracted from a book under preparation, in which these issues are discussed in more detail.

Contents

1 Background

After a hundred years of extraordinary development, radio is entering a new era. The converging computer and communications technologies add "intelligence" to old applications and generate new ones. The enormous impact of radio on the society continues to increase although we still do not fully understand all consequences of that process. There are numerous areas in which the radio frequency spectrum is vital. National defence, public safety, weather forecasts, disaster warning, air-traffic control, and air navigation are a few examples only. Radio and television broadcasting have become the main source of everyday information for most people of the world. They play a principal role in meeting information needs of illiterate people unable to read, a large part of the world's population.

The number of terrestrial and space radio stations grows without precedence and the frequency demand follows that trend. The ITU has recorded more frequency assignments in the last few years than during the whole previous history of radio. Liberalization, privatization, competition, and deregulation trends encourage the introduction of new services and new technologies. In the next few years, new High Altitude Platforms (HAP) and constellations of low-orbiting (LEO) satellites are expected to be launched to fulfil the promise of universal worldwide communication services accessible anywhere, anytime, and at an affordable cost. It is widely accepted that the uses made of the RF spectrum will be the main engine of economic growth and improvement of the living standard in the next few decades.

One of the difficulties radiocommunication confronts is the apparent spectrum congestion and scarcity of radio frequencies. Most of the suitable frequencies have already been used in many regions of the world and new demands exceed what can be accommodated. In some frequency bands and geographical regions there is no place for new radio stations and new services. The same concerns the geostationary satellite orbit. The issue is critical to all radio-dependent activities. The growing disproportion between the demand for radio frequencies and orbital positions on one hand, and what is apportioned on the other, calls for reconsideration of the existing ways these resources have been used. As radio has an immense impact on many aspects of our life, the issue deserves serious considerations by a wider community. This paper reviews some elements that may be helpful in such considerations.

Table 1. Changing approach to the radio frequency spectrum.

Year	Major events	Approach
Now	Global Information Infrastructure * Information Society concept * Wireless computer LAN, WAN * Wireless Internet. * Digital high-definition television (DTV, HDTV) * Digital audio broadcasting (DAB) * Ultra-Wide Band (UWB) systems * Constellations of low-orbiting satellites (LEO) * High Altitude Platforms (HAP)	Privatization of spectrum/ orbit resources? Free Spectrum/Orbit markets?
1995	Record spectrum auctions in USA: 258M USD/MHz	
1995	Major ITU reform. The ITU membership open to non-governmental entities. The IFRB replaced by part-time Radio Regulations Board (RRB).	Direct participation of private sector in international regulation process
1989	Creation of trade-able rights in radio frequencies in New Zealand	Spectrum is a sellable commodity in some countries
1978	First wireless public phone	
1965	First commercial communication satellite	
1963	First World Space Radiocommunication Conference	The geostationary satellite orbit included into spectrum concept
1958	First data transmission via satellite	
1957	First artificial Earth satellite	
1949	First public paging system.	
1949	The ITU became the United Nations' specialized agency for telecommunications	Spectrum is a "common heritage of mankind"
1947	Creation of International Frequency Registration Board (IFRB) and International Frequency List	Spectrum use is to be coordinated and registered and controlled internationally
1939	First commercial TV	
1932	Integration of Radio, Telegraph & Telephone regulatory activities in the framework of the International Telecommunication Union (ITU)	Spectrum is regulated by an intergovernmental organization
1927	Creation of International Radio Consultative Committee (CCIR) with membership open to non-governmental entities, to study questions related to radio communications. International Frequency Allocation Table covers 10 kHz - 60 MHz	Spectrum is allocated to separate services
1925	"...no more spectrum available" declares a US Secretary of Commerce	Spectrum is a scarce resource and requires conservation
1921	First broadcasting network	
1910	First aviation radio	
1906	First Radiotelegraph Conference in Berlin (27 States)	Spectrum is a shared resource requiring coordination among all its users
1901	First transatlantic wireless transmission	Spectrum is an inexhaustible natural resource from which everybody can profit freely
1895	First experiments with wireless communications (Marconi, Popov)	Spectrum is a physical object
1888	First experiments with radio waves (Hertz)	of no value
1873	Concept of radio waves (Maxwell)	Spectrum is an abstract concept
1822	Concept of spectrum (Fourier)	of no practical value

1.1 Basic concepts

What is the RF spectrum? This simple question has more than one answer, as our approach to the spectrum changes, as shown in Table 1. Originally, the spectrum was only an abstract mathematical idea introduced by Jean-Baptiste Fourier (1768-1830). At the beginning, the Fourier's spectrum concept was strongly criticized and considered as a strange curiosity of doubtful value. Only when Peter Dirichlet (1805-1859) and Georg Riemann (1826-1866) resolved the doubts, it was generally accepted to become now a powerful tool used in many branches of theoretical sciences. In the meantime, experimental radio science and technology have been developed and the RF spectrum has become also a measurable physical object: a spectrum analyzer is now a basic instrument in any radio laboratory.

Table 2. The ITU frequency bands.

Band No.	Symbol	Frequency	Wavelength
4	VLF	Very Low Frequency 3 to 30 kHz	Myriametric waves 100 to 10 km
5	LF	Low Frequency 30 to 300 kHz	Kilometric waves 10 to 1 km
6	MF	Medium Frequency 300 to 3000 kHz	Hectometric waves 1000 to 100 m
7	HF	High Frequency 3 to 30 MHz	Decametric waves 100 to 10 m
8	VHF	Very High Frequency 30 to 300 MHz	Metric waves 10 to 1 m
9	UHF	Ultra High Frequency 300 to 3000 MHz	Decimetric waves 100 to 10 cm
10	SHF	Super High Frequency 3 to 30 GHz	Centimetric waves 10 to 1 cm
11	EHF	Extremely High Frequency 30 to 300 GHz	Millimetric waves 10 to 1 mm
12	THF	Tremendously High Frequency 300 to 3000 GHz	Decimillimetric waves 1 to 0,1 mm

The ability to carry energy and messages at a distance, with the speed of light and at no cost, made the spectrum of radio waves a valuable resource from which everybody can profit. Free access to it, from any place and at any time, added much to its attractiveness. The spectrum has become treated as a natural resource, a common heritage of humanity. Not so long ago, another abstract concept, the geostationary satellite orbit (GSO), has been integrated with the original conception of the radio spectrum. Our attitude to the radio spectrum changes, as does our understanding of its value and social role.

Since the First Radiotelegraph Conference, Berlin, 1906, all governments interested have committed themselves to develop common rules and regulations concerning the use of the radio frequency spectrum and to follow these rules in practice. The ITU Member States update periodically these rules and regulations at radiocommunication conferences, to satisfy current needs. The access to the spectrum is now strictly regulated nationally and internationally. To use a specific frequency band or orbital position, one has to pass through a process of coordination, authorization, licensing, etc., as agreed among Administrations.

Internationally, the use of spectrum resources is free, but most countries introduced a system of fees for using the spectrum. A few countries went even further, creating the RF spectrum market. The spectrum has now its price but the market approach has not been universally accepted. There is a growing debate over whether spectrum is a free common heritage of humankind, a scarce natural resource, a renewable and reusable commodity, or a saleable, auction-able, rentable piece of real estate. According to a French jurist J.D. Bedin "the frequency spectrum is technology, industry, money, culture, and power" [Dougan 1992].

1.1.1 Spectrum Metrics

The RF spectrum is a multi-dimensional concept. It is widely agreed in scientific community that its dimensions involve radio frequency bandwidth, time span, geometrical volume, and - for space applications - a segment of the satellite orbit. There have been suggestions that other quantities, such as polarization, are also its dimensions. The argument for including these quantities is that two systems using orthogonal parameters do not interfere with each other. Horizontally and vertically polarized radiowaves, and spread-spectrum systems with orthogonal codes are examples. However, these suggestions have not been universally accepted. The Radio Regulations are built around the frequency allocation table that traditionally differentiates only between frequency bands and administrative regions, see Table 2 and the Annex.

1.1.2 Spectrum Use

"Used" means "denied to others". It is important to differentiate between the active and passive spectrum uses. The active ones involve radiation of RF energy whereas passive applications are based on the absorption of that energy. A broadcasting transmitter is an example of active usage whereas a radioastronomic observatory is an instance of passive one. The service area around a transmitter in which the usable signal can be received is usually smaller than the area in which the same transmitter can cause unacceptable interference to neighbouring systems. It is the area that is denied to other potential users that is related to spectrum congestion. The same concerns the frequency bandwidth and time denied to other users, see Figure 1.

It is important to differentiate between the physical denial and administrative denial [Berry 1985]. The spectrum space is physically denied if it is filled with sufficient RF power to interfere with other proposed operations. The space may also be denied administratively by spectrum management rules and radio regulations. Administrative denial is applied to simplify spectrum management and often represents practical approximations to physical denial. It is a means to reserve spectrum for passive applications, that is, for receiving radio stations. In that convention the transmitters and receivers use the spectrum in a complementary way. A protected transmitter denies use of a specific amount of spectrum space to receivers wishing to receive other communications. A protected receiver denies some amount of the space to transmitters whose operation would interfere with it. The spectrum administratively denied by a specific system may differ from that denied physically.

1.1.3 EMC

A compatible operation of radiocommunication systems implies two conditions. First, the radio system at hand must operate correctly in its electromagnetic environment. Second, the operation of that system must not introduce intolerable disturbance to its environment. These are the conditions of electromagnetic compatibility (EMC). They assure what the language of politics qualifies as '*peaceful co-existence'*. The criteria of 'correct operation', 'intolerable disturbance' and 'electromagnetic environment' are application-dependent. Generally, the '*electromagnetic environment*' includes radio waves of any origin, natural and man-made, intended and unintended.

The EMC theory says that each radio system can be associated with some specific '*sphere of influence*' in a multidimensional (multivariable) space within which no other outsider station should operate. The sphere of influence is known as the area denied to other systems. Transmitters deny space to extrinsic receivers and receivers deny it to extrinsic transmitters. The variables involved are application dependent. They include time and the length, width, and height of three-dimensional geometrical space that we know from everyday experience. In addition, they embrace the frequency, polarization, direction and power of the electromagnetic wave used, and other parameters.

A simplified interpretation of EMC conditions is shown in Figure 1. Only three variables are shown: the frequency, the North-distance and the East-distance. For simplicity, a non-directional station is assumed. The radio station under consideration is inside the cylindrical volume shown. No extrinsic station is allowed to operate within that volume, as a collision occurs otherwise. The associated frequency band is shown on the vertical axis, and the geographic area denied to other systems is shadowed on the North-distance - East-distance plane. EMC theory involves a large variety of physical phenomena in a complex manner, but we will leave aside all these meticulous considerations and focus on basic concepts only.

The frequency band and geographic area occupied are denied to other stations because of harmful interference. For actual systems, the forbidden volume has much more complex shape, as shown in Figure 2. The figure presents computer simulations of operation of the LEOSAT-1 satellite system near Buenos Aires, where the existing terrestrial microwave stations use the same frequency (18 GHz band). The figure represents only two variables: the North-distance and the East-distance. The microwave stations can cause severe interference to the satellite user terminals, and the interference zones must be excluded from the satellite service. These exclusion zones, shadowed in the figure, occupy 37% of the reference circle of 40 km diameter.

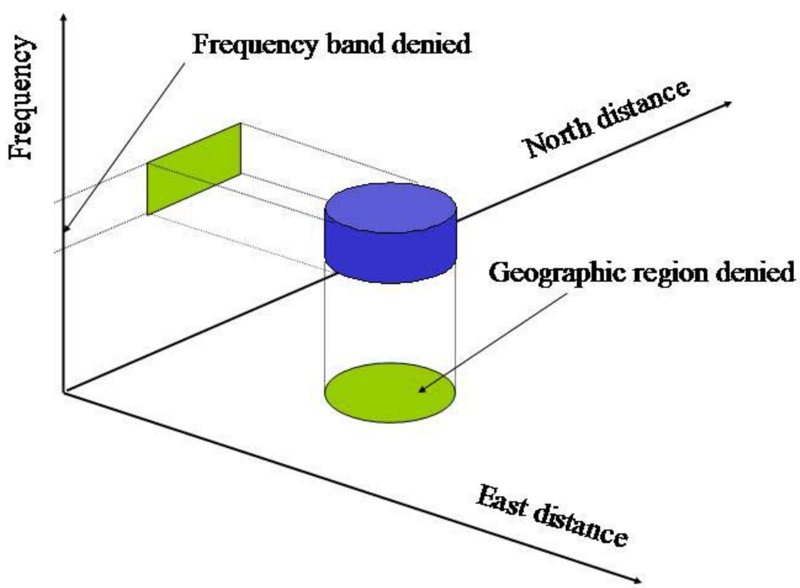


Figure 1. A radio station can be associated with a specific volume it ‘occupies’ in multi-dimensional space.

1.2 Sharing the Spectrum

1.2.1 Free-Pasture Model

Common resources such as the radio frequencies and geostationary-satellite orbit have one disadvantage which can be best explained on a model of free pasture. Because the pasture is open to all and free of charge, and because each cattle is a source of income, it is to be expected that everybody keeps his herd on it, and that each herdsman tries to maintain as many cattle as possible. Such an arrangement works well until the number of beast reaches the carrying capacity of the pasture. At this point, the scenario develops following the inherent logic of the commons, as described by Hardin:

"As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks 'What is the utility to me of adding one more animal to my herd?' This utility has one negative and one positive component:

1) The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1.

2) The negative component is a function of the additional overgrazing created by one more animal. Since, however, the effects of overgrazing are shared by all herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

Adding together the component partial utilities, the rational herdsman concludes that the only sensible course for him to pursue is to add another animal to his herd. And another; and another... But this is the conclusion reached by each and every rational herdsman sharing a commons.

Therein is a tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons." [Hardin 1968]

Is that model applicable to the radio frequencies and the geostationary- satellite orbit? Certainly the pasture and the radio spectrum are quite different, but there are some analogies. The spectrum, like the open pasture, cannot be fenced. Until now it has been available (for states) free of charge. It has a limited carrying capacity, the limits resulting from the laws of physics, and the available technology and capital. A portion of spectrum resource used by one system is denied to other systems. If, therefore, we replace the word '*animal'* in the Hardin's text by 'r*adio station'* and ‘*herdsman’* by ‘*Administration’*, we obtain a simplified global model of unrestricted use of the spectrum/ orbit resources.

A quantitative analysis of spectrum congestion and resultant transmission capacity loss due to mutual coupling of the links (based on a generalisation of Shannon’s law) has shown that the total capacity of a set of radio links tends to zero when their number increases without limits (Struzak 2002). The conclusion is that the concept of free use of the spectrum resources may work well only if the number of the resource users is small in comparison with the resource carrying capacity.

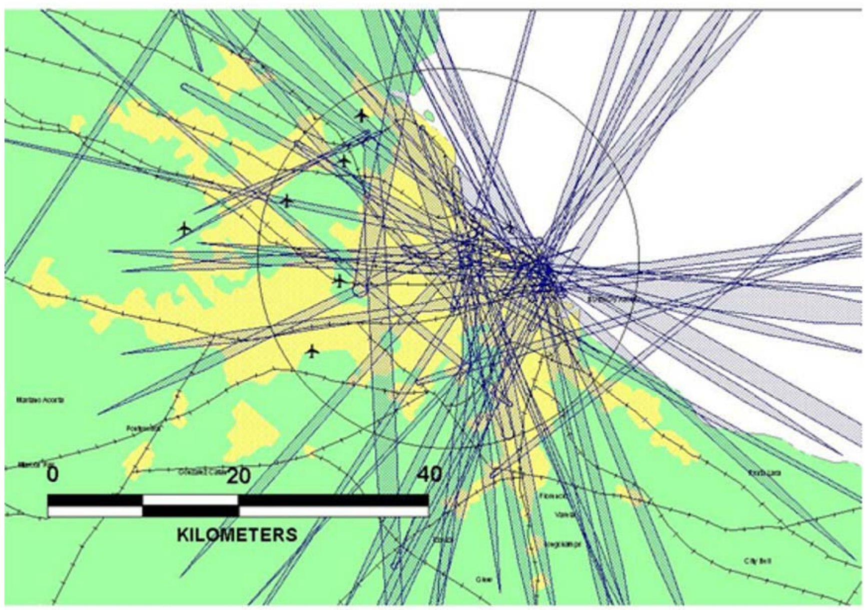


Figure 2. Service area of the planned LEOSAT-1 satellite system in the region of Buenos Aires (Results of computer simulation). Shadowed areas are excluded from the service because of interference from terrestrial microwave links. They occupy 37% of the 40 km reference circle shown. Exclusion regions due to satellite-generated interference to terrestrial systems are not shown. (Courtesy of T. Hayden).

