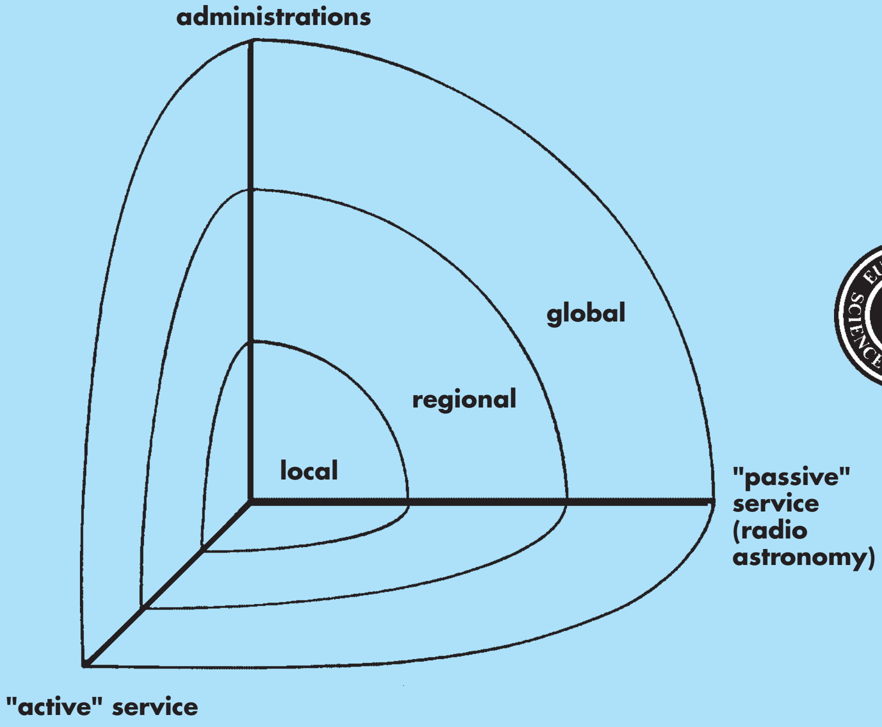
Committee on Radio Astronomy Frequencies (CRAF)

CRAF handbook for frequency management



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Committee on Radio Astronomy Frequencies (CRAF)

The Committee on Radio Astronomy Frequencies (CRAF) is an ESF Expert Committee. CRAF was established in 1988 to coordinate the European efforts for the protection of radio spectrum bands used by the Radio Astronomy Service and other passive applications.

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Cover: Frequency management problem space

CRAF handbook for frequency management

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Preface

T*his document,* CRAF Handbook for Frequency Management*, reflects the work of the Committee on Radio Astronomy Frequencies, CRAF, of the European Science Foundation, ESF. It provides a review of Administrative frequency regulation mechanisms, and guidelines, warnings and recommendations to scientists involved in using the radio frequency spectrum. It has been written with the daily practice of the operation of scientific radio observation stations in mind and the data quality necessary for the progress of science.*

Since the author's background is in radio astronomy, many references to radio astronomy are made. However, where possible, generalisations relating to other sciences are made and where in cases a specific scientific application other than radio astronomy needs to be addressed, this is also attempted.

This publication is complementary to the CRAF Handbook for Radio Astronomy. *The hope of the author is that it will be of help to scientists using radio frequencies in spectrum management issues. Where necessary, it may also assist Administrations to facilitate communication with scientists and to understand better their needs and preoccupations.*

The author thanks his colleagues for fruitful discussions and corrective remarks, because their questions and the need for clarification gave him much guidance. A special word of thanks is directed to Prof. Dr. R. G.Struzak of the ITU Radio Regulations Board, Mr. T. Bøe of the CEPT European Radiocommunications Office, Mr. J. F. Broere of the Dutch Ministry for Transport and Public Works, Mr. J. J. Verduijn of the Dutch Rijksdienst voor Radiocommunicatie, Dr. K. Tapping and Dr. W. van Driel for helpful discussions, reading the manuscript in different stages of drafting and helping the author to improve the text. The author thanks the European Science Foundation for assistance in the publication of this document.

Titus Spoelstra

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1. Introduction

Today's society depends heavily on the facilities, equipment and possibilities that make use of the radio frequency spectrum. Some of these uses are now fundamental in making life in our modern society work in a way to which we have become accustomed, such as telecommunication by radio, radio navigation, safety-of-life services and information exchange by radio. These are all of fundamental importance in the public and private sectors. Other uses serve our culture, education and entertainment, such as broadcasting. Some add to our comfort, such as various remote control tools. The list is non-exhaustive. Besides these everyday interests, some important research in many fields of science can be done only by radio means. Whatever interests are defended and whatever priorities may be considered, a fact of modern society is that the communications industries are the touchstone for many of the changes at work in our dynamic society.

Struzak (1999b) observed that radio and television play a principal role in meeting information needs of illiterate people, who make up about two-thirds of the world's population. Non-communication applications of radio waves have become indispensable too, as evidenced by millions of household microwave ovens in daily use. Many industrial processes and scientific experiments have been triggered or improved through the ingenious use of radio waves. He also observes that "remote-sensing satellites are irreplaceable in discovering the Earth's natural resources and in monitoring the climatic changes" and that "radio astronomy has opened new windows on the universe and contributed to a better understanding of nature."

Use of radio on Earth has become crucial for security and economy, nationally and worldwide, like the nervous system in a living organism. The uses of radio waves create business. In spite of economic fluctuations, the telecommunication sector alone has been one of the most profitable industries, after pharmaceuticals and diversified financials (ITU, 1998a).

Such a development leads to an increasing demand for radio frequencies. Given the pressure on the radio frequency spectrum, it is obvious that regulation and proper management are a fundamental prerequisite for all users of the radio spectrum in order to operate in an interference-free environment, and to safeguard against unconstrained technological, industrial, scientific, and other developments. Managing the radio spectrum must take into account the specific characteristics of the services involved, the culture-specific criteria that must be accommodated as well as the technological developments which are an ongoing process. In this world, science has to find its place as well.

Various data collection techniques that form the basis of scientific research use electromagnetic waves. In fact all electromagnetic frequencies from low wave radio to high-energy gamma rays are used. It is hardly possible to list all these scientific uses. They range from physical sciences, via health care and meteorology, to archeology. Many of these uses take place in the radio frequency part of the electromagnetic spectrum.

The paramount example of a science using radio waves is radio astronomy, which investigates, by various kinds of radio telescopes, radio waves generated by cosmic radio sources into the far depths of the universe. Given the special characteristics of this science, many examples elaborated in this publication are taken from radio astronomical practice. However, the radio astronomy issues are often applicable to other sciences, particularly those that use "receive-only" facilities, as radio astronomy does. A "receive-only" facility is called "passive". When both a transmitter and a receiver are used within the scope of the scientific experiment, we speak of an "active" application. Passive use of radio can be encountered not only in radio astronomy, but also in various remote sensing applications, such as meteorology, aeronomy and environmental studies. In contrast to radio astronomy, which is exclusively a passive radiocommunication service, other sciences also have active radio frequency applications, such as the active sensing with a radiosonde for meteorological purposes and various radar-related experiments and facilities.