Our past indicates that the approach to our resources changes, as does our understanding of their value and social role. We have discovered that many common resources, considered long time as being inexhaustible, have become scarce. Firstly, the commons in food gathering were abandoned. Farmland has been enclosed, and there is no free farmland now. Later, open pastures and free hunting and fishing areas have been restricted. Then, using the commons as a place for waste disposal has been abandoned and restrictions on the disposal of sewage are now widely accepted throughout the world. A concept of environmental protection was developed, and restrictions were also imposed on the pollution of land, water and air. Not so long ago, the radio frequencies and geostationary satellite orbit were added to the list of critical resources.

The issue of rational use, sharing, conservation, and protection of limited common resources has become an essential element, on national and world-wide scales. When discussing their future, several possible approaches can be indicated:
"We might sell them off as private property. We might keep them as public property, but allocate the right to enter them. The allocation might be on the basis of wealth, by the use of an auction system. It might be on the basis of merit, as defined by some agreed-upon standards. It might be by lottery. Or it might be on a first-come, first-served basis... " [Hardin 1968].

Any of these options implies an organizational framework necessary for coordination and negotiations among the parties interested. For common benefit, these parties have to agree common rules to be observed in sharing the resource, and mechanisms to settle unavoidable conflicts.

1.2.2 Preferences

Which of the approaches listed above is the best one? Each of them can be questionable, dependent on the criteria applied. The final answer results from human preferences of goals and hierarchies of values. In practice, it is often impossible to separate technical aspects of resource sharing from their economical, social and political contexts, and from the interests affected by them. The problem of sharing scarce resources cannot be solved by technical means, without involving systems of human values and ideas. Tradition and past experience play a significant role here:

"Every adoptable set of resource process will be one which is valued by some population in terms of that population's own system of activities. ... Where a resource process involves beliefs and techniques that are incongruous with a people's system of activities, it will not be adopted by that people, however superior it may be by other criteria." [Firey, 1977]

However, in a pluralistic society the goals and hierarchies of values are often inconsistent and conflicting:

"...The hierarchies of values and preferences of each individual are inconsistent among themselves and different individuals and ... groups have different hierarchies

of preferences which are partially in conflict with those of other groups and individuals. Furthermore, the capacities of different groups to implement their preferences ... are widely different" [Brooks 1972].

Inconsistency means here that progress toward realization of one value or goal is destructive of another value or goal held by the same individual or group, and the lack of consistency may be not obvious to the individual or group concerned. *Conflicting* goals or values mean such goals or values of two groups that cannot be served by the same policies: what enhances one will degrade the other.

The way in which the spectrum/ orbit resources are used follows the technological, economic, political and social changes in the world. Our past experience shows that societies follow the example of a leading or dominating nation and accept more or less voluntarily its "mode of life" and hierarchy of values.

1.2.3 Competition and Cooperation

The first uses of radio waves were military, to communicate with warships at sea. Soon, however, military secrets were abandoned under the pressure of private business rushing to exploit the “nobody land” of civilian radio. It was at the turn-out of the century that competition in radio communication started. In a liberal environment, without any control, regulation, and negotiations, soon mutual interference began to paralyze the operation of systems. Two tendencies appeared, one diverging and another converging. The diverging one was the competition among the operators, service suppliers and equipment manufacturers. It was leading to separate communication networks, mutual interference, and incompatible equipment. The converging force came from users, who wanted to communicate freely one with another, independently of the service or equipment supplier. Their pressure forced the service providers and equipment manufacturers to cooperate. The partisans of liberal capitalism would probably say it was the “invisible hand of free market” that forced the cooperation.

Finally, all parties came to a conclusion that coordination of their activities is necessary for common benefit. Such coordination activities started on a national scale, with strong governmental involvement. A global nature of the problem required, however, an international cooperation. Only two years after the first transatlantic wireless communication had astonished the world, the first international conference was called to coordinate the spectrum resource use. It was the so-called “preliminary conference” held in Berlin, in 1903. That conference marked the end of the first period of liberalism and uncontrolled rivalry in radio communications.

There were several separate maritime radio communication networks in operation at that time. However, because of competition, no communication was possible between the networks of different operators, and the following story is a good illustration of the problem. When Prince Henry of Prussia attempted to send President Theodore Roosevelt of the United States a courtesy message via radio while crossing the ocean in 1902, he was refused the service. The shore radio station, operated by the Marconi Company, was forbidden by its owner to deal with a ship station of the German competitor, in spite of the fact that there were no technical obstacles for the two stations to work together. Not without the influence of that incident, the Berlin International Radiotelegraph Conference of 1906 ruled that a communication service with ships must be provided regardless of the system used.

1.2.4 First agreements

The Berlin conference agreed upon the principles of radio spectrum management. One of major steps at the conference was the establishment of the International Bureau in Bern to register the operating frequencies of radio stations to control the spectrum occupancy and avoid mutual interference. It was the first attempt to manage the radio frequency spectrum, worldwide. The register of the occupied frequencies was named later “The Bern List”.

International treaties are all part of a world-wide game governments agree to play following certain rules. Agreement is an inevitable ingredient here, and there is nothing to force nations to abide by these rules. And governmental delegations represent interests of their citizens, including private sector interests. If competitive forces are stronger than cooperative ones, no progress could be made.

At the Berlin conference, it was not possible, due to conflict of interests, to reach consensus on issues related to inter-communication. Great Britain and Italy, where Marconi had a strong say, did not agree to final agreements and made reservations. Soon, a test of life showed in full light its tragic consequences. It was the well-known disaster of Titanic in April 1912. The Titanic was the most luxurious, most modern, and largest ship at that time, claimed as being unsinkable. During its maiden voyage with richest passengers on the board, it hit an iceberg and sank on the night of 14-15 April 1912, making it one of the deadliest peacetime maritime disasters. The story was revived by the movie under the same title that won 11 Academy Awards in 1997. Inquiries alleged that another liner was nearby and could have helped had its radio operator been on duty to receive the distress signals of the "Titanic".

Only three months later, and not without the influence of public opinion, the second radio conference was held in London. It finally settled the problem of inter-communication between ships on the sea: the reservations were removed. To a large degree, it was under the pressure of public opinion, shocked by the *Titanic* disaster just before the conference.

The World War I interrupted international cooperation for few years. Radio science and technology, harnessed to military applications, got an enormous impetus. When the war finished, all the scientific progress, technical developments and operational experience gained during the war time could be used again in peaceful service for the humanity. In new circumstances, the old international agreements regulating the use of radio waves were not appropriate.

The next international radio conference was called to Washington in 1927. The problem of frequency demand exceeding the available spectrum resource appeared sharply there, and the unending battle of frequencies had started. At that time, spark-type transmitters were in use. They occupied wide frequency bands, much wider than needed to transmit the information. (It is interesting to note that modern spread-spectrum techniques again use frequency band much wider then minimum necessary to transmit information, but discussion of that issue goes beyond the scope of the lecture.)The demand for a complete outlawing of spark-type transmitters was pressed strongly, but not passed because of conflict interests.

The spectrum shortage problem was settled in Washington by two actions. On the one hand, more stringent technical standards were imposed, to limit the radiation out-of the band necessary for transmission of information. On the other hand, the spectrum resource limits defined in old radio regulations were moved to embrace additional portions of spectrum, not yet regulated. That approach has been copied at all later radio conferences.

The drawing up of the first Frequency Allocation Table, regulating the use of the spectrum, was considered as one of the most important results of the Washington conference. Another one was to set up the International Frequency registration Board and International Radio Consultative Committee, CCIR. Its aim was to study technical ad operational issues relevant to radiocommunications and to issue recommendations on them. Later, under the pressure of service and equipment suppliers, administrations allowed the non-governmental sector to participate directly in the work of the ITU-CCIR. In the following years, the involvement of that sector increased. In 1992 one-third of entities participating in the CCIR work were nongovernmental.

1.3 Spectrum management

1.3.1 Background

The concept of spectrum management embraces all activities related to planning, allocation, assignment, use, and control of the radio frequency spectrum and satellite orbit resources. Three major objectives have been shaping spectrum management:

minimize conflicts, convey policy goals, and rationalize the use of the spectrum/ orbit resources. An alternative concept involves profit maximization only (Figure 3).

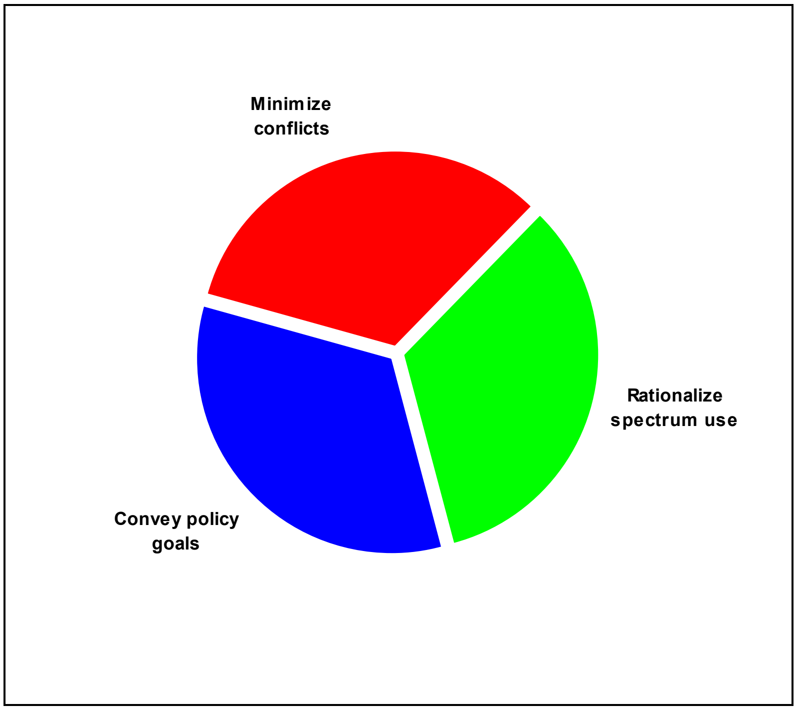


Figure 3. Three major objectives have been shaping spectrum management. An alternative concept involves profit maximization.

The society is composed of various groups, each with its particular interests, goals and views on how to use and manage the available resources (Figure 4). As a consequence of the scarcity, conflicts arise between those who have access to the resources and those who have not. Conflicts arise also between the proponents of competing uses of the spectrum as well as between those who manage the spectrum and those who use it. These conflicts are of various natures: commercial, political, physical interference, etc. [Huang 1993].

For those whose needs have already been satisfied, spectrum management should assure the continuation of the existing status. Any modification would threaten their acquired benefits. On the other hand, for newcomers, the principal aim of spectrum management would be to change the way the spectrum is apportioned and to eliminate obstacles that prevent them to enter the market. What is the best for one group is not necessarily good for another. The spectrum management rules and regulations tend to reflect the relative balance of powers of the competing interest groups. As demand on the spectrum increases, the management tasks grow more complex.

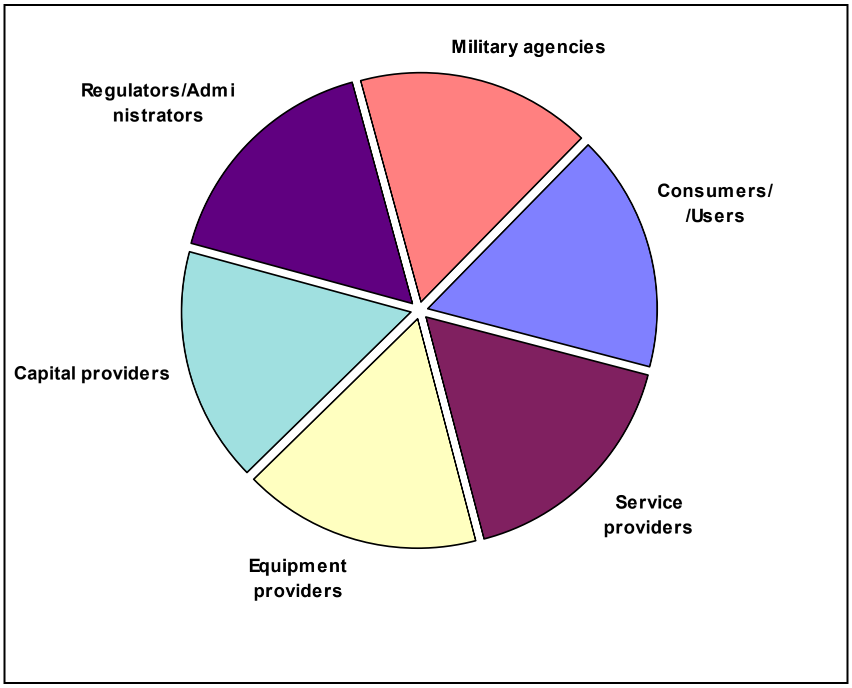


Figure 4. Major players in spectrum management. They are active in every ITU Member States, which involves also national interests and politics.

Few elements add international aspects to spectrum management tasks:

1. The development of international wireless services,
2. The threat of cross-border interference,
3. The pressure of equipment manufacturers and service providers for worldwide markets.

International spectrum management is presently voluntary and the International Telecommunication Union (ITU) creates its framework. The ITU Radio Regulations have been created step-by-step since the very beginning of radio. Each time a serious problem is recognized by the majority of ITU Members, the existing regulations are reviewed at an intergovernmental conference. However, only minimum modifications necessary to solve the problem at hand are agreed at each conference, leaving fundamental principles essentially untouched. One reason is that the process of intergovernmental conferences is often more about the art of politics and public relations than an exercise in economics and engineering, as the ITU Secretary General noted [Tarjanne 1992].

1.3.2 International Telecommunication Union (ITU)

The use of the radio frequency spectrum is now coordinated and regulated world-wide through the International Telecommunication Union (ITU). The ITU is a specialized agency of the United Nations since 1947, but its history goes back to 17 May 1865 when the International Telegraph Convention was signed. It is thus the oldest of all international organizations existing today, but its structure, working methods and regulations have been regularly revised, updated and extended to keep pace with new technologies, new services, and new needs. Since 1906, all uses made of radio are negotiated and regulated at the world level in the framework of the ITU. In 1963, the first World Space Radiocommunication Conference integrated the satellite orbit with the radio frequency spectrum into a combined concept of the spectrum and orbit resources that has entered permanently the ITU agenda.

The purposes of ITU are formulated in the Constitution and Convention which have the treaty status. They include, among others: "... *facilitating peaceful relations, international cooperation among peoples and economic and social development..., effect allocation of bands of the radio-frequency spectrum, the allotment of radio-frequencies and registration of radio-frequency assignments and any associated orbital positions in the geostationary-satellite orbit in order to avoid harmful interference between radio stations of different countries... coordinate efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of the radio-frequency spectrum and of the geostationary satellite orbit for radio-communication services;..."* This activity must, however, not interfere with the principle of sovereignty, and *" ...the sovereign rights of each country to regulate its telecommunications"*.

Allocation deals with frequency bands and services. It means designation of a given frequency band for its use by one or more radiocommunication services or applications, terrestrial or space. Allotment refers to frequency channels and geographic regions. It means designation of a specific radio frequency channel ('radio frequency') for use over a specified geographical area. Assignment deals with frequency channels and radio stations. It means authorization given by an administration for a radio station to use a radio frequency channel. Another major duty of ITU is the coordination of efforts to eliminate harmful interference between radio stations of different countries and to improve the use made of the radio frequency spectrum and satellite orbits. The agreed general rule of rational use of the resources is *"... to limit the number of frequencies and the spectrum used to the minimum essential to provide in a satisfactory manner the necessary services. To that end, [the ITU member countries] shall endeavour to apply the latest technical advances as soon as possible."*

The Constitution and Convention determine also working arrangements and the rights and obligations of the Union's members. The membership includes governments, scientific and industrial establishments, as well as private sector enterprises. It is a relatively new arrangement. Previously, the private sector could not participate directly in the work of the ITU (except for the participation in the work of CCIR and CCITT). The only possibility for private companies was to be a part of governmental delegation. In the time of this writing, the ITU membership consists of 189 Member States and about 700 non-governmental entities. The constitution and convention are reviewed at the Plenipotentiary Conferences called every four years or so. The most recent one took place in Marrakech, Morocco, in 2002. Each ITU member state, big or small, rich or poor, has a single voice, and there is a tradition in the ITU to reach agreement on controversial issues by consensus. One of major responsibilities of the union is the allocation of bands of the radio-frequency spectrum and registration of radio-frequency assignments and associated orbital characteristics of satellites.