The radio frequencies of interest for the individual sciences depend on the characteristics of the object studied. Celestial radio sources radiate radio waves varying with time and frequency, with intensity and with the polarisation determined by their physical conditions. It is obvious that no human being can ever be able to have any control over the characteristics of cosmic radio sources. Each part of the spectrum gives specific information about a source, implying that it is practically impossible to find two parts of the radio spectrum which would convey the same information and which thus could be substitute for each other. Radio astronomy has to follow these constraints on frequency selection imposed by nature on humankind. A similar situation holds for atmospheric studies, or aeronomy, in cases of studies based on observation of atmospheric gases. These gases generate radio emission at one or more discrete frequencies – such a discrete frequency is called a *spectral line*. These spectral lines are often also of interest for radio astronomy (of course, since the laws of nature are the same from our immediate environment to the farthest depths of the universe). In addition to the study of spectral lines, various scientific projects depend on measurements of broadband or *continuum* emission. For this work well-chosen radio frequencies (often every octave) are needed to investigate the variation of the intensity as a function of frequency, i.e. the radio spectrum of the transmitting source.

The meteorology situation is somewhat different. It uses radio frequencies to study structures of clouds and precipitation in space and time (also by passive measurements of radio spectral line data). Meteorology also makes use of active applications of radio. One may think of the radiosondes launched frequently to measure temperature, air pressure and humidity as a function of altitude. Facilities based on radar technology are also used in meteorology. The sum total of the results of all these measurements forms the basis for a weather forecast. The quality of the weather forecast depends on the quality of the measurements. And meteorology is eagerly looking for the best possible way of extracting the necessary information from atmospheric radio emission.

The upper atmosphere, particularly the ionosphere, is studied by various techniques based on radar technology. The characteristics of the ionosphere, specifically its degree of ionisation, electron density and the vertical distribution of the electrons, determine at which frequencies the experiments have to be done (usually below 30 MHz). Passive uses of radio for ionospheric research also exist: an example is the study of ionospheric refraction by accurate direction measurements towards satellites and celestial radio sources (Spoelstra, 1997).

Environmental studies that make use of radio frequencies investigate for example the development of vegetation in a given region, the distribution and nature of this vegetation. These studies are very important for deforestation studies, development of agricultural policy, studies of the ecosystem processes and the impact of natural and anthropogenic-induced change upon these processes, and similar tasks (see: publications in the *International Journal for Remote Sensing,* etc.).

The radio frequency selection is not exclusively determined by the physics of the radiating medium. The propagation characteristics of the terrestrial atmosphere also constitute an important parameter. At frequencies below about 30 MHz the atmosphere is not transparent for the radio waves that enables long distance radio communication by reflecting radio waves off the ionosphere. This phenomenon has been known since Marconi did his experiment in 1895.

At frequencies above about 10 GHz the troposphere becomes increasingly important: the density of the different gases and the water vapour content have a major impact on the tropospheric propagation characteristics. Some frequency intervals turn out to be completely opaque, while in other regions of the radio spectrum the atmosphere is transparent to various degrees. This fact often results in complementary interests of different sciences: e.g. terrestrial radio astronomy prefers a transparent atmosphere, while remote sensing scientists can be interested in measuring the transparency at a function of frequency even into the frequency intervals where the troposphere is opaque.

Some sciences use receive-only applications although they use transmissions of man-made signals generated for different purposes. An example of such a science is geodesy that makes heavy use of signals from the US Global Positioning System, GPS.

The importance of science has grown to such an extent that hampering its progress can easily have important impact on society:

- An unreliable weather forecast may have immediate safety-of-life consequences (e.g. for air traffic) or an economic impact (e.g. unexpected flooding or storms).
- Incorrect measurements on deforestation or urbanisation effects can result in major environmental problems or erroneous major political decisions.
- Ionospheric data of insufficient quality may have an impact on radio communications. It is for this reason that the radio communication industry prefers the use of radio frequencies above about 30 MHz. However, effects of the ionosphere on radio communication is observed even at frequencies as high as 30 GHz (Mawira, 1990).
- Many university students of physics have chosen their subject because they came into contact with astronomy or radio astronomy. This shows the important cultural role of this science.

- Radio frequencies are used in various geodetic studies: geodesy, studying among other things the shape of the Earth and continental drift, measures GPS signals for path-length measurements. Also Very Long Baseline Interferometric, VLBI, observations of celestial radio sources are made using different interferometer elements located at various well-selected locations: with the VLBI telescopes on Sicily and Sardinia included in the European VLBI network, the drift of the African plateau on which Sicily is located can be measured with respect to the European plateau.

Science provides a major service to mankind in many ways and for the benefit of mankind all scientific endeavours require facilities to improve this service. For many of these facilities the use of radio frequencies is unavoidably necessary and should, therefore, be adequately protected. This fact has been recognised by the UNISPACE-III Conference (Vienna, 19-30 July 1999) which adopted a resolution stating that in advancing scientific knowledge of space and protecting the space environment, action should be taken to ensure that all users of space consider the possible consequences of their activities, whether ongoing or planned, before further irreversible actions are taken affecting further utilisation of near-Earth space or outer space. The declaration related to areas such as astronomy, Earth observation and remote sensing, as well as global positioning and navigation systems, where unwanted emissions have become an issue of concern because they interfere with bands in the electromagnetic spectrum already used for those applications (Vienna Declaration, 1999).

Radio frequencies are a scarce resource. This is apparent from the complexity of the discussions and negotiations in relation to the allocation of frequencies to the different user communities, or radiocommunication services. The highest international level at which the use of the radio spectrum is regulated is the International Telecommunication Union (ITU), while in addition regional organisations play an important role in radio frequency management (see chapter 3). These sovereign state governmental regulatory bodies (Administrations, see secstion 3.3) are Members with the right to vote. They develop international regulations as international treaties with international legal status to enable usage of radio without interference from one radiocommunication service with another and interference between the use of the same service in different countries. This is similar to the role of the national regulatory authorities for air traffic, which are meant to enable all participants in the traffic to have a safe and well-ordered journey, regardless of the nature of each of these participants.

Thus, “safety”, “avoidance of harm” and “efficiency” are keywords which also apply to the use of radio frequencies. The safety aspect is especially visible in the protection of frequencies used for safety-of-life services. The regulatory task concerning the radio frequency spectrum deals with these important aspects. Through this, users of the radio frequency spectrum can make use of radio frequencies according to their terms of reference, mandate, characteristics, aims, etc.

Scientific use of radio frequencies differs from industrial and commercial use of the radio frequency spectrum.

In industrial and commercial applications, the frequency selection is not constrained by the fundamental laws of physics to the same extent as is the scientific use of the radio spectrum. The developments of their spectrum-need stems largely from industrial and market planning and developments. Furthermore, this development can actively be influenced by well-steered technological development (often by the same industries). If constraints exist, these may be of an industry-political nature or from a market point of view. Both depend on management knowledge, ability and will.

Scientific development depends heavily on discovery. Discovery, by its nature cannot be scheduled and planned. Therefore, nobody is able to determine the amount of funding nor the time a project would require to guarantee an expected result. If these were possible, industrial users of the spectrum may rightly ask after what time interval a frequency band can be freed for other users, and they would surely bring this to the attention of the Administrations. Furthermore, in many cases the radio frequencies important for scientific research cannot be selected by man at will: nature tells us at which radio frequency e.g. an atom or molecule "likes" to transmit its emission. Other guidance to science for the selection of its preferred radio frequencies is given by the propagation characteristics of the terrestrial troposphere and ionosphere. Fundamental laws of physics play a key role in the selection of radio frequencies for science, particularly for passive radio frequency use. Scheduling scientific experiments and observations depend on the characteristics of the project as well as the programme for the radio facility. Furthermore, other factors also play an important role: for example, many radio astronomers know that a celestial radio source never informs mankind beforehand when it likes to behave the way it does and at which frequency it prefers to do so.

We may wonder what a scientist considers important conditions for successful experiments, measurements or observations when his work depends on data collection at radio frequencies. Asking this, a radio astronomer may well answer with a statement such as:

> *"Radio astronomy is only possible when it can use frequency bands which are sufficiently free of interference considered harmful to radio astronomical observations"*.

Usually, his colleagues working in other sciences, using similar sentiments will immediately endorse such a statement.

This statement may seem clear, but this clarity is only superficial, since it contains a large degree of uncertainty and vagueness.

We observe that this simple and naive statement implies that it costs effort to guarantee that sufficient "frequency space" is available to enable radio astronomy to exist, work and progress. Generally speaking, the fact that radio astronomy still exists, is result of a technical and educational effort by radio astronomers, regulatory efforts of Administrations and the technical effort of active users. The technical effort by radio astronomers deals with the proper design of their instruments to reduce susceptibility to radio interference without reducing their sensitivity. Technical effort by active users also deals with proper system design to avoid spectrum pollution.

These efforts continuously represent huge challenges, which however will certainly pay off since good design implies mutual protection of users of radio frequencies against mutual radio interference, resulting in quality guarantees.

In addition, other questions are often asked specifically on the degradation of the successful acquisition of radio data. These concern the characteristics of radio astronomy, how the concept of *harmful* to radio astronomy observations is defined and in relation to this, through which parameter the *quality* of a radio astronomical observation can be expressed.

What is said here specifically about radio astronomy and radio astronomers, is true in similar ways for all scientific users of the radio spectrum.

Part 1

Spectrum management and regulation

2. What is spectrum management?

A growing number and variety of users and user communities are requiring access to the radio frequency spectrum. These users and user communities are found in all layers of society. The converging computer and communications technologies add intelligence to old applications and generate new ones. Related to these developments are dramatic changes to digital modulation techniques, both in the fixed and mobile services and in the developing new generation of broadcasting (Digital Video and Audio Broadcasting, DVB and DAB). There is increasing interest in the field of satellite communications to provide mobile services and, in a broader field, radio is providing the means to quickly introduce new telecommunication services, to provide competition in developed countries and to provide basic telephone services in developing countries.

The enormous impact of radio on society continues to increase. There are numerous areas in which the radio frequency spectrum is vital. National defence, public safety, weather forecasts and disaster warning, air-traffic control, environmental monitoring, are only a few examples. 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 the information needs of the illiterate, about two-thirds of the world population. All of these applications have to coexist alongside scientific and hobby use of radio, as well as against a background of radio frequency emissions from non-radiocommunication sources.

The number of terrestrial and space radio stations keeps growing and the frequency demand is increasing without precedence. The ITU has recorded more frequency assignments in the last few years than during the whole previous history of radio (Struzak, 1996, 1999a). Other developments concern deregulation and convergence. Deregulation trends encourage the introduction of new services and new technologies and convergence opens new applications previously unknown. Furthermore, it is widely accepted that the exploitation of the radio frequency spectrum will be the main engine of economic growth and improvement in the standard of living over the next few decades.

2.1. Spectrum management

The above-mentioned developments lead to an increasing scarcity of radio frequencies. Most suitable radio frequencies are already being used and new demand exceeds what can be accommodated. The pressure is most dramatic on those frequencies for which the technology is relatively simple and cheap, and for which user equipment is easy to produce and handle. In some frequency bands and geographical regions there is no place for new services due to spectrum congestion that hampers further development of radio applications. We note that in some parts of the radio spectrum this spectrum scarcity is partly caused by the use of equipment that is kept cheap and simple for various reasons, this implies that it lacks an optimal design which results in spectrum inefficiency or pollution. One of the objectives of frequency management is to reduce this spectrum inefficiency.

A consequence of the spectrum scarcity is the conflict that arises between those with access to the spectrum resource and those without. Conflicts arise also between the proponents of competing uses of the spectrum and those who are already using it. These conflicts can be of various natures: commercial, political, physical interference, etc. The question posed is whether these conflicts are unavoidable, and if the scarcity is due to laws of physics or to our incorrect management of the spectrum (Huang, 1993; Struzak, 1996, 1999a).

Spectrum scarcity is not only due to the increase in the number of radio stations. To some degree, it is also due to inefficient use of the spectrum, equipment deficiencies or the use of an unnecessary large amount of spectrum by this equipment. A part of the spectrum resource is wasted because of spurious, non-essential radiation from transmitting stations and spurious channels in receiving stations. Improved use of the spectrum through the refinement of technology is usually more expensive than those achieved through enhanced management. Industry for commercial reasons will not always be inclined to install this technology .

The scarcity is also due to a combined effect of an inadequate approach to the spectrum, simplistic management rules and regulations, primitive tools, and over-simplified engineering models. Inadequate spectrum management in a country can easily cause economic losses for many tens of millions of Euros or US$ per year (DTI, 1994).

> *"Spectrum management concept embraces all activities related to planning, allocation, use, and control of the radio frequency spectrum (and satellite orbits). Three objectives shape any spectrum management system: conveying policy goals, apportioning scarcity, and avoiding conflicts."* (Struzak, 1996, 1999a).

In our view, spectrum management is not restricted to the commercial, monetary and industrial aspects of the radio frequency spectrum only. Such a management concept is also reflected and receives broad attention in the strategic views of the International Telecommunication Union, ITU, (ITU, 1997a, 1997b). Scientific and other non-commercial use of radio cannot be handled under such a restricted management vision. We note that this restricted view is widely accepted in our modern society: for instance, new treaties and legislation to protect computer-based material which regulates the access and use of databases – which used to be open for "fair use" by scientific and educational use (as allowed in the Bern Convention for printed matter) – are being developed as if dealing with commercially sensitive material. Such a development poses "a major threat to research, especially in the astronomical, solar-terrestrial and environmental sciences" which constrains the openness required for "public domain" exchange of data necessary for the benefit of the scientific community (Risbeth, 1997). Market forces are pushing to close not only the radio frequency windows for scientific research, but also the access to scientific data. Such a perspective is disastrous for development for which science is the basis.

However, the essence of "management" is "the sparing or frugal mode of administering scarce resources to serve all humankind" (Dooyeweerd, 1969).

A correct management strategy for telecommunication, standardisation and development demands an integral analysis, which also deals with matters of commercial, financial and industrial interests (*but which is not based on it exclusively*). This perspective is expressed in recent ITU documents on its strategy, where it is stated that "with respect to the overall development, there is the need to ensure that economic forces are kept in balance with protection of the natural, social and cultural environment so that development remains sustainable. (ITU, 1997a). Attention to implementing and maintaining this balance is important since commercial and industrial interests frequently hamper the technological development necessary for a more sparing and frugal use of scarce resources (like the radio spectrum). If commercial and other materialistic forces get too much exclusive power, this implies hampering the development of developing countries and the enrichment of those already rich. Furthermore, the natural, social and cultural environment is then being sacrificed for the benefit of a fortunate few.