Changes in the world require the policies and structure of ITU to be reviewed time to time. In this connection, the Members of the Union meet, at regular intervals, at a Plenipotentiary Conference. This is the supreme authority which lays down the general policy and structure of the ITU, reviews the Union's work and revises the Convention itself, if it considers this necessary. It also establishes the calendar of all ITU conferences, and sets a limit on expenditure until the next Plenipotentiary Conference. The Plenipotentiary Conferences of 1992 and 1994 have introduced major changes in functioning of the Union, marking the end of one era in the history of the ITU. The "new" ITU follows closer the liberalization trend seen around the world. Its functions have been separated in the three Sectors:

- Telecommunication Development Sector,
- Telecommunication Standardization Sector and
- Radiocommunication Sector.

1.3.3 ITU Radiocommunication Sector

To keep pace with technological, economic, and political changes, the ITU periodically reviews the spectrum management rules. Fig. 5 illustrates the process of global spectrum management in the ITU, in force since 1993. It forms a closed-loop system built around consensus-seeking studies and negotiations. The supporting organizational framework for international spectrum management is concentrated in the ITU Radiocommunication Sector. Its mission is, inter alias, to ensure rational, equitable, and economical use of the radio-frequency spectrum by all radiocommunication services, including those using the geostationary-satellite orbit, to solve international conflicts, and to carry out studies on radiocommunication matters. The mission is accomplished by

- ensuring meeting the specific needs of Members through Radiocommunication Conferences and Radio Regulations
- coordinating efforts to eliminate harmful interference between radio stations of different countries
- making recommendations on technical and operational radiocommunication matters through Radiocommunication Assemblies and Study Groups.
- maintaining Master International Frequency Register
- assisting Administrations in solving problems related to the use of radio frequencies and satellite orbits

The Sector consists of the following organs:

- World and Regional Radiocommunication Conferences
- Radio Regulations Board
- Radiocommunication Assemblies & Study Groups
- Radiocommunication Advisory Group
- Radiocommunication Bureau.

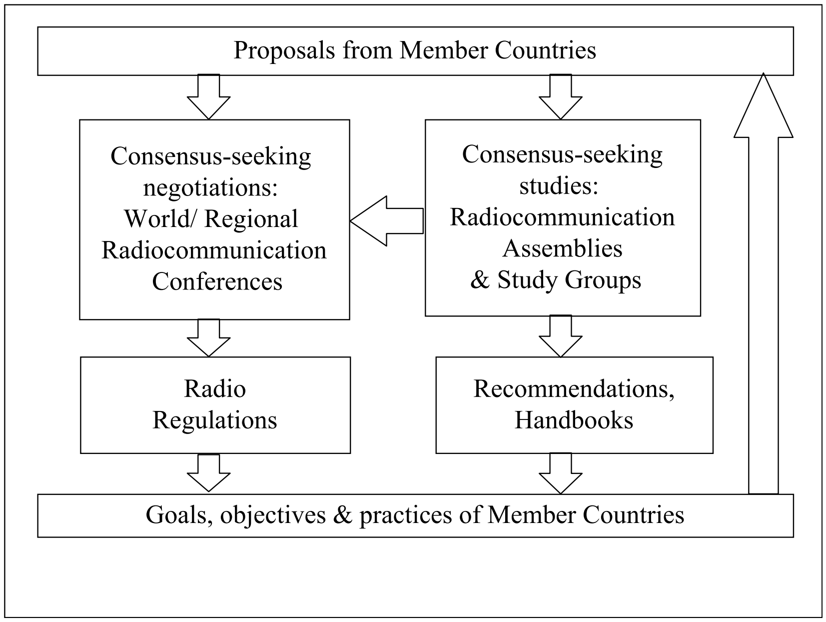


Figure 5. The ITU spectrum management process

1.3.4 ITU Radiocommunication Conferences

As the radio waves do not stop on political borders, international aspects of use of radio waves have been involved since the very beginning. For that reason, radiocommunication conferences have been organized to avoid or to minimize potential conflicts between states exploiting mechanism of multilateral coordination and negotiations. In the early years of radio, an administration was generally required to co-ordinate with one administration only. Later, the spectrum scarcity resulted in a necessity to co-ordinate among three and more Administrations. The negotiations with one may lead to modifying the characteristics of the network. This, in turn, often makes necessary re-negotiations with the other, and even the involvement of a third party, new in the processing. Such an iterative co-ordination and search-for-agreement process became absorbing much effort and time and lead to multilateral radio conferences. Following the tradition originated in Berlin, London, and Washington, the use of the radio frequency spectrum continues to be based on negotiations and consensus among all Members of ITU at radio Conferences. The general principles are:

- the radio frequency spectrum and satellite orbits are public resources, to which each country has equitable and free access;

- the use of the spectrum resource is based on mutually agreed regulations and administrative allocation of frequency bands and positions in the geostationary satellite orbit;
- the principles of electromagnetic compatibility (EMC) have to be followed by all parties (this term was introduced later).
- the regulations and frequency allocations are set through the mechanisms of consultations, negotiations, and consensus.

The Radio Conferences review and negotiate the current and expected usage of radio frequencies. They may establish and revise the frequency allocations, operational rules, standards, and relevant procedures. A collection of legal, administrative, operational and technical arrangements agreed by all parties at the Conferences are included into the ITU Radio Regulations. These Regulations are binding on all parties, and only the Conferences have the authority to revise them.

The participants in the Conferences are official governmental delegations of the ITU Member Countries. Each has one voice, independently of its size or economic significance. The Conferences are also open to the United Nations, international organizations, regional telecommunication organizations, intergovernmental organizations operating satellite systems, the specialized agencies of the United Nations, and the International atomic Energy Agency. The national delegations represent interests of all domestic groups, but there is a growing pressure to allow non-governmental entities a more direct involvement. Since 1993, non-governmental entities authorized by their countries to participate in the work of the Radiocommunication Sector are admitted also to radio conferences.

The Radiocommunication Conferences may be world-wide or regional, general or specialized. The general WARCs are authorized to deal with virtually all aspects of spectrum use. The specialized WARCs dealt with particular services and/or particular portions of the spectrum. The regional conferences are held to solve specific spectrum use problems within particular geographic regions. Some Radiocommunication Conferences are convened to negotiate and agree international frequency plans for certain application, geographical regions, and frequency bands which are subject to *a priori* planning. A frequency plan is a table, or more generally, a function that assigns appropriate characteristics to each of the radio stations at hand. It may be one, a few, or all characteristics by which radiocommunications can be distinguished one from another. Examples are: the operating frequency, power radiated, antenna location, height and radiation-pattern, polarization, service area, etc. Initially, in the early days of radio, only the frequency was assigned, and this explains the traditional name “frequency planning”.

In *a priori* frequency plans, specific frequency bands (and geographic areas) are reserved for particular applications well in advance of their real use. Individual regions may have various allotment plans for specific services (e.g., broadcasting), within their respective areas. *A priori plans* make a one-time distribution of the spectrum resource on the basis of the expected or declared needs of all parties interested. That approach has been used, for instance, for the sound and television broadcasting in Europe and in Africa, and for some satellite services. The techniques used for that purpose are discussed in the following sections. Critics of the *a priori* planning indicate that it freezes technological progress. Indeed, technological progress is very fast, and implementation of the plan may require several years. Technology known at the time of creation of the frequency plan may be obsolete at the time of its implementation. Another difficulty is the impossibility to predict future requirements with a needed degree of accuracy. Plans based on unrealistic data have no value at all.

The radio spectrum is available at no cost at international conferences, and there is no mechanism to limit the requirements. Although the ITU Convention calls for minimizing the use of the spectrum resource, *" ... each country has an incentive to overstate its requirements, and there are few accepted or objective criteria for evaluating each country's stated need. In fact, the individual country itself may have only the dimmest perception of its needs over the time period for which the plan is to be constructed ... Under these circumstances, it is easy to make a case that allotment plans are not only difficult to construct, but when constructed will lead to a waste of resources as frequencies and orbit positions are 'warehoused' to meet future, in-determinate needs..."* [Robinson 1980].

For the major part of its history, the ITU focused almost exclusively on the technical and operational standards necessary for smooth and interference-free international telecommunications (including tariffs). With the time, some issues related to policy matters and social impacts of telecommunications have been added to its agenda. Recently, the ITU initiated the World Policy Forums (WTPF). At these forums, all ITU members, states and private entities, discuss key policy and regulatory matters trying to elaborate a common position. The final documents agreed at the forum have no binding force, but serve as recommendation to be taken into consideration by the competent ITU body. The first WTPF held in 1996 debated the development and implementation of global mobile personal communications by satellite. The second forum, held in 1998, dealt with accounting rates. For 2003, the ITU is preparing the World Summit on Information Society. One may expect that modern technology will be discussed as one of the means that will contribute to closing the information gap.

1.3.5 Radio Regulations Board

The Radio Regulations Board is an elected collective body that approves technical criteria used by the Radiocommunication Bureau in the applications decisions of radio conferences and in applications of Radio Regulations between the radio conferences. It also provides advice to radio conferences and may perform any additional duties relating to the utilization of frequencies and the use of satellite orbits, within the competence of ITU-R.

1.3.6 ITU-R Study Groups

In addition to the international radio regulations, the ITU produces also recommendations concerning technical and operational matters and accounting rates, but these have no treaty status. They must be followed only if they are explicitly referred to in the Radio Regulations, or are included in the national regulations. The recommendations will not be dealt with here.

More than 1'500 specialists from telecommunication organizations and administrations around the world participate in the work of the eight study groups of the sector. They

- draft the technical bases and regulatory and procedural steps for consideration at radiocommunication conferences
- develop ITU-R recommendations on the technical characteristics of operational procedures for radiocommunication services and systems
- compile handbooks on spectrum management and on emerging radio services and systems

These studies are performed by the ITU-R members on a voluntary basis.

2 ITU Agreements

2.1 Radio Regulations

The Radio Regulations originated at the International Radio Conference, Atlantic City, 1947. They replaced the Service Regulations established at the first International Radiotelegraph Conference in Berlin in 1906 (and modified thereafter). The original Berlin regulations counted only 12 pages, whereas the current Radio Regulations occupy over 2000 pages, not counting a thick volume of Rules of Procedures. The Rules of Procedures are not part of the treaty, but are necessary for the implementation of its provisions in the ITU headquarters, as approved by the Radio Regulations Board. The provisions of Radio Regulations can be modified only by a competent World Radiocommunication Conference (WRC). Since the Atlantic City conference, they were updated a number of times. These updates embraced not only an increasing sweep of radio frequencies, but also a widening range of services, following the changing needs of member states. Figure 6 shows how the volume of the Radio Regulations increased in response to the growth of various radio systems and rising complexity of interactions among them.

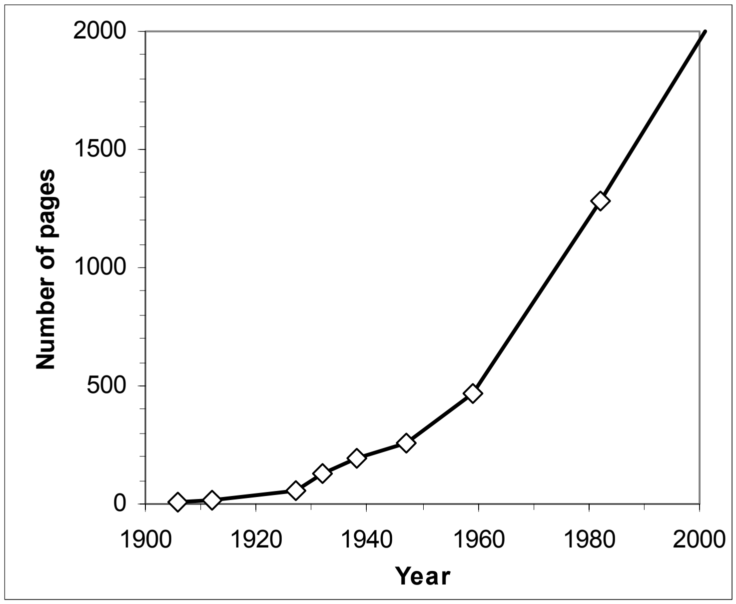


Figure 6. Increase of the volume of Radio Regulations in the years 1906 – 2001.

Space telecommunications issues were included into the Radio Regulations for the first time at the radio conference held in Geneva in 1971. The most recent WRC dealing with satellites was held in Istanbul, Turkey, in 2000; the next one is planned for 2003. The Radio Regulations define the allocation of radio frequencies to specific uses. They also specify operating procedures for stations and restrictions imposed, as well as detailed coordination, examination, notification and recording procedures. The aim is to assure an efficient use of radio frequencies and orbital positions, and international recognition of national frequency assignments. Not all frequency assignments need to be registered internationally. The uses that by their nature cannot cause interference across the border (low-power applications, short-range devices), or are immune to interference and do not require international recognition, do not need to be notified within the ITU. The Radio Regulations contain also frequency allotment plans for a number of services, including plans for broadcasting-satellite service.

2.1.1 Orbits

In the case of satellite systems, the space denied involves also elements of satellite orbit. Due to laws of physics, orbits of objects launched into space are open or closed, depending on the object's velocity. Open orbits (parabolas and hyperboles) are orbits of objects that escape the Earth attraction and run away. The velocity necessary for escaping is about 11 km/s at an altitude of 200 km, and decreases at higher altitudes. Objects at lower velocities either circulate the globe periodically as artificial Earth satellites at closed (elliptical) orbits, or fall down to the Earth. The Radio Regulations require the orbital parameters and frequencies of satellites to be registered in the ITU Master International Frequency Register.

These parameters must be kept within tight tolerances during the whole lifetime of the satellite. Usually, the orbital position of satellite must be corrected periodically (e.g. once a week or once a month) to compensate for the perturbations due to irregularities of gravitational fields of the Earth, and the attraction forces of the Moon and Sun. Geographical region irradiated by the satellite depends on the antenna radiation pattern and satellite position. Both have to be coordinated among the states irradiated by the satellite station. This is to be verified by the ITU using the methods and criteria specified in the Radio Regulations. The regulations forbid irradiating foreign territories without explicit agreement of competent administration, unless the incident power density is sufficiently low.

Synchronous orbits are orbits in which a satellite move in the same direction as the Earth and has the same period of 24 hours (more precisely 23 h 56 min 4.1 s). A synchronous orbit that is circular and lies in the equatorial plane is known as geostationary orbit (GSO), and satellites in it – as geostationary satellites. A satellite in a non-equatorial geosynchronous orbit will, when observed from a fixed point on the Earth, appear to move northward and southward. If the synchronous orbit is not perfectly circular, the difference in angular velocities of the Earth and satellite change in time, and the satellite will appear to move eastward and westward. The combination of these two motions will produce a figure-8 pattern as seen from the Earth.

Of all orbits, the geostationary orbit has generated greatest interest. It is at the altitude of about 36 thousand kilometres (theoretically 35'786 above the Equator or 42164 km from the Earth centre). The distance and direction from any point on the earth to a geostationary satellite do not change in time, except for some fluctuations due to the orbit perturbations. This has significant implications, as the directive antenna used to communicate with a stationary satellite does not need any tracking mechanism. Consequently, its construction is simpler, its reliability is higher, and its cost is lower than that of a comparable antenna for communication with any non-geostationary satellite. No other orbit offers comparable benefits.

However, with a fixed distance between neighbouring satellites, the number of possible satellite positions on the GSO is limited. For instance, the satellite separation of two degrees implies maximum of 180 separate satellite positions (as the GSO angular dimension is 360 degrees and 360/2=180). As new satellites are launched in the geostationary orbit every year, old satellites must be moved into other orbits. Some countries that expect to launch geostationary satellites in future worry that there may be no free place for them when they will be ready to launch. They therefore insist to make early reservations of the orbital positions and associated frequency bands they need. This is done in the form of frequency plans discussed in a section below.

A serious shortcoming of the geostationary orbit is that it is not visible from regions in far north and in far south, so that these regions cannot be served by geostationary satellites. To cover these regions, polar, or inclined orbits must be used. If the Earth were not rotating, a satellite in the polar orbit would travel along the same North-South meridian form one geographical pole to another. With East-West rotation of the Earth, the sub-satellite point traces more complex lines over the Earth surface. The same concerns the inclined orbits. Of all inclined orbits, the most famous is that of the Russian satellite 'Molnya', launched in 1965. This is an elliptic orbit inclined 63.4 degrees in relation to the equatorial plane. Its period is 12 hours, so that the satellite visits the same places at the same hours of the day. With the perigee (the orbital lowest point) of 500 km and apogee (the highest point) of about 39 thousand kilometres, the satellite moves very slowly in the sky near the apogee. Its angular velocity there approached that of the Earth rotation around its axis. The satellite behaves thus like a geostationary satellite, being 'practically geostationary' during 5 to 6 hours. In this orbit, it takes about 11 hours to travel across the north hemisphere and only about one hour to pass over the other hemisphere.

Low Earth orbits (LEO) are orbits in the altitude range 500 to 2'000 km, and Medium Earth Orbit (MEO) are those at altitudes of 8'000-20'000 km above the Earth. Figure 7 shows the difference between LEO satellites that make dozens of revolutions around the Earth per day, and MEO satellite that make few revolutions, and the geostationary satellites that apparently does not move at all. LEO satellites offer lower power requirements and shorter propagation delays than can be achieved geostationary satellites, or MEO satellites. Two LEO groups have emerged, *Little LEO* for data-communications satellites and *Big LEO* for data-and-voice communications, each using pre-assigned frequency ranges. Satellite systems offering true global coverage use polar orbits and a number of 'cooperating' satellites. As an individual non-geostationary satellite can be 'seen' only during a part of its period, another satellite must continue the service on its place. For instance, the Iridium Satellite System uses a constellation of 66 satellites in six orbital planes inclined 86.4 degrees. At time of writing it was the only provider of truly global, truly mobile satellite voice and data solutions with complete coverage of the Earth, including deserts, oceans, and Polar Regions.

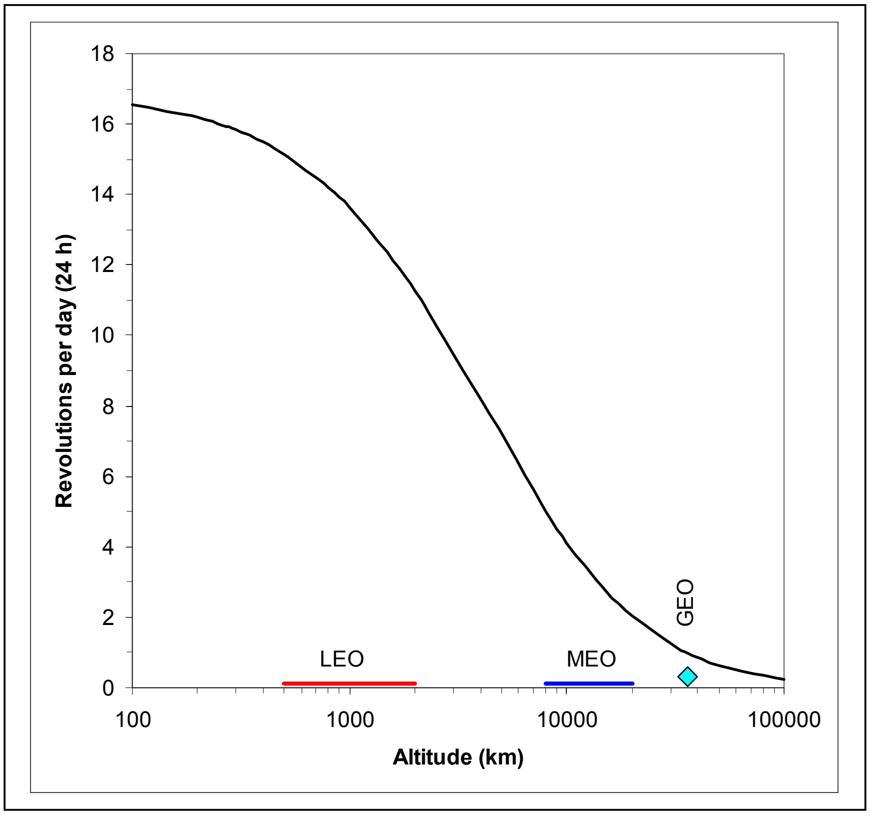


Figure 7. Number of revolutions of satellite versus its altitude above the Earth (circular orbit). LEO: Low Earth Orbit; MEO: Medium Earth Orbit; GEO: Geostationary Orbit.

2.1.2 Services

Radio Regulations are based on a concept of Radiocommunication Service. Such a service is defined as transmission, emission, and/or reception of radio waves for telecommunication purposes. For instance, Table 3 lists satellite services. Some services are active whereas others are passive. Active services use equipments that radiate radio waves. Passive services use non-radiating devices only. Radio Astronomy, considered within the Union as radiocommunication service, is an example of passive service. Passive services that use signals of natural origin, like

Radio Astronomy, require special protection, as they cannot choose the operating frequency. The choice has been made by Nature.

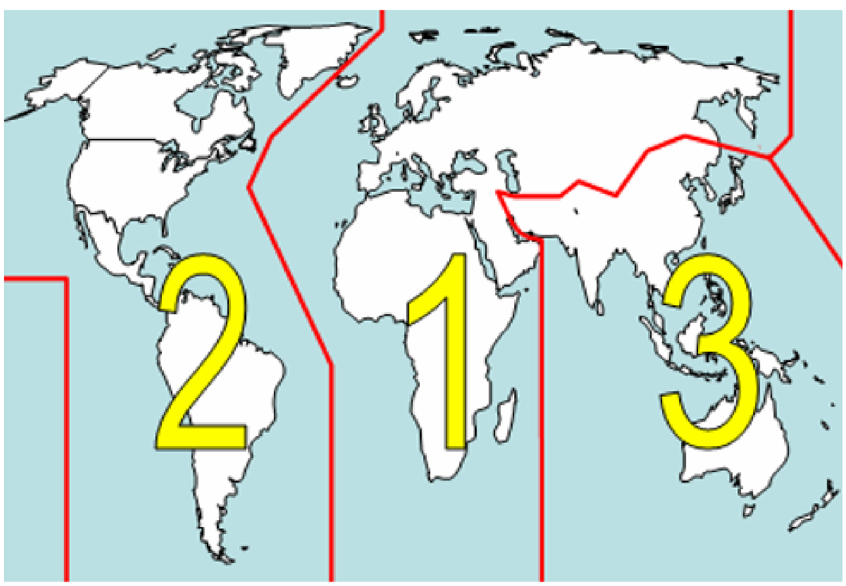
Table 3. Satellite services defined in the Radio Regulations.

Aeronautical mobile-satellite (OR) service [*off-route*]
Aeronautical mobile-satellite (R) service [*route*]
Aeronautical mobile-satellite service
Aeronautical radionavigation-satellite service
Amateur-satellite service
Broadcasting-satellite service
Earth exploration-satellite service
Fixed satellite service
Inter-satellite service
Land-mobile satellite service
Maritime mobile-satellite service
Maritime radionavigation-satellite service
Meteorological-satellite service
Mobile-satellite service
Radiodetermination-satellite service
Radiolocation-satellite service
Radionavigation-satellite service
Space operation service
Space research service
Standard frequency and time –satellite service

Each service is treated separately. The radio frequency spectrum is insufficient to allocate a separate frequency band for an exclusive use by each radiocommunication service. Some bands must be shared by two or more services. In such a case, one of the services may have the status of primary service whereas the other services have the status of secondary service. Stations of a secondary service shall not cause harmful interference to stations of primary services to which frequencies are already assigned or may be assigned later. They cannot claim protection from harmful interference from stations of a primary service to which frequencies are already assigned or may be assigned later. However, they can claim protection from harmful interference from stations of the same or other secondary service(s) to which frequencies may be assigned later. When two or more services of equal status have to use the same frequency band, the principle of seniority applies, known also as the 'first-come, first served' rule. That principle, however does not apply to frequency bands included in the approved frequency plans and other special agreements.

2.1.3 Regions

For the purpose of radio regulations, the world has been divided into three geographical regions (Figure 8). Region 1 includes the whole Europe, Africa, Middle East and northern part of Asia. Region 2 covers the Americas, and Region 3 - the southern part of Asia, Australia and Oceania. In addition, defined are the African Broadcasting Area, European Broadcasting Area, and European Maritime Area. Each region has its individual frequency allocations but some services have worldwide frequency allocations, i.e. identical in all three regions. Global allocations are desirable to avoid incompatibilities in border regions and to create large markets for equipment and services. The divided world does impede trans-regional services and trade: with different frequency allocations, radio designed to work in one region would usually not work in another region. The reasons why such a division was decided have not been disclosed. No physical or technical phenomena justify it. One only may speculate that the original purpose was to protect monopolistic markets in regions of economic and political influence.



R. Struzak

Figure 8. For the purpose of Radio Regulations, the world has been divided into three geographical regions numbered 1, 2, and 3.

2.1.4 Frequency Allocations

The radio frequency spectrum has been divided into a number of specific frequency bands allocated to specific services in each of the three regions. A competent conference may allocate a specific frequency band to a service that has convincingly demonstrated its need for that band and that the new allocation will be compatible with the existing uses of that band and adjacent bands. The conference may also modify earlier allotments ('spectrum re-farming'). The frequencies below 9 kHz or above 275 GHz were not allocated at the time of this writing. The allocations between 9 kHz and 275 GHz are defined in the Table of Frequency Allocations and Footnotes to it (see the Annex). Some of the footnotes specify additional constraints on the use of frequency bands while others provide additional or alternate frequency allocations to individual countries or group of countries. Each use made of frequencies subject specific restrictions. For a given service, the frequency allocations and restrictions may depend on the communication direction. For instance, uplinks and downlinks may use different frequency bands subject different restrictions.

The division of the frequency spectrum into small portions to separate various services has historical justification, but not always matches the needs of modern technology. For instance, the spread-spectrum systems use correlation methods to separate wanted signals from unwanted ones and are, by their very nature, broadband, whereas most of classic systems are narrowband. With narrow frequency bands allocated, potential capabilities of the spread-spectrum systems are sometimes not fully exploited. An Ultra Wideband (UWB) system can use bandwidth of 1.5 GHz or more (fractional bandwidth greater than 0.25) which extends over a number of individual frequency bands defined in the Radio Regulations. UWB proponents claim that their system can co-exists with all of the current services. However, the issue is open, as those dealing with GPS, radioastronomy, and some other passive services do not share that opinion. The issue will be discussed at one of the forthcoming WRCs.

2.1.5 Frequency Plans

The Radio Regulations contain also frequency assignment plans for some services, frequency bands, and regions. Such a plan, if related to space, defines frequency and position of the satellite-born station in the orbit. A variation of the planning process is the allotment plan which specify the uses made over a specific area without defining precise location of stations (as in the assignment plan). Allotment is converted into a specific assignment before bringing it into use. A country may use its assignment without involving full coordination procedures, as necessary coordination had been done earlier, when the plan was negotiated.

Frequency bands and orbital positions included in frequency plans and reserved for use by specific states or group of states. This is sometimes strongly criticized, as wasting precious resources and creating artificial congestion. The reserved frequency bands may remain unused for many years and for various reasons. At the same time, other applications cannot find free frequencies. The Radio Regulations contain the Plan for the Broadcasting-Satellite Service in the frequency bands 11.7-12.2 GHz (in Region 3), 11.7-12.5 GHz (in Region 1) and 12.2-12.7 GHz (in Region 2). The plan, originally produced in 1977, was modified a number of times, last time in 2000. It defines a set of characteristics, such as the satellite positions in the geostationary orbit, frequency channels, and space station antenna pointing and radiation characteristics. It also specifies the procedures for coordination, notification, examination and recording in the Master International Frequency Register. Moreover, it defines power flux-density limits to protect terrestrial services from space-borne interference. Similar frequency plans exist for the associated feeder links (in the frequency bands 14.-14.8 GHz and 17.3-18.1 GHz in Regions 1 and 3, and 17.3-17.8 GHz in Region 2) and for the fixed-satellite service in the frequency bands 4.500-4800 MHz, 6725-7025 MHz, 10.70-10.95 GHZ, 11.20-11.45 GHz and 12.75-13.25 GHz.

2.1.6 "Forbidden" Frequencies

The Frequency Allocation Table of Radio Regulations allocates some frequency bands for use by passive services such as radio astronomy or Earth exploration-satellite service (passive). Table 4 lists these bands. All emissions are prohibited in these frequency bands and the uses made of the adjacent frequency bands (spill-over including) must not extend specific frequency and power limits. The last column of the table identifies the relevant footnote to the Table of Frequency Allocations.

2.1.7 "Free" Frequencies

The Radio Regulations allocates some frequency bands for non-telecommunication purposes. These are known as 'ISM frequencies', 'free-radiation frequencies', or 'non-licensed' bands. They are listed in Table 5. The last column of the table identifies the relevant footnote to the Table of Frequency Allocations. The abbreviation 'ISM' means industrial, scientific, domestic and medical applications. Note that the use of specific ISM bands requires special authorization (RR 5.138). Some ISM bands have been used also by interference-immune communication systems, such as low-power wireless local area networks (WLANs). However, systems operating within these bands are unprotected and must accept interference.

Table 4. Frequency bands in which all emissions are prohibited.

Lower Frequency	Upper frequency	Unit	RR Footnote
1400	1427	MHz	5.340
2690*	2700	MHz	5.340
10.68*	10.7	GHz	5.340
15.35*	15.4	GHz	5.340
23.6	24	GHz	5.340
31.3	31.5	GHz	5.340
31.5*	31.8	GHz	5.340
48.94*	49.04	GHz	5.340
50.2*	50.4	GHz	5.340
52.6	54.25	GHz	5.340
86	92	GHz	5.340
100	102	GHz	5.340
109.5	111.8	GHz	5.340
114.25	116	GHz	5.340
148.5	151.5	GHz	5.340
164	167	GHz	5.340
182*	185	GHz	5.340
190	191.8	GHz	5.340
200	209	GHz	5.340
226	231.5	GHz	5.340
250	252	GHz	5.340

*) with some exceptions

3 UN Space Agreements

The development of telecommunications has been strongly influenced by space activities. The Space Era has began when the first artificial earth satellite was launched by the Soviet Union in 1957. This event was prepared by earlier publications of Arthur C. Clarke of Great Britain, Herman Potocnik (1892-1928), an Austro-Hungarian of Slovene origin and Konstantin Tsiolkovsky (or Ciolkowski), (1857-1935), a Russian scientist of Polish origin. The Soviet's monopoly did not last for long time. The first American satellite, Explorer 1, was put in the orbit only a few months later. Both satellites were products of military research laboratories. Explorer 1 was designed, built, and launched under the direction of Wernher Von Braun, the ex-prisoner-of-war and the creator of the famous series of German rocket missiles V1 and V2 that were used in the attempt to destroy London during the World War II.

The first satellites were small and short living when compared with the modern International Space Station (ISS) see Table 6. The table illustrates the progress made: the satellite mass increased more that thousand times! The ISS is shown in Figure 9.

It is the largest and most complex international scientific project in history. With its lifetime cost estimated for ~US$100 billion, it is also the most expensive and controversial project. The ISS serves as an Earth-orbiting laboratory drawing upon the scientific, technological and financial contribution of 16 nations: Brazil, Canada, the eleven members of the European Space Agency, Japan, Russia, and the USA.

Table 5. Frequency bands allocated to ISM applications.

Lower Frequency	Upper Frequency	Unit	RR Footnote
6.765	6.795	MHz	5.138
13.553	13.567	MHz	5.150
26.957	27.283	MHz	5.150
40.66	40.70	MHz	5.150
433.05*	434.79*	MHz	5.138
902**	928**	MHz	5.150
2.4	2.5	GHz	5.150
5.725	5.875	GHz	5.150
24	24.25	GHz	5.150
61	61.5	GHz	5.138
122	123	GHz	5.138
244	246	GHz	5.138

*) In some countries of Region 1. **) In Region 2

During the first nine years of the space history, 1957 to 1965, only two countries were able to launch satellites: the USSR and the United States. They collected invaluable data on the space environment and its effects on equipment and on living organisms. The Explorer 1 mission evidenced an unusual concentration of cosmic radiation in some region around the Earth. That region has been called the Van Allen radiation belt after James A. Van Allen of the University of Iowa who designed the experiment. This discovery was of great importance. The satellite orbits are designed to avoid the Van Allen belt as much as feasible, since electronics, and hence satellite lifetime in the orbit, is strongly affected by the radiation, and millions of dollars are at stake.