When the concept of management is considered to be *"the sparing or frugal mode of administering scarce resources to serve all humankind"*, this will result in a much better equilibrium and, in a structural way, in a more beneficial situation for non-commercial, non-industrial applications of radio. The Administrations should play a major role "*to ensure that the international community retains and improves mechanisms to manage and provide a stewardship function for scarce communication resources which should rightfully be regarded as the property of mankind"* (ITU, 1997a).

It is the task of spectrum management to accommodate all radio services and systems in the finite usable range of radio frequency spectrum. This process is mainly the responsibility of governmental Administrations (although some degree of delegation is possible) and it is imperative that those Administrations coordinate their efforts internationally. There are several reasons for this:

- Radio transmissions do not respect national boundaries and interference is possible over considerable distances, especially in certain frequency ranges.
- Some radio services need to operate internationally, for example aeronautical and maritime communications, overseas broadcasting and satellite services, and hence frequency planning and operational practices need to be harmonised.
- There is a growing interest in providing mobility for users, for example through the provision of cellular radio telephones which can operate in a number of countries.
- There are significant economies for large international markets, which benefits both users and operators (Goddard, 1994).

The framework in which the spectrum is managed at international and national levels is reviewed in chapter 3.

This view on spectrum management also implies an active attitude of the scientists towards the development of interference-robust equipment. The obvious statement that everyone designing, building and operating radio equipment must do so to achieve maximum reduction of susceptibility to interference, results directly from the international opinion on frequency regulation and spectrum management. However it is not always appreciated by scientists in practice. The reasons for this are often found in the area of scientific priorities and time scales, limited budgets and inadequate planning of system design and construction. But considering the scientists' responsibility for the economic management of radio frequencies, these arguments are to a large extent invalid.

It could be argued that spectrum management should ensure the continuation of the existing status for those whose needs have already been satisfied, as any modification would threaten their acquired benefits. However, as society is composed of various groups, each with its own interests, goals and views on how to use and manage the spectrum resources this may too conservative an approach and ultimately be to the detriment of spectrum users. In upholding this principle, spectrum management could oblige users to use more modern equipment if this would lead to improved spectrum efficiency which will pay off for the user. On the other hand, for newcomers who do not have access to the spectrum they want, the principal aim of spectrum management would be to change the way the spectrum is apportioned and to eliminate obstacles that prevent competition. In principle this could be achieved with or without violating the general rule of first come – first served. But in practice this rule is usually applied regardless of the allocation status of a radiocommunication service already using a specific frequency band. Furthermore, the general rule, which applies to society as a whole, applies also to spectrum management: 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 power also of the competing interest groups.

From these observations and comments it is obvious that commercial interest in radio frequency issues is rapidly increasing. In some countries this leads to change in the application of the first come – first served principle to the competition principle. At the international level, increasing commercial pressure is also felt from the World Trade Organisation, WTO, which seeks to remove barriers that could hamper free trade and commercial development. This pressure requires a creative application of spectrum management for radio frequencies used by scientific applications.

2.2. Spectrum management issues in specific frequency domains and the interest of science

2.2.1. Frequencies below 50 GHz

The frequency domain below 50 GHz basically hosts all possible radiocommunication services. Most of the scarcity occurs in this frequency range : especially below 10 GHz. The various interest groups using it range from the terrestrial services such as fixed, mobile, maritime, broadcasting, aeronautical radionavigation, radiolocation, amateur, radio astronomy and others, to space services such as fixed-satellite, mobile-satellite, broadcasting-satellite, Earth exploration-satellite, space research and other services. Frequency allocations to scientific usage of radio occupy less than about 2% of the radio spectrum of which less than 0.8% is exclusively allocated to passive radio frequency use.

Spectrum management, in trying to take into account the requirements of all interest groups including passive use of radio, finds itself confronted with strong commercial and political pressure to give priority to the needs of those services which are currently “attractive” for whatever reason. While space applications receive much attention, especially in North America, in Europe great attention is also given to terrestrial services. Scientific and hobby use of radio frequencies hardly figures on the political agenda in many countries. Therefore, scientists must make their case clear to the Administrations, who play the key role in spectrum management at national and international level.

2.2.2. Frequencies between 50 GHz and 275 GHz

At the time of writing, the frequencies between 50 and 275 GHz are hardly used for industrial and commercial applications of radio, and almost exclusively for scientific applications, such as radio astronomy, various remote sensing techniques and geodesy. Other users of the radio spectrum are interested in having allocations in this area, but the technology does not exist at the moment to enable the large scale deployment of telecommunication facilities such as those found at frequencies below 50 GHz. A large fraction of the spectrum is allocated to scientific applications of radio frequencies (either exclusive or shared with active services). These allocations made by the WRC-2000 are optimised for atmospheric propagation conditions: the atmospheric windows are open for scientific research.

Science services need not expect harmful interference from non-scientific applications for the next decade or so. Scientists may interpret this situation as if for the time being no problems exist. However, nothing could be further from the truth because industry and non-scientific users of the radio spectrum, being aware of the potential possibilities this part of the radio frequency spectrum offers, are supporting technological developments to open it up for commercially attractive applications. Currently, there are developments on vehicular radar and space-borne radar systems at frequencies even up to about 100 GHz.

Scientists must, therefore, remain active in developing interference-robust equipment to the greatest extent practicable.

2.2.3. Frequencies between 275 GHz and 1000 GHz

The radio spectrum at frequencies between 275 GHz and 400 GHz is currently used only for scientific research and applications. At present, this use is almost exclusively receiver-only, i.e. passive. It is expected that because of pressure from industrial and commercial users of radio frequencies, frequency allocations to the non-scientific services will not longer be excluded in the not too far future. Nevertheless, it is not expected that industrial and commercial users of the radio spectrum will have radio stations operating at these frequencies within the next decades.

2.2.4. Frequencies above 400 GHz

Allocations of radio frequencies to non-scientific services are not expected within the next decade of this publication. Scientist have developed various instruments to investigate radio waves of cosmic origin (radio astronomy) or terrestrial origin (e.g. remote sensing) which enable measurements at frequencies up to about 2 THz.

2.2.5. Priorities

Given the fact that each part of the radio frequency spectrum provides its own special information as a source for scientific research, it is generally not possible to indicate which part of the frequency domain could possibly be used as a substitute for another part. This statement does not exclude the possibility of such a substitution, but indicates that this may be applicable in very special cases only, depending on the scientific question and the development of scientific research. On the other hand, scientists must be open-minded and look for alternative frequencies when pressure on some frequency area becomes difficult to manage.

2.3. Principles for allocation of frequencies to science services

To enable adequate access and use of radio frequencies by scientific applications, several principles must be taken into account in the frequency allocation and management process. Furthermore, scientists must make every effort to ensure that these principles are respected. The development, definition and application of such principles are a major aspect of spectrum management.