Relations among nations change. We have seen throughout history how cooperation between nations changes into competition, peace into war, forth and back, affecting strongly activities of individuals and nations. The USSR and the USA, ex-allies during the World War II, turned into enemies when the war was over. Soon after the Charter of the United Nations, claiming a new peaceful order among nations, was approved in 1945, the ‘cold war’ started. Each superpower worked on new weapons to assure its worldwide dominance. In that competition, satellites served as a deterring propaganda element. A heavier satellite in the sky meant a more powerful rocket engine and bigger nuclear bomb carried to and dropped at any place on the Earth.

Figure 9. Artist's rendering of the International Space Station following the undocking of the Space Shuttle Atlantis. Still being build, the station will accommodate six astronauts making scientific experiments at an altitude of 200 to 600 km. (Courtesy of NASA)

The arms race resulted in a menace of mutual annihilation, which in turn generated a need for some survival assurance. Spy satellite technologies were thus developed to monitor military activities with required precision. A degree of cooperation in space became both possible and necessary to solve problems the space era brought with it. For instance, a satellite, its crew, or its component parts could land on a foreign territory, under foreign jurisdiction. Or, a satellite crew could need assistance that only the other state could deliver. Such situations never happened before the space era and thus mutual responsibilities and obligations of the both states involved were undefined. In the meantime, other states became also interested in space activities. The USA-USSR space domination was broken in 1965. France launched its satellite on 26 November 1965, using its own rocket and becoming thus the third space power in the world. In 1971, each of the two blocks involved in the cold war created an intergovernmental satellite operating organization: Intelsat and Intersputnik respectively. Later, other similar organizations originated, see Table 6. International cooperation in space has accelerated.

Table 6. The first and the largest artificial satellites of the Earth.

	Sputnik 1 (USSR)	Explorer 1 (USA)	ISS (International)
Launch date	4 October 1957	31 January 1958	31 October 2000
Form	Sphere	Cylinder	Complex
Diameter, m.	0.58	0.15	---
Length, m.	---	~2	~88
Width, m	---	---	~108
Mass, kG.	83	14	~430'000*
Min altitude above Earth, km.	227	358	~200
Max altitude above Earth, km.	945	2550	~600
Orbit period, min.	96	115	90
Mission length	21 days	112 days	25 years*
*) The ISS hardware has not yet been completed at the time of writing			

The first satellites were developed by governmental (military) research laboratories, and the governmental monopoly lasted seven years after Sputnik 1. The monopoly was broken 10 July 1962 when Telstar I, the first non-governmental satellite was launched in the USA. Developed by the AT&T private company, the Telstar I was the prototype for a constellation of satellites that AT&T intended to develop and operate. The constellation would consists of 50 to 120 satellites at random orbits at the height of the order of 10'000 kilometres and would provide service 99.9 per cent of the time between any two points on earth. The cost of the space part of such a system was estimated in 1961 at US$500 million. The project was halted when the Kennedy Administration decided to give the monopoly on satellite communications to Comsat.

Telstar I was the first telecommunication satellite with transponders, and the first satellite that transmitted the live broadcasts between the United States and Europe. At that time, the satellite provided almost 10 times the capacity of the submarine telephone cables for about 1/10th the price. The cable-satellite price-difference was maintained until the laying the first fibre-optic cable laid across the Atlantic in the late 1980s. Satellites were especially competitive in point-to-multi-point (broadcasting) applications, and that advantage continues. Canada began domestic satellite service in 1972. It was joined by the United States (1974), Indonesia (1976), Japan (1978), India (1982), Australia (1985), Brazil (1985), Mexico (1985), and others. The satellite industry, dominated for long time by governments, began to move fast towards the free market. Even Intelsat, Eutelsat, and Inmarsat (that were originally created as intergovernmental entities) have been reconstituted as private companies.

Table 7. International Agreements on Space-related Organizations.

1971	Intelsat	Agreement Relating to the International Telecommunications Satellite Organization -Intelsat (www.intelsat.com)
1971	Intersputnik	Agreement on the Establishment of the Intersputnik International System and Organization of Space Communications (www.intersputnik.com)
1975	ESA	Convention for the Establishment of a European Space Agency (www.esa.int)
1976	Arabsat	The Agreement of the Arab Corporation for Space Communications - Arabsat (www.arabsat.com)
1976	Intercosmos	Agreement on Cooperation in the Exploration and Use of Outer space for Peaceful Purposes (Intercosmos)
1976	Inmarsat	Convention on the International Maritime Satellite Organization - Inmarsat (www.inmarsat.org)
1982	Eutelsat	Convention Establishing the European Telecommunications Satellite Organization - Eutelsat (www.eutelsat.org)
1983	Eumetsat	Convention for the Establishment of a European Organization for the Exploitation of Meteorological Satellites – Eumetsat (www.eumetsat.de)

3.1 Space Treaties

This section reviews major multilateral international agreements that have been negotiated in the framework of the United Nations (UN). This organization, founded in 1945 to promote peace, security, and economic development is now composed of most of the countries of the world. A first significant step in developing international cooperation in space was the adoption by the General Assembly of the United Nations in 1963 of the Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space. It was the birth of international space law, uniting the customary law and international treaties. Customary law bases on commonly observed practices in the past. A treaty is a formal explicit agreement negotiated between two or more sovereign states, binding for the states that have ratified it (i.e., national laws in these states must be in accordance with the treaty). Treaties base on the principle of *good faith* and principle of *not doing any harm to the treaty signatories*, as Titus Spoelstra, CRAF Frequency Manager/Secretary, formulated it shortly [Spoelstra 2002].

International law deals with the state and its relationships with individuals or with other states. In contrast, private law deals with the legal rights of private individuals.

Non-governmental entities (private companies, individual persons, foundations) under international law are legal objects, not subjects. If a private company of one state enters in conflict with a company of another state, the conflict becomes a public case in terms of international law. Disputes between the states may be settled according to procedures established by the relevant treaties, by negotiation through diplomatic channels, via arbitration, or by any other method mutually agreed. Violating international treaties usually experiences only a moral sanction: the public opinion of the civilized world. In some cases, however, economic or even military sanctions can be applied. Table 8 lists major treaties relevant to space activities. The year indicated in the table is the year when the treaty was opened for signature (its entry into force was usually a few years later), or the year of adoption of the principle by the UN General Assembly. The table indicates also the internet Web page address where the original text of the agreement can be consulted.

The Outer Space Treaty (OST) furthered the purposes and principles of the Charter of the United Nations of 1945. It furnished a general legal basis for the peaceful uses of outer space and provided a framework for the developing law of outer space. Outer space is considered a *common heritage of humanity.* It identifies few basic principles concerning the exploration and use of outer space. Among these principles, freedom of scientific investigation, exploration, and use is at the top of the list. International cooperation is strongly encouraged. Another principle proclaims exploration and use to be carried out for the common benefit and in the interests of all countries, rich and poor. The OST also states that outer space is not subject to national appropriation. Further, it declares activities to be pursued in accordance with international law and uses for peaceful purposes only. Moreover, it requires space activities to be duly authorized and continuously supervised by the state, even if these activities are performed by a private entity. According to further articles of the Treaty, each state that launches or procures the launching of an object into outer space retains jurisdiction and control over that object during and after the mission, and is liable for any damage caused by it or by its component parts. This requirement should be seen in conjunction with the Liability Convention and Registration Convention.

Table 8. Major International Agreements Related to Space Activities.

1963	Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space http://www.oosa.unvienna.org/SpaceLaw/lpostxt.htm
1967	Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty) http://www.oosa.unvienna.org/treat/ost/ost.html
1968	Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue Agreement) http://www.oosa.unvienna.org/SpaceLaw/rescuetxt.htm
1972	Convention on International Liability for Damages Caused by Space Objects (Liability Convention) http://www.oosa.unvienna.org/SpaceLaw/liability.htm
1974	Convention Relating to the Distribution of Programme-Carrying Signals Transmitted by Satellite (Brussels Convention) http://www.wipo.org/clea/docs/en/wo/wo025en.htm
1975	Convention on Registration of Objects Launched into Outer Space (Registration Convention) http://www.oosa.unvienna.org/SORegister/registxt.htm
1979	Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement) http://www.oosa.unvienna.org/SpaceLaw/moon.html
1982	The Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting http://www.oosa.unvienna.org/SpaceLaw/dbstxt.htm
1986	The Principles Relating to Remote Sensing of the Earth from Space http://www.oosa.unvienna.org/SpaceLaw/rstxt.htm
1992	UN – The Principles Relevant to the Use of Nuclear Power Sources in Outer Space http://www.oosa.unvienna.org/SpaceLaw/nps.html
1998	General Agreement on Trade in Services – Annex to the Fourth Protocol of the General Agreement on Trade and Services http://www.wto.org/english/docs_e/legal_e/legal_e.htm
2001	Radio Regulations (on sale at www.itu.int)
2002	International Telecommunication Constitution and Convention http://www.itu.int/publications/cchtm/cns.html

Other articles impose on the states the requirement to avoid harmful contamination of outer space and celestial bodies. Adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter must also be avoided. If a state has reason to believe that an activity or experiment planned by it or its nationals in outer space would cause potentially harmful interference with activities of other state in the peaceful exploration and use of outer space, it shall undertake appropriate international consultation before proceeding with any such activity or experiment. The treaty imposes the requirement to inform the public and the international scientific community on space activities and to promote international cooperation. It also sets a legal framework for setting and operation of bases on the Moon.

The other treaties developed further certain general concepts included in the 1967 Outer Space Treaty. Regarding the 1975 Registration Convention, there are proposals of unification of national registers and clarification of certain terms, such as 'launching state'. Regarding the 1979 Moon Agreement, there are suggestions to review its provisions concerning the exploitation of moon resources, to make it more adapted to today's international scenario. After 1959, data on objects launched into outer space became distributed by the Committee on Space Research (COSPAR). These are available also via the World Wide Web (http://nssdc.gsfc.nasa.gov/spacewarn/spacewarn.html). Most of space-related treaties refer explicitly to the *Related International Agreements,* namely the International Telecommunication Union (ITU) Constitution and Convention and the ITU Radio Regulations that we already discussed in an earlier section. Some issues relevant to space activities are also negotiated in the framework of the World Trade Organization (WTO). These will be treated in separate sections.

4 WTO Trade Agreements

This section reviews two multilateral agreements reached within the World Trade Organization (WTO). WTO is a UN forum developed to promote free markets and trade liberalization through dispute settlements and multilateral trade negotiations and agreements aimed at abolishing trade obstacles.

4.1 GATS

In 1997, the WTO completed the round of negotiations on basic telecommunication services, in the framework of General Agreement on Trade in Services (GATS). Immediately after the agreement was reached on basic services, a new negotiations round started on additional services. Indeed, modern digital communication systems make the basic and the value-added services indistinguishable. The objective is an open worldwide telecommunication services market, advantageous to all, without unduly regulations and restrictions. In such a market, the public telecommunications networks can be accessed under non-discriminatory terms and at cost-oriented and affordable rates.

4.2 TRIPS

WTO is also involved in the Agreement on Trade Related aspects of Intellectual Property Rights (TRIPS Agreement) to protect patents on, for example, communication equipment and software developments. The negotiations are not easy. In his inaugural address to the 2000 forum on Intellectual Property Policy and Strategy in the 21st Century held in New Delhi, Thiru Murasoli Maran, the Indian Minister for Trade and Commerce, provided a stinging critique of the agreement. It unduly protected the economic interests of right owners and ignored the basic human values, he said. Instead of advancing creativity and a larger vision of global benefits, the TRIPS Agreement was promoting inequities and injustices, in his opinion. He regarded the agreement as a component of technological protectionism aimed at consolidating an international division of labour, where the rich countries of the north generate innovations and the poor countries of the south constitute the market for the resulting products and services. Anyway, the WTO introduced new elements of business reality, to which neither national regulations, nor the ITU treaties were well prepared. In spite of all critics, the WTO agreements are expected to facilitate the evolution of truly global telecommunication services and service providers, and accelerate the convergence of telecommunication, electronics, and entertainment sectors.

5 Topics for Discussion

This section deals with some challenges the society is confronting today. New inventions and new applications are emerging continuously. At the same time, the trend of liberalization and privatization is progressing. The first space treaties and radio treaties were created when the private sector was not yet directly interested in these agreements. Many of the spectacular radio and satellite applications we witness today were considered science fiction at that time. When the space treaties were signed, no one ever expected problems with space tourism, orbital debris or with paper satellites. Very few were thinking on enormous potential benefits of common projects serving the whole humanity, the rich and the poor, such as a worldwide emergency communication network for instance.

5.1 Astonishing Applications

Space tourism belongs to the category of most astonishing applications. Not so long ago, it was a pure fantasy, but now the era of space tourism is a reality. Millions of dollars have already been invested in projects of suborbital tourist vehicles, orbital hotels and lunar cruise ships. Some American and Japanese business predictions suggest that space tourism could be a US$10 billion-per-year industry within two decades or so.

The space tourism era has begun on 28 April 2001, when Dennis Tito started his visit to the International Space Station on the board of Russian vehicle, for a price estimated for 'only' US$20 million a week. As Mr. Tito was an American businessman, one could think that space tourism can attract only people from the "Rich North". However, the world's second paying guest in space come from the "Poor South". Mark Shuttleworth, an African citizen, started his journey on 25 April 2002, for a figure similar to that paid by his predecessor. After his "historic mission", as the press named it, thousands of people gathered 10 June 2002 in Cape Town to welcome him as a national hero. And all this happens in times when there is a chronic lack of funds to solve environmental problems, eradicate famine and misery, or improve public health care and education. That indicates how much different are hierarchies of values and preferences in our divided society.

5.2 Emergency Communications

Two billion people are affected per decade, and losses reach US$740 billion, due to windstorms, floods, and other disasters that touch both the rich and the poor with no difference. These are data from the World Disasters Report 2000. In the field, reliable communications is often a matter of life or death, and special emergency communication systems have already been created in many countries. However, terrestrial systems are rarely operational where disaster occurs, and if they are there, their terrestrial components are usually destroyed during the disaster. The necessary equipment must be transported, often from distant places, and deployed each time they are needed. Moreover, the current emergency telecommunications is a patchwork of various technologies, equipment, and protocols, not always working together smoothly, as summarized in the Report on Emergency Telecommunications [Struzak 2000]. There is an urgent need for a global satellite broadband emergency communication network, as stipulated in that report. The current technology is capable to build such a network; what is missing is the political will and financial support. The suggested global broadband emergency communication/ information infrastructure, permanently present in the sky and universally accessible from any point on the Earth, would play an important role in timely warning and in effective disaster preparedness.

The proposed system could transmit satellite images of hurricanes, flooding, or fires to any place where they are needed. Figures 10 and 11 are examples of such images. Material threats and losses could be evaluated immediately and objectively by international experts, no matter at what distance from the disaster area they actually might be. The population threatened could timely be warned and evacuated from the area affected. The evacuation plans could be updated quickly to match the changing situation, and the disaster relief activities can be planned more precisely and with no delay. If only one percent of these losses could be avoided due to the proposed emergency communication/ information system, it would mean 20 million affected people less and US$7.5 billion material losses less. It is just the population of a country like Australia and the GPD of a country like Iceland. One may also speculate that such a common system would cost less than the total cost of a number of individual national systems operating separately. However, such analysis has never been made.