- The allocations to the passive services should be in response to physical processes in space or the atmosphere.
- Passive sensors of the Earth Exploration-Satellite Service are operated on a global basis, and coordination with other services is not practical. The only sharing possibility resides in a strict compliance with the interference threshold of the passive sensors.
- The particular vulnerability of the Radio Astronomy Service to space-to-Earth transmissions from satellites and downlink transmissions from aeronautical stations implies that no allocation should be given to services operating such facilities within important Radio Astronomy Service-bands or within bands adjacent to those with allocation for radio astronomy.
- Co-allocation of the Radio Astronomy Service and terrestrial services (except high altitude platforms) is possible, provided there is the necessary coordination around the radio astronomy station. For frequencies above about 70 GHz, the number of mm-wave observatories world-wide is expected to remain very limited, because, among other things, few sites on Earth fulfil the stringent requirements that justify the required investment. The sites of these stations are selected mostly on the basis of the low water vapour content of the atmosphere and stability of the climate. Preferred locations are high mountaintops or plateaux in a desert environment, far from major cities and centres of urbanisation. Therefore, the Radio Astronomy Service should be able to share its frequency bands with terrestrial services at these high frequencies. (See also ITU Radio Regulations Article S.29).

3. Spectrum regulation

The radio frequency spectrum is being used by a growing variety of radiocommunication applications. Although the traditional uses of broadcasting, maritime and aeronautical communications, point to point fixed links, land mobile radio and numerous navigation services remain, in almost all of their categories new applications are being introduced at a growing pace and novel uses of radio spectrum are being exploited. Recent years have seen a dramatic change to digital modulation techniques, both in fixed and mobile services and the next generation of digital broadcasting services is close to implementation. There is increasing interest in the field of satellite communications to provide mobile services, and more generally, radio is offering the means to rapidly introduce new telecommunication services, to provide competition in developed countries and to establish basic telephone services in developing countries. All of these applications have to coexist alongside scientific and other, e.g. amateur, uses of radio as well as against a background of radio frequency emissions from non-radiocommunication sources.

The task of accommodating all of these radio services and systems in the finite usable range of radio frequency spectrum comes under the generic title of *spectrum management*. This process is mainly the responsibility of government Administrations (although some degree of delegation is possible) and it is imperative that those Administrations coordinate their efforts internationally. There are several reasons for this (see section 2.1.).

This chapter describes the framework in which spectrum is managed internationally and nationally.

3.1. The ITU, its structure, its operations and its role

3.1.1. ITU responsibilities

The international Administrative cooperation body having the responsibility for coordinating spectrum management at the global level is the International Telecommunication Union (ITU). The ITU is the oldest specialised agency of the United Nations and its origins extend back to the International Telegraph Union which was founded in 1865, that is before the invention of the telephone and the demonstration of the practical application of radio transmission. The ITU currently has a membership of about 190 sovereign countries, the Member States, and about 500 non-governmental entities, including equipment manufacturers and operators/service providers, the Sector Members, and a permanent headquarters in Geneva, Switzerland

A list of other UN organisations deploying activities related to spectrum regulations and scientific use of radio frequencies are given in Figure 3.1.

The importance of the ITU in the field of spectrum management can be judged by the prominence given to radiocommunication in Article 1 of the ITU Constitution. In that text, the Union is required to "effect allocation of bands of the radio-frequency spectrum, the allotment of radio frequencies and registration of radio frequency assignments and any associated orbital position in the geostationary-satellite orbit in order to avoid harmful interference between radio stations of different countries" and to "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 radiocommunication services".

UN organisation	**Administrative headquarters**	**Scientific interest**
International Civil Aviation Organisation (ICAO)	Montreal, Canada	
International Telecommunication Union (ITU)	Geneva, Switzerland	
International Trade Centre UNCTAD/WTO	Geneva, Switzerland	
Office for Outer Space Affairs	Vienna, Austria	*Outer Space studies*
United Nations Educational, Scientific and Cultural Organisation (UNESCO)	Paris, France	*IUCAF* (see section 6.3.1)
World Meteorological Organisation (WMO)	Geneva, Switzerland	*Remote sensing, meteorology*

Figure 3.1: The United Nations and some of its organisations

3.1.2. The International Radio Regulations

The ITU sets the overall international spectrum management framework through the International Radio Regulations. This body of text has international treaty status and thus the Regulations are binding for all members of the ITU. The Radio Regulations contain, in Article S5, the international Frequency Allocation Table. For the purpose of the international frequency allocation table, the world has been divided into three Regions. Region 1 covers the whole of Europe, the Middle East and Africa; Region 2 comprises the Americas and Region 3 Asia and Australia (see Figure 3.2).

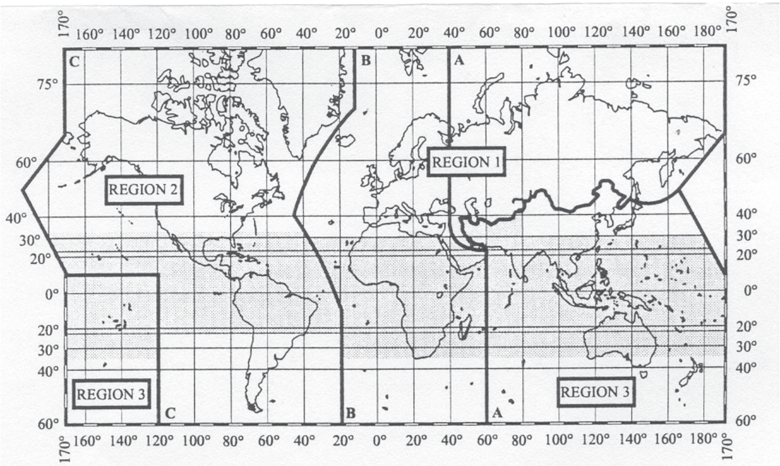

Figure 3.2: For the allocation of frequencies the world has been divided into three Regions as shown in this map.

An extract of one page of Article S5 is shown in Figure 3.3. This article shows the allocation of the radio spectrum, broken down into a large number of discrete bands and to a number of defined radiocommunication services. The frequency range covered is from 9 kHz to 1000 GHz. The radiocommunication services defined in the Radio Regulations and for which there are allocations, include broadcasting, mobile radio, the fixed services, amateur radio, radionavigation and radiolocation, a number of science services, and, in nearly all cases, the corresponding satellite-based transmissions of a space service. The Radio Regulations do not in general sub-divide the basic radio services into detailed applications. For example, although the mobile service is sub-divided into its land, maritime and aeronautical variations, there is no provision in the regulations relating to paging, private mobile radio or cellular radiotelephones.

For many radio services it is necessary to have common world-wide allocations, for example in the high frequency (short-wave) bands where signals propagate over vast distances, in bands used for international maritime and aeronautical communications and navigation, and where satellite-delivered services are involved. In other cases, global allocations may be desirable to minimise incompatibilities in border regions or to create large markets for equipment. However, historic differences in usage and subsequent difficulties in negotiating changes have resulted in some significant variances in the allocations from Region to Region. Another important element is the use of different allocations to create and maintain "exclusive" regions of political and economic influence and closed monopolistic markets.

In addition to the broad applications of the international table, which may provide for more than one radio service in any given band, the table contains a large number of footnotes. Some of these specify constraints on the use of the radio service or frequencies in question, while others provide additional or alternative frequency allocations to individual countries or groups of countries. Some footnotes represent real operational needs or usage; others are the results of compromises in international negotiations.

The Radio Regulations contain much more than the international frequency table alone. They contain rules for the use and operation of frequencies; they specify operating procedures for stations, especially in the maritime and aeronautical services; and they lay down the procedures for the coordination of frequencies. The latter is the mechanism used to check if the use of frequencies in one country will cause interference to, or suffer interference from, other existing frequency assignments of other countries. If not, the frequency can then be registered and afforded protection from other, future, users. This procedure can be very complex and time consuming but it forms the core of the regulations and achieves order in what would otherwise be utter chaos. Not all frequency assignments need to be cleared internationally in this way: existence of low power applications, those well inside a country's border, or cases where special bilateral or other arrangements are in force, are exempt. But coordination is necessary in order to be able to claim international recognition and hence protection. It is therefore essential for many applications, including virtually all satellite-based ones.

MHz
1610.6 – 1631.5

<table>
<tr><th colspan="3">Allocation to Services</th></tr>
<tr><td>Region 1</td><td>Region 2</td><td>Region 3</td></tr>
<tr>
<td>1610.6–1613.8
MOBILE-SATELLITE
(Earth-to-space)
RADIO ASTRONOMY
AERONAUTICAL
RADIONAVIGATION
S5.149 S5.341 S5.355
S5.359 S5.363 S5.364
S5.366 S5.367 S5.368
S5.369 S5.371 S5.372</td>
<td>1610.6–1613.8
MOBILE-SATELLITE
(Earth-to-space)
RADIO ASTRONOMY
AERONAUTICAL
RADIONAVIGATION
RADIODERTERMINATION-
SATELLITE
(Earth-to-space)
S5.149 S5.341 S5.364
S5.366 S5.367 S5.368
S5.369 S5.371 S5.372</td>
<td>1610.6–1613.8
MOBILE-SATELLITE
(Earth-to-space)
RADIO ASTRONOMY
AERONAUTICAL
RADIONAVIGATION
Radiodetermination-
Satellite
(Earth-to-space)
S5.149 S5.341 S5.355
S5.359 S5.364 S5.366
S5.367 S5.368 S5.369
S5.372</td>
</tr>
<tr>
<td>1613.8–1626.5
MOBILE-SATELLITE
(Earth-to-space)
AERONAUTICAL
RADIONAVIGATION
Mobile-Satellite
(space-to-Earth)
S5.341 S5.355 S5.359
S5.363 S5.364 S5.365
S5.366 S5.367 S5.368
S5.369 S5.371 S5.372</td>
<td>1613.8–1626.5
MOBILE-SATELLITE
(Earth-to-space)
AERONAUTICAL
RADIONAVIGATION
RADIODERTERMINATION-
SATELLITE
(Earth-to-space)
Mobile-Satellite
(space-to-Earth)
S5.341 S5.364 S5.365
S5.366 S5.367 S5.368
S5.370 S5.372</td>
<td>1613.8–1626.5
MOBILE-SATELLITE
(Earth-to-space)
AERONAUTICAL
RADIONAVIGATION
Mobile-Satellite
(space-to-Earth)
Radiodetermination-
Satellite
(Earth-to-space)
S5.341 S5.355 S5.359
S5.364 S5.365 S5.366
S5.367 S5.368 S5.369
S5.372</td>
</tr>
<tr>
<td>1626.5–1631.5
MARITIME MOBILE SATELLITE
(Earth-to-space)
Land Mobile-Satellite
(Earth-to-space) S5.532
S5.341 S5.351 S5.354
S5.355 S5.359</td>
<td colspan="2">1626.5–1631.5
MARITIME MOBILE SATELLITE (Earth-to-space)
S5.341 S5.351 S5.354 S5.355 S5.359 S5.373A</td>
</tr>
</table>

Figure 3.3: Extract of a page of Article S5 of the ITU Radio Regulations. The cells in this table apply for a specific frequency band and Region as indicated. Radiocommunication services having a primary allocation are printed in CAPITAL characters. General footnotes applying to a specific frequency band are added at the bottom of each cell. Footnotes applying to a specific service only are added behind this service. The footnotes are explained elsewhere in the Radio Regulations.

For some radio applications, the frequency requirements of each country are met in a pre-determined *frequency assignment plan*. This approach is most common in the broadcasting and broadcasting-satellite services. In many cases the plan is on a regional or sub-regional basis. Once the plan has been agreed, a country may use its assignments without further formal coordination. Normally, a plan-modification procedure provides the mechanism for bringing into use assignments with different characteristics from those specified in the plan.

A variation of the planning process is used in the *allotment plan*. Here, the plan may specify a particular frequency or frequencies to be used by a country in a particular area (as compared to a specific location for an assignment plan). Allotment plans are used in the aeronautical and maritime mobile services. A special case of allotment plan has also been used for certain fixed-satellite bands in which each country has been allotted a range of frequencies for use over a specified portion (arc) of the geostationary-satellite orbit. In this case, the allotment is converted into a specific assignment before bringing it into use.

In spite of the official recognition of science services, such as the Radio Astronomy Service, the Earth Exploration-Satellite Service and the Space Research Service, the ITU does not fully recognise the extent to which their characteristics are different, and sometimes even very different, from those of the other radiocommunication services. This holds especially for the passive services. The Radio Regulations place all services on an equal footing and do not provide preferential treatment to the more vulnerable *passive services* as is clear from the Radio Regulations Articles S4.5, S4.6 and S4.7.

Article S4.5 reads:

> *"The frequency assigned to a station of a given service shall be separated from the limits of the band allocated to this service in such a way that, taking account of the frequency band assigned to the station, no harmful interference is caused to services to which frequency bands immediately adjoining are allocated."*

Article S4.6 reads:

> *"For the purpose of resolving cases of harmful interference, the radio astronomy service shall be treated as a radiocommunication service. However, protection from services in other bands shall be afforded the radio astronomy service only to the extent that such services are afforded protection from each other."*

Article S4.7 reads:

> *"For the purpose of resolving cases of harmful interference, the space research (passive) service and earth exploration-satellite (passive) service shall be afforded protection from different services in other bands only to the extent that such services are afforded protection from each other."*

Although it is the mission of the ITU, i.e. of its Radiocommunication Sector, to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services (see section 3.1.4.1), the specific case of passive services is at present not handled on an equitable basis in the physical and technical sense. It is common practice in the design of active services to raise the power of emitted signals to a point where the level of natural, additive noise onto the received signal becomes negligible. In such a context, where active spectrum users may raise their transmitting powers beyond such a level, spectrum management is reduced to ensuring each user has its required signal-to-interference ratio, i.e. to handling relative signal power levels. Passive services, on the other hand, are based on measurements of natural radiation, sometimes of very low levels; hence, they need protection in absolute terms.

The Radio Astronomy Service has suffered a number of harmful interference cases during the last years, a situation which continues at present. This interference is mainly caused by satellites with inadequate protection for radiocommunication service(s) in an adjacent frequency band. Some radio astronomy operations in protected frequency bands have thereby been made very difficult or even impossible for a number of years to come, although the Radio Regulations specifically permit no harmful interference in these bands.

3.1.3. The International Radio Regulations in the context of global regulation

On a global scale, the international regulatory framework for frequency regulation and spectrum management is the ITU Radio Regulations. These regulations have the status of an international treaty.