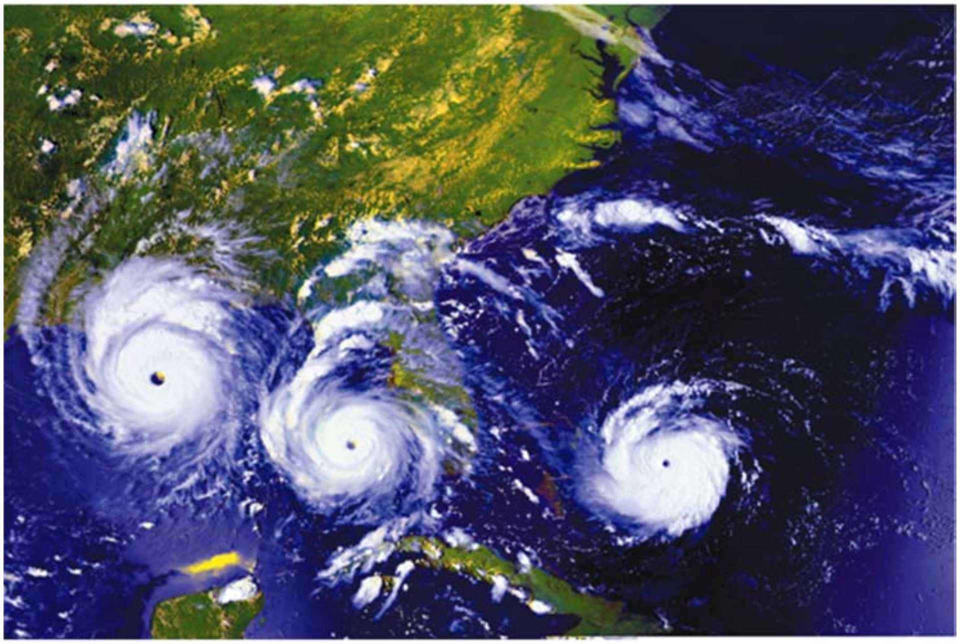


Figure 10. Three consecutive satellite views of hurricane Andrew on 23, 24 and 25 August 1992 showing its path from East to West over the Florida peninsula. The hurricane caused 26 deaths and US$26'75 billions in damage. Such images help to prepare people and goods threatened to survive the disaster. (Courtesy of NASA)

A LEO satellite network, like the failed Teledesic system, could ideally serve as global emergency communication/ information system. Its cost would be about a half of the budget of the Apollo project that culminated in the displaying the US national flag on the Moon. This comparison of the Apollo and Teledesic projects leads to reflections on the hierarchy of values of our society. It was easier to find US$19 billion to put the flag on the Moon than to find a half of that amount for a global emergency communication system that matches ideally the noble goals and declarations included in international treaties. The Teledesic failure illustrated basic limits of the social system that prefers "profit over people", as Noam Chomsky, professor at Massachusetts Institute of Technology, formulated in his book under the same title [Chomsky 1999].

Figure 11. Two consecutive images of the Elbe River (Germany) taken on 14 and 20 August 2002. The river is visible as a thin line from the lower right corner to the upper left corner of the upper image. The lower image shows the flooding in full progress. The summer 2002 floods in Europe have killed more than 100 people and have led to US$20 billion in damage. Such images help to evacuate people and goods threatened and to evaluate the disaster effects. (Courtesy of NASA)

5.3 "Paper satellites" and "Illegal Satellites"

'Paper Satellites' is the name invented for satellite systems that are submitted for notification in the ITU but never will really operate. This results in a significant waste of time and effort spent on the coordination, examination and notification process in the ITU and in administrations involved. It also blocks access to spectrum and orbital resources and produces their virtual scarcity. The ITU receives 400 to 500 requests for coordination and notification each year whereas only 10 to 20 satellites are actually launched yearly. About 1'200 satellites are waiting coordination (as of September 2002), according to Robert Jones, Director, ITU Radiocommunication Bureau [Jones 2001]. With such a long queue, delay processing reaches in some cases up to 6 years or so. It is rather a long time. In that time, four generations of electronic technology change according to the Moore's Law (which says that the number of transistors on integrated circuits -- a rough measure of computer processing power -- doubles every 18 months). Satellite business sometimes cannot wait so long. Consequently, some satellites are coordinated outside the ITU process, or launched before the process is concluded, which evidently introduces chaos. Formally, the Radio Regulations allow for such a practice on the express condition that it "*shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of [...] these Regulations.*"

The huge world demand for satellite services has seen steady increase, reflecting the growing economic value of the spectrum/ orbit resources. It has resulted in increasing competition, spectrum/orbit congestion, and in a scramble for desirable orbital slots. This rush could increase further with new services planned such as the third generation mobile telephony or broadband access systems. There may be various reasons behind the 'overfilling'.

The overfilling might because the submitting organizations expect that some of the proposals will be rejected as unacceptable during the coordination process. A satellite operator may submit multiple variants of the planned system for coordination as it increases chances of favourable findings, and it costs nothing or near to nothing. Finally, only one of them will actually be launched, whereas the remaining will become 'paper satellites'. Or they may intend to reserve some orbit positions for potential future applications or commercial arrangements. As a number of years may pass between the submission date and the launch date, many things may happen in the meantime, on which the operator may have no influence. Bankruptcy or launch failures are examples. When the investors withdraw, all planned satellites became 'paper satellites'. Finally, there may be also other reasons why the coordinated and notified satellite is actually not launched.

Opinion is also growing that some administrations tend to initiate the coordination procedure within the ITU system for more orbital positions (or spectrum) than really needed. But within the sovereignty principle, there is no objective way to judge whether the submitted demand is "real" or not, "justified" or not. Anyway, overfilling blocks the available spectrum resources, multiplies non-existing networks with which coordination is required, and increases complexity and coordination burdens. The reliability of the database is deteriorating and it is increasingly difficult to assess the real status of the available resources.

The problem of satellite notification backlog has been known within the ITU for years, and various remedies were sought. However, instead of improving the process, discussions focused on how to limit the number of submissions received. One proposal was to discourage 'overfilling' by the processing fees. In spite of the protests of satellite operators and some developing countries, the plenipotentiary conference in Minneapolis approved the fee principle in 1998. However, if the fee is small in comparison with the other costs to be born before the satellite finds its place in the orbit it can have only a limited impact. If, on the contrary, the fees will constitute a substantial part of the total costs, they will gravely restrict the free access to spectrum/orbit resources, which is guaranteed in the ITU Constitution, Convention, and Radio Regulations. Every sovereign country-member of ITU has the right to submit as many satellite systems notifications as it feels appropriate without asking for somebody's permission and nobody can take that right away from it as long as the current ITU Constitution, Convention, and Radio Regulations are in force. Only automation of the examination, coordination, notification and monitoring process could probably solve the backlog problem, as I proposed just before the World Radiocommunication Conference Geneva 1993 [Struzak 1993]. There are technical means ready to be used for that purpose, what is only missing is the political will and financial contribution of the ITU members.

The same effects have been observed for some years with terrestrial transmitters, especially those operating in the short-wave bands. There have been no strong incentives to limit the number of transmitters notified to obtain the international recognition according the Radio Regulations. Should any limiting mechanism be introduced? Should the assignments not used for some period be cancelled and opened for new applications?

Quite opposite problems are with satellites (generally: radio systems) that operate but are not registered as required. There is growing concern about cases of satellites launched before the regular coordination process is properly concluded, or even initiated. Furthermore, a number of satellites have been re-positioned without required re-coordination. It may indicate that, for operational reasons, the time required for coordination (re-coordination) under the current Regulations may be too long. Even though not-registered, or "illegal" terrestrial transmitters have been observed since the first radio regulations were agreed, the problem becomes much more critical with satellite-based transmitters. First, the range of satellite transmitters is usually much greater than that of terrestrial transmitters. Second, it is practically impossible to identify the entity responsible for the operation of the transmitter if it operates in the outer space. While each country commits itself to comply with the ITU regulations, it also reserves its sovereignty in dealing with the spectrum matters, and no explicit penalties are foreseen if a country does not follow these regulations. Should non-observance of the regulations be internationally penalized? How?

5.4 GSO Ownership

The geostationary-satellite orbit is generally considered as a part of outer space and common heritage of humanity, but some states reject that idea. Brazil, Colombia, Congo, Ecuador, Indonesia, Kenya, Uganda, and Zaire, the eight countries traversed by the Equator, proclaimed the segments of the GSO over their territories to be under their sovereignty. Only the segments of the GSO over the open seas are common heritage of humanity and can be accessed freely, according to their declaration of 3 December 1976, known as Bogotá Declaration (from the name of city where it was signed). The devices to be placed permanently on the geostationary orbit over an equatorial state shall require previous and expressed authorization on the part of that state, and the operation of the device should conform to the national law of the country over which it is placed. Such an authorization may involve licensing process and appropriate fees. However, the equatorial states do not object to the free orbital transit of satellites following the provisions of Radio Regulations, when these satellites pass through space outside their geostationary orbit.

The signatories of Bogotá Declaration justify the national sovereignty over the GSO by the fact that the GSO depends exclusively on natural gravitational phenomena generated by the Earth. Therefore, they conclude, it must be considered as a natural Earth's resource and not as a part of the outer space. Further, they refer to "*the right of the peoples and of nations to permanent sovereignty over their wealth and natural resources that must be exercised in the interest of their national development and of the welfare of the people of the nation concerned*," set forth in Resolution 2692 (XXV) of the UN General Assembly. The Bogotá declaration questions at this occasion the terms of the Outer Space Treaty. Its signatories believe that these terms were elaborated when developing countries could not count on adequate scientific advice and were thus unable to evaluate omissions and consequences of the proposals, which were prepared by the industrialized powers for their benefit. Further, they consider that the 1967 Outer Space Treaty does not concern the geostationary satellite orbit, as there is no valid or satisfactory definition of outer space.

Indeed, legal discussions on the delimitation between the Earth and outer space have not been concluded to the full satisfaction of all parties interested. Actually, no physical border exists that could help the lawyers, as there is a continuous transition from the Earth atmosphere to outer space and further to deep space, which is defined in the Radio Regulations as space at distances from the Earth equal to, or greater than, 2 million km. Without sharp physical criteria, lawyers have to invent other acceptable criteria, and a number of proposals have been suggested. One proposal refers to the lowest altitude at which a satellite can orbit without burning or falling down because of friction of the atmosphere, and it is about 100 km. Another proposal involves the highest altitude up to which a subjacent state is able to maintain effective control over its airspace. That limiting altitude depends on technology being at the disposal of the state. Until now, none of the Bogotá Declaration signatories has been able to control effectively the GSO and their declaration has been disregarded by all non-equatorial states. However, the significance of geographical position of states has been included in radio agreements. Both, the Radio Regulations and the ITU Constitution and Convention stipulate that, in using frequency bands for radio services,

"Members shall bear in mind that radio frequencies and the geostationary-satellite orbit are limited natural resources and that they must be used rationally, efficiently and economically, in conformity with the provisions of these [Radio] Regulations, so that countries or groups of countries may have equitable access to both, taking into account the special needs of the developing countries and the geographical situation of particular countries." [Collection.. 1999]

However, in view of lacking commonly agreed binding interpretation of this wording, each state is free to understand it as it feels it appropriate.

5.5 Orbital debris

Space debris near the Earth, known also as 'orbital debris' consists of natural micrometeoroids and of man-made objects that do not serve any useful purpose, now or in the foreseeable future. During the forty years of space exploration, the near-Earth environment has served as a gigantic rubbish collector. Almost all objects that have been launched in outer space are still there and will remain for many years to come. Only few escaped towards other celestial bodies, felled on the Earth, or burned in the atmosphere. What forces satellite to fall down is the air drag, but the drag decreases with altitude, and at high altitudes is negligible. Table 9 lists orbital lifetimes for selected circular orbits. At the geostationary altitude, no effective natural removal mechanism exists, except for solar radiation pressure. Practically, objects located in the geostationary orbit will remain in its vicinity indefinitely, if not moved at the end of mission.

Table 9. Circular orbits lifetime.

Orbit altitude (km)	Lifetime
200	1-4 days
600	25-30 years
1000	2000 years
2000	20'000 years
30'000 (GSO)	Indefinite

(According to W. Flury, The Space Debris Environment of the Earth, in D. McNally: *The Vanishing Universe*, Cambridge University Press 1994, p. 128, 130)

A few countries do radar, optical, and infrared surveillance of space for security reasons. The smallest tractable objects are of about 10 cm in diameter at low altitudes and about 1m at the geostationary orbit. They all are catalogued. From all man-made objects catalogued, only about six percent are operational satellites. The rest are dead satellites (21%), upper stages (16%), fragments of upper stages and fragments of satellites (45%), and other abandoned objects (12%), according to Walter Flury of European Space Operations Centre [Flury 1994]. They all move at hyper-velocities averaging 36 thousand km/h (10 km/s). The total number of these objects is counted in the millions of pieces, increasing with every new launch of a space object and with each new satellite explosion and fragmentation accidental or due to anti-satellite tests in outer space. Some of the objects launched come back to the Earth, especially after the invention of re-utilizable space vehicles, but the creation rate of debris has outpaced the removal rate. The debris population in low Earth orbit grows at an average rate of approximately five percent per year, according to NASA estimations.

The threat of debris impact damage on satellites and spacecraft is a major growing concern. Medium size objects (0.1-10 cm in diameter) are the greatest challenge because they are not easily tracked and have kinetic energy high enough to cause catastrophic damage to spacecraft and satellites. For instance, a particle of 1 cm diameter and weight 10 gram moving 10 km/s has the kinetic energy of a 1.3-ton car running on a highway at the speed of 100 km/h. Penetration even a small particle through a critical component, such as the flight computer or propellant tank, can result in loss of the spacecraft. If a 10-cm object, weighing 1 kg collides with a typical 1,200-kg spacecraft bus, over one million fragments 1 mm in size and larger can be created, according to the NASA. This collision results in formation of a debris cloud, which poses a magnified impact risk to any other spacecraft in the orbital vicinity. Mutual collisions can multiply their number further. Encounters with clouds of smaller particles can also be devastating, as evidenced by the damages made to the Hubble Space Telescope. The debris tends to concentrate in some regions in space and, ultimately, these regions may become dangerous for future missions. They also may efficiently block the astronomical observations of some regions in the sky.

Maintaining the current design and operational practices could ultimately render some regions in space useless and even dangerous. International space law is not addressing explicitly the space debris issue. Ultimately, internationally regulations are needed concerning debris management and debris control.

5.6 Electricity from Space

New, cheap, and environmentally friendly electricity sources are now sought in several countries. The world's population is expected to reach 10 billion people by the year 2050, and the present energy sources will be insufficient to satisfy its needs, according to current projections. Among various ideas, the Space Solar Power (SSP) concept has been studied. In the USA, the studies started during the oil crisis in the seventies, aiming at limiting the dependence of national economy on foreign oil. In 1974, a patent was granted in the USA for a solar power satellite, to collect power from the sun in space and then transmit it down to the Earth for use. The original patent indicated the microwave beam as the transmission medium, but later a laser beam alternative was also taken into consideration. For the conversion of sunlight to electricity, huge arrays of photovoltaic cells would be placed in a geostationary Earth orbit or on the Moon. Such arrays would be unaffected by cloud cover, atmospheric dust or by the Earth's twelve-hours day-night cycle. To reduce the necessary area of costly solar arrays, sunlight could be concentrated using giant mirrors or lens. The current photovoltaic technology offers energy conversion with efficiency rate reaching 50 percent or so, according to the NASA studies.

With such efficiency, about half of the absorbed Sun radiation could be converted into electricity using photovoltaic process. A large part of the remaining half, which would manifest itself as heat, could also be converted into electricity using thermoelectric devices. These would serve as thermal pumps removing heat from the photovoltaic panels and lowering their temperature. The electricity would then be converted to microwaves and beamed by composite space antenna towards a huge Earth antenna. The latter would contain a large number of receiving antennas combined with rectifiers and filters (called a rectenna) that would convert the microwave power into electrical current injected into the power network. To limit the health danger, the receiving antenna would be located in the desert or in mountains far away from populated areas. According to the proponents, the size of the microwave beam could be large enough to keep the power density within the safe limits. High-power laser beam has also been under study as a potential candidate to transport energy from the space system. According to the NASA, a space solar power system using today's technology could generate energy at a cost of 60 to 80 cents per kilowatt-hour, about ten times the current market price. They estimate that it would take 15 to 25 years of further research to nullify that difference. In 2001, Japan announced that also they plan to launch a giant solar power station by 2040.

However, both, the high-power microwave beam and laser beam create health and environmental problems, not solved yet. Moreover, both are potentially double-application technologies. A SSP station could easily be converted into a dangerous weapon and the current treaties prohibit locate weapons in outer space. Space weapons using solar energy are not a new idea. In times of the World War II, some German scientists were speculating the use of gigantic mirrors that could concentrate solar energy to set fire to enemy’s forest, crop fields and cities during the war time. Between wars, the mirrors could be used to control local weather conditions over a selected region. The size, complexity, environmental hazard, and cost of an SSP undertaking are daunting challenges.