In terms of international law, the national Administrations play a key role in spectrum management. In some local situations, where coordination between private users of the radio spectrum is required or desired, agreements between these private users can be obtained. These agreements should be reached in proper coordination with the national Administration, otherwise the private users undermine their own case (see section 7.1). Furthermore, such agreements or "memoranda of understanding" should obey the legal principles as given above and conform to the current national and international legislation, i.e. the ITU Radio Regulations. The legal status of such agreements is very limited and even non-existent in terms of international law.

The ITU Radio Regulations apply to terrestrial, aeronautical and space radiocommunication services. As concerns the space-borne systems, the following comments should be made:

A treaty with a status higher than the ITU Radio Regulations is the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and other Celestial Bodies*, the Outer Space Treaty, OST (United Nations Treaties and Principles on Outer Space, 1994). An even higher status for the OST is being considered, based on the fact that it was formulated within the most comprehensive world organisation, the United Nations Organisation, as a sort of Magna Carta for Space. But this interpretation is subject to dispute.

OST articles relevant to the protection of terrestrial radio stations in general and scientific radio stations in particular are*:

Article I:

> *The exploration and use of outer space, including the moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective*

* (for additional comments, see *CRAF Handbook for Radio Astronomy*, 1997, pp.108-116)

of their degree of economic or scientific development, and shall be the province of all mankind.

Outer space, including the moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.

There shall be freedom of scientific investigation in outer space, including the moon and other celestial bodies, and States shall facilitate and encourage international cooperation in such investigation.

Article VI:

States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organisation, responsibility for compliance with this Treaty shall be borne both by the international organisation and by the States Parties to the Treaty participating in such organisation.

Article VII:

Each State Party to the Treaty that launches or procures the launching of an object into outer space, including the moon and other celestial bodies, and each State Party from whose territory or facility an object is launched, is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons by such objects or its component parts on the Earth, in air or in outer space, including the moon and other celestial bodies.

Article VIII:

A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return.

Article IX:

> *In the exploration and use of outer space, including the moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty. States Parties to the Treaty shall pursue studies of outer space, including the moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose. If a State Party to the Treaty has reason to believe that an activity or experiment is planned by it or its nationals in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the moon and other celestial bodies, it shall undertake appropriate international consultation before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the moon and other celestial bodies, may request consultation concerning the activity or experiment.*

A second specific convention based on the Outer Space Treaty 1967, in particular on its Articles VI and VII, is the Liability Convention 1971 concerning international responsibility and liability of States for their national activities in space.

Articles 1, 2, 5.1 and 5.3 of this *Convention on International Liability for Damage Caused by Space Objects* are especially relevant for the protection of scientific radio stations (*CRAF Handbook for Radio Astronomy*, 1997, pp.108-116). These articles address the definition of damage and the liability of the responsible State if a space station causes damage.

The third specific convention based on the Outer Space Treaty 1967 is the *Convention on Registration of Objects Launched into Outer Space* of 1974, in particular its Articles VIII, X and XI. These articles deal, respectively, with the obligation of States where a vehicle is launched into outer space and is registered, to retain jurisdiction and control over such an object and over any personnel thereof (Art. VIII); the opportunity to observe the flights of space objects (Art. X); to inform the Secretary-General of the United Nations, the public and the international scientific community, of the nature, conduct, location and results of such activities (Art. XI).

Given the increasing threat of harmful interference to radio astronomy and other passive scientific applications of radio frequencies by transmissions from satellites, and the fact that satellites used for international direct broadcasting contribute significantly to this, it should be noted that in the *Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting* (1972) it is stated clearly that:

> *"In order to promote international co-operation in the peaceful exploration and use of outer space, States conducting or authorising activities in the field of international direct television broadcasting by satellite should inform the Secretary-General of the United Nations, to the greatest extent possible, of the nature of such activities. On receiving this information, the Secretary-General should disseminate it immediately and effectively to the relevant specialised agencies, as well as to the public and the international scientific community* (item 12)."

And:

> *"With respect to the unavoidable over-spill of the radiation of the satellite signals, the relevant instruments of the International Telecommunication Union shall be exclusively applicable* (item 15)*."*

The ITU itself, its Constitution and Convention, and the ITU Radio Regulations are considered "*Related International Agreements*". This implies that international law at its highest level should in the context of the current problem be the Outer Space Treaty, while the ITU documents, treaties and agreements, act as appendices to this law. Therefore, the ITU Radio Regulations and related documents should be read in the context of the OST as far as space applications are concerned.

For the protection of radio frequencies relevant for scientific research, the key articles are *Articles VI and VII* of the OST. It should be noted that in the OST "damage" is a generic term and understood in the sense that the victim defines the damage, just as in the case of physical damage. However, in the strict juridical sense, the definition of damage is often subject to the general interpretation intended by the drafters and the participating states, subject to reasonableness and ultimately also subject to a decision of the judicial body called upon to judge a particular case.

Working on the spectrum management and in relation to the interest of the scientific community, scientists should base their arguments not only on the ITU Radio Regulations and related ITU documentation, but they must also be aware of the protection argumentation based on the OST. The OST contains no restriction concerning the kind of exploration of outer space, including the Moon and other celestial bodies: this can be done by launching space vehicles, but also done by various different techniques used in scientific research. This treaty uses the term "exploration" only in a generic way. The same holds for "damage".

3.1.4 The ITU Structure

The structure of the ITU is illustrated in Figure 3.4 (p. 30). The most senior organ of the ITU is the *Plenipotentiary Conference*. This conference determines the *Constitution* and *Convention* of the Union, sets the overall policy and strategy, determines the budget, the way in which the ITU operates, etc. Plenipotentiary Conferences are held every four years. In between Plenipotentiary Conferences, the ITU *Council*, an elected body of approximately one-quarter of the ITU Member States, meets to manage the Union.

The ITU organisation is comprised of three *sectors – Telecommunication Standardisation (ITU-T), Radiocommunication (ITU-R)* and *Telecommunication Development (ITU-D)* Sectors. Each Sector has its own Bureau in the Geneva headquarters, headed by a Director who reports to the Secretary General who is assisted by the Deputy Secretary-General. However, it should be noted that the ITU has a somewhat federative structure with its sectors (and directors) which are almost independent from the Secretary General, except for the financial and legal aspect. The Director of the sector-bureau of each Sector organises and coordinates the work of the Sector.

3.1.4.1 The ITU-R Sector

The functions of the Radiocommunication Sector are to ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radiocommunication services, including those using geostationary-satellite orbit and to carry out studies without limit of frequency range and to adopt Recommendations on radiocommunication matters. Close coordination is carried out (mainly at national level) between the ITU-R, ITU-T and ITU-D Sectors.

The Radiocommunication Sector works through *World and Regional Radiocommunication Conferences,* the *Radio Regulations Board, Radiocommunication Assemblies*, and *Radiocommunication Study Groups*. The ITU-R activities are supported by the *Radiocommunication Bureau*, headed by a Director.

Among its various activities, the Radiocommunication Bureau has the responsibility for operating a database containing the declared (not the actual or real) frequency use and related parameters for all stations of a radiocommunication service and for radio astronomy stations. The national Administrations notify this Bureau about these stations according to a well-defined procedure. Such notification enables the ITU to serve the international community and the Administrations in their spectrum management, for example by providing information about the characteristics of a station for which measures to protect it from interference must be taken. A station, for which the notification has not been done properly, may find difficulties in getting due attention for protection requests. This notification process is done for all kinds of stations, both terrestrial and space-borne.