5.7 Passive Services

All satellites have been sources of major concern for passive services, and especially for radioastronomy. Satellites and satellite constellations such as the Iridium system produce signals that may be billions times stronger than those exploited by radio astronomy. They can block the normal operations of sensitive sensors, or even damage them. Passive services benefit from some provisions of outer space law and Radio Regulations, but the degree of protection is insufficient. For instance, the Radio Regulations stipulate protection from services in other bands to *"be afforded the radioastronomy service only to the extent that such services are afforded protection from each other*" [RR 4.6]. This nullifies the principle of electromagnetic compatibility.

The way the unintended emissions due to unavoidable imperfections of equipment are treated often favourites the offending system at the expense of the victim one. These emissions include out-of-band emissions and spurious emissions (including unintended antenna sidelobes and unintended reception mechanisms). None of them carries useful information and the intended transmission would not loose a bit if they were eliminated. The problem is that such elimination involves additional efforts and costs.

Out-of-band emissions, a by-product of the modulation and encoding/decoding process, spill over frequency bands immediately adjacent to the band used by the intended transmission. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products, etc. (excluding out-of-band emissions) and their products fall into bands that may be far away from the assigned frequency band. Spurious products can be generated not only within the equipment, but also due to non-linearities in the neighbourhood of transmitting antenna and in the propagation medium (e.g. in the ionosphere). The net effect of all these mechanisms is equivalent to the transfer of energy from the assigned frequency band to other bands (in the case of antenna sidelobes - from the assigned direction to other directions). Usually only a tiny part of the power of intended transmission escapes this way, but the escaped portion can be billion times stronger than signals used in the victim bands, jamming or blocking the victim service. Many passive services, like Radioastronomy, do not make any direct monetary profit. They lose each time when involved in conflict of interest with any commercial industry as the following examples illustrate.

Dr. Titus Spoelstra, mentioned earlier, gives instructive examples concerning the radio-related treaties. The US military satellite TEX launched in 1990 ended its mission in 1991, and its onboard transmitter was expected to cease its operation at the same date. However, the satellite has remained in the orbit and has continued to radiate useless signals. The reason was simple: the transmitter has not been equipped with the 'off' switch and the power system has continued to work longer than planned. This polar-orbit satellite has visited every place on the Earth at least twice each 24 hours at an altitude of about 700 km, and its radiation blocked the radio astronomical observations in the 322.0-322.5 MHz frequency band allocated to the fixed, mobile and radio astronomy services. As the satellite decay is about one km every two years, it would take about one thousand years until it falls and burns in the atmosphere. It took six years, lot of effort, and international cooperation until the defective satellite was finally traced in 1998, and its silencing arranged. To keep it silent, the company responsible for the system must employ work force and tracking station and keep providing regularly the satellite with special commands. Should the satellite designers follow the Radio Regulations, they certainly would add a simple switch – it would change neither the cost, nor weight of the satellite.

Another example is the ASTRA-1D, a geostationary satellite used heavily in Europe for direct-to-home broadcasting. Due to its out-of-band emissions in adjacent frequency bands that extend far above the acceptable limits, the satellite produces harmful interference to radio astronomical observations. This has been discovered when the satellite was already in the orbit, and a complete cure of the problem has not been possible until now. In view of the high investments made in the satellite, a wide use of the service and political influence, the satellite operation will continue during its lifetime. If the project were properly coordinated and the satellite checked before launching, the problem would not appear.

A similar case is the mobile-satellite Iridium system, a constellation of 66 LEO satellites orbiting at the altitude of 780 km. It uses the 1616-1626.5 MHz band in space-to Earth direction. The Radio Regulations (Footnote 5.372) says explicitly that stations of the mobile-satellite service operating in this band shall not cause harmful interference to stations of the radio astronomy service using the band 1610.6 – 1613.8 MHz. In reality, the Iridium system does produce harmful interference due to its excessive out-of band radiations, according to the 2002 CRAF Handbook for Frequency Management. No complete cure of the problem was possible until now. Like in the case of the Astra system, because of high investments made in the satellites, a wide use of the service, and political influence, the system will continue during its lifetime. Again, coordination and checking before launching would eliminate the problem,

These examples show that the Radio Regulations are not known as widely, and observed as carefully as they should be. Moreover, they illustrate the limits of international agreements that are not supported by appropriate enforcement mechanisms.

5.8 Fragmentation, Data & Tools

The ITU Convention and Constitution recognize the sovereign rights of each State to regulate its telecommunication. Thus, the approach to spectrum management has been different in various countries, tailored to the specific needs and priorities of the country and its traditions. These elements are unique for each country and, consequently, the domestic regulations in one country are not necessarily compatible with those in another country. This creates substantial obstacles in developing a worldwide wireless services and global markets for equipment. The famous "footnotes" to the ITU Frequency Allocation Table are examples of such a fragmentation, as they actually mean different allocations. Other differences are hidden in technical standards and engineering details. In most cases, these differences are probably unintentional, but can serve as barriers against undesired import of goods and services across the borders. Figure 12 illustrates such a fragmentation in Africa. Fragmented spectrum management means in practice the fragmented markets for services and equipment.

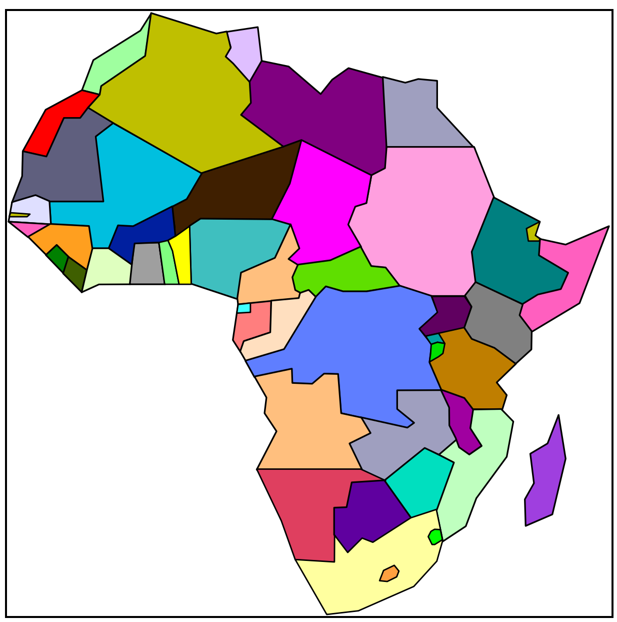


Figure 12. Spectrum management follows the political fragmentation. The ITU recognizes the sovereignty of each State to regulate its telecommunications. Consequently, national spectrum management practices are different in different countries. Such fragmentation creates substantial obstacles in creating trans-border services and markets.

That fragmentation has lead also to a paradoxical situation with emergency communications. If anywhere on the ocean a vessel with a crew of one is in distress, all related communications have absolute priority and are free of charge. The absolute priority of distress signals from the sea has been recognized worldwide since after 14 April 1912, when the 'Titanic' hit an iceberg and sunk.

However when, after an earthquake, some 10,000 persons are trapped under the debris of constructions, any custom official can prevent the rescue teams arriving from outside the affected country from bringing in their radios. And another official can prevent them from using these radios, until they obtain a license from the national spectrum management authority, whose building may just have collapsed in the earthquake. Also if they are nevertheless able to use their satellite terminal, they may be presented with telephone bills for tens of thousands of dollars. Such is the experience of those who provide international humanitarian assistance in the age of information super highways, says Hans Zimmermann, a high UN official [Zimmermann 1995].

Inadequate Data & Tools. The multidimensional character of the spectrum resource was mentioned earlier. In practice, however, most often the use of that resource continues to be measured in one or two dimensions only, the frequency and geographical position, or position on the geostationary satellite orbit. The Radio Regulations are built around the frequency allocation table that traditionally differentiate only between frequency bands, services, and administrative regions, leaving other parameters aside.

Reliable and easily accessible information about the actual usage of the spectrum is vital for service providers and equipment manufacturers, and is a key element in spectrum management. However, the needed information does not exist in an integrated form. It is dispersed among various separate bits of data, often incomplete and contradictory, in separate local, national, and ITU spectrum management systems. All parties concerned agreed in principle on the need to maintain and follow common standards to facilitate interchange of data, but the direct interworking of national spectrum management computer systems does not exist. The data elements required for national, bilateral and multilateral coordination are often kept separately and independently which results in unavoidable data inconsistencies. After years of such practices, the ITU master register, with about one million entries, contains an unknown proportion of unreliable records that have nothing to do with reality. The results of analyses based on such data are thus questionable, as is the need to maintain such databases. Unreliable or inaccessible data mean unknown resources, fictitious coordination and, consequently, fictitious spectrum resource scarcity and unused its portions.

Wider application of advanced mathematical methods and computer techniques involving also monitoring capabilities could increase efficiency, flexibility, and objectivity of spectrum management. Improved frequency planning tools, propagation prediction models and electromagnetic compatibility analysis models would widely be applied. Creation of common ITU Digital Terrain Elevation Model, worldwide, accessible for all ITU members, could facilitate frequency sharing at high frequencies. Modern techniques of simulation and virtual prototyping could allow for fast assessment of the resources available, comparison of alternative uses and selection of the best variant according to agreed criteria [Struzak 1992]. The system could offer immediate and user-friendly access to necessary data and tools. New computer-assisted techniques would make on-going, or dynamic, coordination practicable among all parties interested.

Integration of databases could solve the problems of data inconsistency and data access mentioned earlier. Current technology calls for one geographically distributed computer system integrating the fragmented local, national and ITU spectrum management systems. Instead of the multiple exchange of correspondence, the parties interested would do most of the coordination preparatory tasks by themselves, using modern computer network, automated software, following the Internet model. All components of such a system exist today, waiting to be assembled [Struzak 93, 94].

5.9 Spectrum scarcity?

Is the spectrum scarcity real? Is the lack of frequencies and places in the geostationary satellite orbit due to the growth of the population of radio stations or, perhaps, due to our wrong management? Is there any way to solve the scarcity problem? Such questions need to be answered. Certainly, the scarcity is in part due to equipment deficiencies. Spectrum resources are wasted because of spurious non-essential radiation from transmitting stations as well as from RF equipment used for various industrial, domestic, medical and scientific purposes. Spurious channels in receiving stations also contribute significantly to misuse of the spectrum wastage. Technological progress offers improvements; however, it should be stressed, capital-intensive commitments in older technologies demand protection. Further discussion of these issues, however, is beyond the scope of these notes.

There is growing opinion that the spectrum/orbit scarcity is in a great part due to a combined effect of inadequate approach to these resources, inappropriate rules and regulations, simplistic engineering models, tools and methods, and lack of precise data. Improved spectrum uses through refined technology are usually expensive, more expensive than those achieved through enhanced management. It suggests that our present spectrum management system needs to be critically reviewed. All parties, governments and private sector, are increasingly concerned about costs and value for money. The requirements are simple: increase efficiency, cut costs, shorten decision-time, and improve transparency.

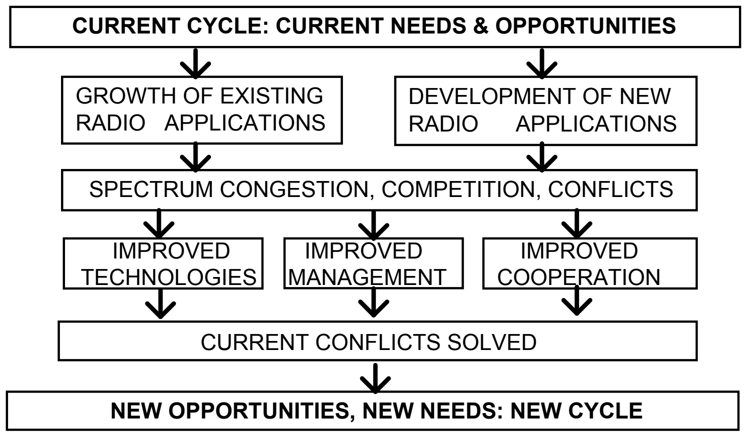


Figure 13. Cyclic character of spectrum scarcity.

Finally, we should note that spectrum scarcity is not a new issue. It was a US Secretary of Commerce who first declared: "There is no more spectrum available." The Secretary was Herbert Hoover. The year was 1925 [Dougan 1992]. Today, we are seeking new solutions to an old problem.

5.10 Monitoring & Enforcing

The Radio Regulations are effective to the degree to which they are respected. Like any law, they require an enforcement system. The responsibility of law enforcement agencies is to detect the law violation, apprehend the perpetrators, and provide evidence that will convince the court that the perpetrators are guilty beyond a reasonable doubt. In many instances, it is not difficult to identify the offenders, but there are also difficult cases that cannot be solved without sophisticated methods and equipment, without highly qualified experts and specialized organizations. The famous Scotland Yard and Interpol are examples of such specialized organizations, national and international, respectively. Such organizations have proved their utility above any doubts.

The issue of the Radio Regulations infringements belongs to the most difficult cases. In spite of the fact that such infringements are able to cause significant losses in multi-billion-dollar radio- and satellite-related industries and/or research activities, there is no equivalent of the Interpol, no international court, and no sanctions. Instead, the Radio Regulations encourage the usage of diplomatic procedures and appeal to goodwill of the governments. While it was the most appropriate course of action when radiocommunication was a state monopoly and satellites did not exist, is seems highly impractical now, when there are hundreds of satellites operated by private international companies. The process is simply not adapted to the present day needs – it is too costly, too slow, too bureaucratic, too ineffective, simply -- too impractical.

Whereas the detection of an infringement of the Radio Regulations is usually easy, the identification of the perpetrator can be an extremely difficult task, as illustrated by the examples quoted earlier. Very expensive devices might be necessary for efficient identification, as well as highly qualified staff. Whereas some rich countries use their military antimissile defence surveying systems to monitor space-based radio systems, other countries have to build special installations from scratch, or to be fully dependent on foreign assistance. At a few discussions of this matter, I proposed the International Astronomical Union (IAU) to consider its role as an independent space monitoring organization ('Space Interpol') but the proposal has not found sufficient support. There are few arguments for such an arrangement. First, this organization unites the existing network of radio and optical telescopes, a part of which could be used to some monitoring/ surveillance tasks, which would minimize additional investments necessary. Second, the IAU has already united people of highest qualifications, which would minimize the necessary education/ training costs. Third, and most important, radio astronomers are interested in keeping order in outer space more than any other professional group.

The Radio Regulations contain a number of 'compromise' provisions on controversial issues, formulated during conferences in such a way that each of the negotiating parties could interpret them in its own way, to its own satisfaction. When two different interpretations of a provision are possible, that provision cannot be implemented by the ITU staff without being accused of favouritism. To avoid such situations, the Atlantic City Conference mentioned earlier established the International Frequency Registration Board (IFRB). The board was envisioned by its proponents as something of a cross between the Federal Communication Commission (FCC) of the USA and the International Court of Justice. Solving the implementation problems of Radio Regulations was one of the principal responsibilities of the board. The board might also be involved in the dispute settlements. In view of their high international responsibilities, the Board members must be elected by the plenipotentiary of member states, must be independent, must be '*thoroughly qualified'*, and must act as '*custodian of an international public trust'*. Later the IFRB was transformed later into the present Radio Regulations Board (RRB).

In reality, the board never achieved any status comparable to the original vision, in spite of the fact that individual Board members always enjoyed high professional prestige. While some member states wanted a strong Board, the others preferred the opposite and did not allow performing all of its functions as the arbitrator of the radio uses of all nations of the world. The 1965 Montreux Plenipotentiary Conference reduced the size of the Board from 11 members to five. The conference might even have abolished the Board completely, had it not been supported by the developing countries. The Kyoto Plenipotentiary Conference of 1994 replaced the full-time IFRB by a part-time RRB, which meant a serious reduction of its power, and still there are some open problems related to its functioning.

5.11 Regulations vs. Flexible Use Doctrine?

How frequency bands and orbital positions are allocated and assigned by the ITU process, have important implications. For instance, the WTO commitments for market opening measures are all '*subject to availability of spectrum/ frequency*'. However, the relationship between the WTO and ITU has been ambiguous since the very beginning, when the WTO included telecommunication matters into its agenda. The two organizations share documents and observer status of certain official events, but they have different agendas, different approaches, and different methods of operation. One of significant differences is sanctions that may be imposed on a party that does not follow a WTO agreement. This, of course, implies a kind of international tribunal and appeal arrangements, an element missing in the ITU system. The ITU relationships are based on good will and consensus, whereas a violation of the WTO agreements may result in severe sanctions.

The WTO terms involve some issues monopolized earlier by the ITU. Among others, they involve technical abilities to interconnect to the public network, which may imply a forced use of standardized, open interfaces instead of proprietary ones. They also require the spectrum allocation/ assignment rules to be flexible enough to accommodate a variety of technologies. Full transparency and fairness in licensing procedures for the right to use the radio spectrum is another issue not fully solved within the ITU. It has been so because the issues related to national telecommunications have been considered internal matters to be decided by each sovereign member state. Borders between technology-related and commerce-related regulations are blurred, and so are borders between international and national issues. State representatives at the ITU radio conferences and study group proceedings represent national interest that involve differing industrial and spectrum policies aimed at creating advantages for national industries at the expense of foreign competitors. So far, however, no one has tested spectrum allocation proceedings basing on the WTO principles. However, Gerry Oberst, partner in a law firm, believes that frequency spectrum decisions will finally be dragged into the international trade arena; it is only a matter of time [Oberst 2000]. The current trends suggest that he perhaps might be right.

With the de-regulation wave, opinions are expressed the use of the radio frequency spectrum is over-regulated. The critics indicate that there is too many regulations, and that the administrative process is too slow, too complex, too expensive, inefficient and not sufficiently transparent. The partisans of liberalization want the regulatory system to be technology-neutral and reduced to a few basic rules that work in practice and are really necessary. A key issue here is to agree specifically what is "really necessary" and "working in practice". The liberals believe that most of the spectrum-related problems can be solved more effectively by bilateral negotiations between the interested parties and, even better, by the market mechanism.

One of proposals advocates the *flexible use doctrine*. In contrast to the rigid 'taboos' imposed by the present Radio Regulations, the license holder would be free to choose how he or she will use the resources, provided the interference levels in adjacent frequency bands and geographical areas are acceptable by the neighbours. License holders could negotiate any technical standards and interference levels they wish. The rights to use a portion of spectrum/orbit resources would be given with no time limits. This would legalize the current practices, as most of current temporary licenses have already been given practically forever, and the license renewal process became more a ritual than reality in many countries, as noted by Jon Peha, professor at Carnegie Mellon University [Peha 1998]. He indicated that 99'9 percent of all spectrum licenses in the United States were renewed successfully during the years from 1982 to 1989.

With the flexible use doctrine, first a spectrum/orbit market would exists, and then a secondary spectrum/orbit market would materialize so that the licenses could be sold and bought at will. This would guarantee that the resources are used by those who are capable to pay the highest price, to offer the service that is most valued, and to use the most cost-effective technology, according to the partisans of that approach. Proprietary right and free competition would replace the rigid regulatory mechanism. If this approach were to be applied internationally, it would require substantial revisions of the space and radio treaties discussed in previous sections.

However, privatization and liberal market approach may lead to socially undesired results. First and foremost, it cannot assure universal access, i.e. access to telecommunications in poor, remote, and/or sparsely-populated regions that cannot generate large profits. But it is not only that, as shows the recent story of the UMTS. In spite of the fact that systems were not yet ready to operate, eleven European countries sold the UMTS licenses for some US$100 billion, according to data published by Public Network Europe. The transactions were advised by the best world-class economists, after careful analysis of all factors, which should not be surprising in view of the amount of money involved. However, soon after paying the licenses, instead of boom predicted by the partisans of liberalization and privatization, a number of companies bankrupted, contributing significantly to general crisis. Similarly, the experience gained in the past in the United States, the traditional fortress of liberal capitalism, also shows that liberal approach might not be the best one: "*Between 1894 and 1904, over six thousand independent telephone companies went into business in the United States*", reads the history of the AT&T displayed on the Web, "*But the multiplicity of telephone companies produced a new set of problems -- there was no interconnection, subscribers to different telephone companies could not call each other.*"

The interconnection problem began to be resolved only after 1913, when AT&T started to function "*as a legally sanctioned, regulated monopoly*." Following the theory of Theodore Vail, then the AT&T president, there was general belief at that time that government regulation is better that the competitive marketplace in the telecommunication sector "*provided it is independent, intelligent, considerate, thorough and just*". As a "regulated monopolist", AT&T's Bell System provided soon what "*was by all accounts the best telephone system in the world.* [...] *The percentage of American households with telephone service reached fifty percent in 1945, seventy percent in 1955, and ninety percent in 1969. Much of the leadership came by application of science and technology developed at AT&T's Bell.*"

What happened earlier to wired telephones, happened also to radiocommunications. Today, a hundred years after the Prince Henry's story of no-connection mentioned earlier, we witness similar problems with the multitude of proprietary technical standards. In seeking maximal profit, many equipment manufacturers and service providers oppose to all that could increase the cost of their products and services: common regulations, standards, and any control. The very nature of competition does not encourage closer cooperation or sharing intellectual property and know-how secrets. On the contrary, it tends to an unregulated monopoly. On the other hand, the users of radio want to communicate reliable, cheaply, and without interference, no matter who provides services or supplies the equipment. Common technical standards, interfaces and regulations are necessary to satisfy these requirements, as is also a degree of cooperation between the parties involved in the process. The treaties reviewed in the previous sections created a worldwide framework for such cooperation. However, in spite of the enormous progress made, we still see the radio world too much fragmented, incoherent, and irrational.

Over the years, various improvements have been proposed to the spectrum management on national and international scales, but few have been implemented that touch the fundamental rules. One of such rules has consisted in a separation of spectrum management from economic mechanisms. In the meantime, however, in some countries, the regulatory system is being replaced by a competitive market economy mechanism, to follow the changes in the political and technological environment. For the time being, that action has been limited to few states and few selected frequency bands only.

Advocates of this idea indicate that market forces automatically match the demand to the available resource capacity and that market-based management is inexpensive[1]. Moreover, relying upon administrative decision-making is inferior to relying on market forces because decisions are arbitrary and often mistaken in determining what is the best interest of users [Webbing 1977]. The concept of spectrum management through market forces has as many supporters as opponents. Until now, however, no evidence has been published that selling the spectrum will solve the scarcity problem in a way acceptable for all parties involved. It should be noted that spectrum market might made radiocommunications more expensive, and may influence the existing balance between the wired- and wireless telecommunications.

The main event in recent years was a series of spectrum auctions conducted in the USA and then in Europe. These auctions mark a break with tradition. Earlier, licenses to use radio frequency for wireless communication services were awarded on the basis "first come - first served", by lottery, or by comparative hearings ("beauty contests"), almost for free. Now the governments are granting the licenses to the highest bidders.

The first auction in the USA held in 1994 concluded in assigning three 1-MHz bands around 900 MHz for a total of about US $650 million. In 1995, two pairs of 15-MHz bands around 1900 MHz for personal communication services were assigned for a total of US $7.74 thousand million [Bell 1996]. On top of this, the successful bidders have to pay expenses for relocating thousands of microwave transmission facilities that were already using that portion of the spectrum. These numbers, however, should not be generalized as the price depends on the demand and supply. Spectrum and real estate in the centre of New York or Tokyo will cost much more than somewhere in a far desert. However, consumers will always pay the final costs.

Selling the spectrum and liberal approach to spectrum in general, raised a question on how much does the RF spectrum cost? How much it contributes to the economy? [Goddard 1994, Kalman 1994]. One study showed that overall economic impact of the use of radio may exceed 1% of Gross Domestic Product, not counting the consumer surplus derived from the wireless services [NERA 1995], too difficult to evaluate. The data were collected in one developed country and the question is open as to which degree the conclusions can apply to other countries. Another study showed that inadequate spectrum management could cause economic losses evaluated

[1] It should be noted that the US Army alone spends nearly $40 million each year in frequency compatibility investigations [Dougan 1992].

for many tens of millions of pounds per year in a single country [DTI 1994]. One can argue whether or not it is adequate to describe the impact of RF spectrum in economic terms only, as it would be oversimplification to judge about the function of the human brain on the basis of its weight. (The brain weight is less than 2% of the total weight of the human body).

5.12 Representation, Access & Transparency?

International negotiations related to space, radio, and trade involve a number of complex issues that often necessitate in special studies. This is especially true in the case of Radio Regulations and World Radiocommunication Conferences (WRC). Numerous specialists have to be involved in such studies. Substantial efforts, time, and money have to be invested, as the results of studies done at home must be convincing to the majority of ITU member states participating in relevant working groups, task groups, and other meetings. Contrary to the conferences themselves, restricted to governmental delegations, the conference preparatory studies are open to all ITU members, including private companies. However, the active participation in these preparations is practically limited to experts from few developed countries and big and rich companies. Financial, technical, and human resources of many countries and non-governmental entities are insufficient to assure active participation in these preparations. For the same reasons, the consumers' participation is similarly restricted.

This under-representation may have significant effects. First, the interests of those absent may not be represented as adequately as they should be. Further, the complete documentation of these studies is not easily accessible, as it is exchanged only among the active participants. Who does not participate has only limited (if any) access to the documents, which actually means lack of transparency. As a consequence, contributions to complex negotiations from the non-participating parties can be only limited, as stated in the Bogotá Declaration mentioned earlier. There is also another issue. There is no official interpretation of the Radio Regulations, and their provisions are changed at every World Radio Conference. As a consequence, the Radio Regulations are very complex and there are a number of problems with their practical implementation. Restricted participation in the ITU activities and lacking transparency does augment and perpetuate that 'information gap'. On the other hand, the regulations must be well understood to enable their intelligent implementation. Actually, they must be followed in the same way as the traffic regulations are observed by all pedestrians and car drivers.

With disproportionate resources, the ITU members are advancing at different pace. It would be unrealistic to expect that developing countries or small enterprises could finance themselves their active participation in the ITU study groups in a degree comparable to that of rich countries and companies. That disparity, however, could be alleviated in several ways. For instance, the relevant information could be made available freely via Internet. A number of international organizations already have followed that idea, but not the ITU. In the ITU, the members submit documents they produce at their own cost and risk for common and unrestricted use. However, after processing at the ITU headquarters, these documents become the intellectual property available only at a price (except for single copies delivered to administrations of member countries). No part of them can be reproduced without written permission. This makes that the ITU technical documents are unavailable at most of libraries, including the university ones. They are practically unknown for students that are supposed to follow them in their everyday work when they leave the university.

One explains that such restrictions are necessary to keep the ITU expenses minimal, but it is a misleading argument, as it improperly presents the problem. What we really need is to keep minimal the total costs related to radio regulations including their practical implementation in everyday activities. These, include the cost of documents needed by administrations, equipment manufacturers, service operators, universities and training centres, etc. The calculations should also take into account losses due to not-observation of radio regulations on a world-wide scale. I am convinced that free access to relevant information via Internet would offer significant net benefits, but nobody did analyze deeper that issue so far.

Another possibility would be to charge for the registration of the frequency/ orbit assignments and use a part of the amount collected to support activities of developing countries and small enterprises, including free access to information. A fee system could be used as an instrument to rationalize the use of scarce resources, to limit the excessive demand, to make "warehousing" of frequencies and orbital positions unattractive. The income from the fees could be used for special assistance for developing countries, for the maintenance of the spectrum management system and for its upgrading, for the financing of international research efforts aimed at conservation and improved use of the spectrum resources.

Such proposals were made at various occasions (among others by this author), but have not found sufficient support. To put it in perspective, the total annual income from the sale of ITU publications was about US$10 million in recent years, just about 1% of the yearly value of satellites launched. Free access to regulations is not a new idea. It was practised thousands of years ago by Babylonian king Hammurabi who ordered his regulations to be engraved in block stones and publicly displayed at major roads. It is ironic, that the ITU on the one hand calls for bridging the information gap between the information poor and information rich, on the other hand creates itself barriers in accessing its own information sources. So far, however, no one evaluated losses attributable to the lacking access to information.

6 Concluding Remarks

How the RF spectrum is managed, has profound impact on the society, on its education, culture, prosperity, and security. Radio-related and satellite-related industries have become multi-billion-dollar businesses; all being subject of national regulations and international agreements. These notes have offered a short review of some issues and challenges focusing on international radio regulations. National regulations must follow these regulations and related international agreements. The notes are extracted from a book under preparation, in which these issues are discussed in more detail.

Harmonization of national laws, rules, regulations and standards, and new spectrum-conserving technologies, as well as improvements in spectrum management is needed to allow for further development of various radio applications crucial for the future Information Society. Eventually, technology may remove the need for some functions now included in spectrum management. Future radio systems will be able to automatically coordinate among themselves the use of spectrum resources to avoid interference. Even today, self-adaptive systems are finding various cost-effective applications in that area. However, in view of enormous investments in the "old" equipment, the "new" systems will not be popular soon.

According to current regulations and treaties, the radio frequency spectrum and satellite orbits are considered as common heritage of humanity. The Outer Space treaties and Radio Regulations were first created when the radio and space activities were the governments' monopoly only, but the state monopoly is quietly ceasing. The privatization and liberalization wave is introducing new powerful players: multinational private enterprises. The influence of private entities is growing and the role of governments is changing. At the same time, we witness an unprecedented increase of the number of new systems and applications, which creates new problems and new legal situations. The growing congestion of the radio spectrum and orbital positions leads to increased competition. More and more experts believe that the present regulatory system needs to be changed. New policy concepts are appearing, such as the *flexible use doctrine,* which might undermine the *common heritage doctrine,* the fundament of the present treaties. Some general concepts, such as "*common benefit of all countries*" (used in the Outer Space Treaty), or "*special needs of the developing countries and the geographical situation of particular countries*" (used in the ITU treaties) might need to be clarified anew.

All this requires a wide discussion and re-evaluation of concepts, policies, and practices governing the uses made of the radio waves and satellites. How to best use the valuable spectrum/orbit resources is a multi-disciplinary problem. Engineers, economists, business executives, scientists, lawyers, and politicians should be involved in the discussion -- all intellectuals interested. None should remain indifferent. Satellites are of special interest in remote or sparse-populated regions where they can enable teleeducation, telework, telemedicine, and other modern telecommunication services at affordable prices, bridging the 'Digital Gap'. As long as the spectrum/orbit is still considered a common heritage of the humanity, everybody has the right to express his/her ideas on how it should be best used for common benefit. When it will be fully privatized, such an opportunity will certainly be reduced.

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List of Abbreviations

BR	Radiocommunication Bureau, ITU (successor to CCIR and IFRB Secretariats)
CCIR	International Radio Consultative Committee of ITU
CSIS	Center for Strategic and International Studies, Washington, DC
DAB	Digital Audio (sound) Broadcasting
DTI	United Kingdom Department of Trade and Industry
DTV	Digital Television
EMC	Electro-magnetic Compatibility
GMPCS	Global Mobile Personal Communications Systems
GSO	Geostationary Satellite Orbit
HDTV	High Definition Television
IFRB	International Frequency registration Board of ITU
ITU	International Telecommunication Union, Geneva
OMCM	Orthogonal Multiple Carrier Modulation
PCN	Personal Communication Network
RF	Radio Frequency
RRB	Radio Regulations Board, ITU
UMTS	Universal Mobile Telecommunications System
WARC	World Administrative Radio Conference
COSPAR	Committee on Space Research
CRAF	Committee on Radio Astronomy Frequencies (ESF)
EMC	Electromagnetic Compatibility
ESA	European Space Agency
ESF	European Science Foundation
FCC	Federal Communication Commission (USA)
GATS	General Agreement on Trade in Services
GDP	Gross Domestic Product
GEO	Geostationary Orbit
GPS	Global Positioning System
GSO	Geostationary Satellite Orbit
IAU	International Astronomical Union
IFRB	International Frequency Registration Board (ITU)
ISM	Industrial, Scientific, Domestic and Medical applications.
ISS	International Space Station
ITU	International Telecommunication Union
LEO	Low Earth Orbit
MEO	Medium Earth Orbit
NASA	National Aeronautics and Space Administration (USA)
OCHA	Office for the Coordination of Humanitarian Affairs (UN)
OST	Outer Space Treaty
PTR	Pacific Telecommunications Review

RR	Radio Regulations (ITU)
RRB	Radio Regulations Board (ITU)
SSP	Space Solar Power
TRIPS	Agreement on Trade Related Aspects of Intellectual Property Rights
UMTS	Universal Mobile Telecommunication Systems
UN	United Nations
USSR	Soviet Union
UWB	Ultra Wideband
VSAT	Very Small Aperture Terminal
WRC	World Radiocommunication Conference (ITU)
WTO:	World Trade Organization