World Radiocommunication Conferences, *WRCs, are the only conferences that have the authority to change the International Radio Regulations*. WRCs are held every two or three years. Each WRC will develop and propose an agenda for the next WRC, as well as a provisional agenda for the WRC after that. The final decision on each WRC agenda rests with the ITU Council.

The main issues of the *WRC-95* conference were: the simplification of the ITU Radio Regulations, and new allocations to the Mobile Satellite Service, MSS, including feeder links.

Important issues at the *WRC-97* conference were: allocations for multimedia applications, satellite broadcasting, maritime issues, the problem of paper satellites, and continued pressure to consolidate more spectrum allocations for specific satellite applications.

Serious coordination efforts still need to be made to allow the implementation of many planned (mostly non-GSO) satellite systems and to allow the peaceful coexistence of new and existing systems. It appears that sharing in certain bands between different satellite systems and various terrestrial applications will be very difficult if not impossible. The demand for spectrum has risen dramatically with the possibility of terrestrial and satellite-based high-density data systems. Specific assignments were made for such applications up to frequencies of 66 GHz. Although many of these systems could still be far away in the future, astronomers are warned that the (currently interference-free) mm-wave spectral regions may soon have active applications. Other services, like those of terrestrial fixed and aeronautical radio navigation, are getting seriously worried about “harmful interference”, which was strongly expressed at the Conference.

Among the important results of the *WRC-2000*, we noted: the global assignment of 160 MHz to IMT-2000 (in Europe known as UMTS) in the frequency range 2.5-2.7 GHz to facilitate future developments of mobile communication; allocation of frequencies to the Radionavigation-Satellite Service, RNSS, in the frequency ranges 1.2 GHz, 1.3 GHz and just above 5 GHz. These frequencies are intended to be used by the European civil satellite navigation system GALILEO. The conference also adopted regulatory measures for sharing between the Fixed-Satellite Service, FSS, and terrestrial services in some frequency domains. The conference adopted resolutions asking for further study to conclude on this issue in the next WRC (i.e. WRC 2003). High-density applications in the Fixed Service, FS, and FSS were also a key issue and led to several decisions.

For scientific research, the conference’s main result was a complete reallocation of the frequencies between 71 GHz and 275 GHz. The new allocations imply that frequencies allocated to science services have been identified in the most optimum way to comply with the propagation conditions of the terrestrial atmosphere and to minimise potential coordination and sharing issues with non-science services. Also to the greatest possible extent, space-to-Earth transmissions have been moved as far as possible from frequencies allocated to the science services.

A major result of the conference was the completion of the complete re-planning of the Satellite Broadcasting Plan for the ITU-R Regions 1 and 3, i.e. Europe; Africa; Asia and the Pacific region.

The WRC-2000 also adopted provisional limits for transmissions from space to protect terrestrial science services, e.g. radio astronomy. The resolution of this important issue for scientific research will also be completed by the next WRC.

The agenda of the *WRC-03* contains a number of items that are important for scientific research. Among these, the most important are to:

- finalise the work on spurious emission criteria in Appendix S3 of the ITU Radio Regulations for space services with regard to passive science services;
- consider possible extension of the allocation to the mobile-satellite service (Earth-to-space) on a secondary basis in the band 14-14.5 GHz to permit operation of the aeronautical mobile-satellite;
- consider regulatory provisions and possible identification of existing frequency allocations for services which may be used by high altitude platform stations;

- determine regulatory measures to protect radio astronomy against interference from the radionavigation-satellite service operating just above 5 GHz;
- consider allocations on a worldwide basis for feeder links in bands around 1.4 GHz to the non-GSO MSS with service links operating below 1 GHz;
- consider additional allocations on a worldwide basis for the non-GSO MSS with service links operating below 1 GHz;
- consider technical and regulatory provisions concerning the band 37.5-43.5 GHz, i.e. to protect radio astronomy from interference resulting from space-to-Earth transmissions from FSS applications in adjacent frequency bands.

At the time of writing this document, the conference had not yet taken place.

Provisions have been made for Regional Radiocommunication Conferences, and so Europe has recently requested the ITU to hold a regional conference to review the Stockholm TV Broadcasting plan.

The Radiocommunications Assembly, RA, is responsible for the organisation and work programme of the ITU-R Study Groups, SGs, to approve and issue ITU-R Recommendations and Questions developed by the Study Groups and suggest suitable topics for the agenda of future WRCs. The two main tasks of the Study Groups are:
- to prepare the technical basis for the Radiocommunication Conferences;
- to develop ITU-R Recommendations on technical characteristics and operational procedures relating to the various radiocommunication systems and services, and on associated issues of spectrum management. Thus, the role of the RA is to provide the technical basis for effective use of the spectrum and geostationary-satellite orbits, to recommend performance standards for radio systems and to ensure the effective and compatible inter-working of systems, and to disseminate technical information.

The Study Groups of the Radiocommunication Sector, SGs, are responsible for carrying out the work in each area of activity. This work includes the study of Questions and the preparation of draft Recommendations on the matters referred to them. Those draft Recommendations are submitted for approval to a Radiocommunication Assembly or, between such conferences, by correspondence to Administrations. In practice most of the work is carried out in Working Parties, WPs, and Task Groups, TGs (when work on a specific question has been completed the Task Group is discharged by an RA). There is one Study Group for each main radio service or group of services, plus specialised Study Groups on spectrum management, inter-service sharing, and radio wave propagation. Figure 3.5 shows the different Study Groups of this Sector with their Working Parties.

Much of the output of the Radiocommunication Assembly and the Study Groups provides technical input to the World Radiocommunication Conferences, WRCs. To assist in this process, the Radiocommunication Sector requires an Assembly to be held “associated in time and place” with each WRC. *A Special Committee on Regulatory/Procedural Matters*, SC, supports the preparation of a WRC.

Plenipotentiary Conference

ITU Council (output: *Constitution, Convention, Strategy, Policy, Budgets, Elections*)	**World Conference on International Telecommunications** (output: *Administrative Regulations – incl. Radio Regulations, Resolutions, Recommendations, Conference Agendas)*

World Radiocommunication Conference (output: *Administrative Regulations - incl. Radio Regulations, Resolutions, Recommendations, Conference Agendas)* Note: there are also provisions for regional conferences **Radiocommunication Assembly** (output: *Recommendations that may form a technical basis for negotiations at WRCs)*	**World Telecommunication Standardisation Assemblies**	**World Telecommunication Development Conference** Note: there are also provisions for regional conferences
Radio Regulations Board (output: *Approval of Rules of Procedures that are used by the BR in frequency notification; fulfilling tasks assigned by the WRC and advice on reports from Director of Radiocommunication Bureau on matters of harmful interference, advice to Radio-communication Conferences and Radiocommunication Assemblies*)		
Advisory Group (output*: advise the Director of the Radiocommunication Bureau, recommend steps towards improved cooperation and coordination with other organisations and with the other ITU Sectors)* **World Telecommunication Policy Forum** (output*: Opinions on specific issues)* **Study Groups** (output*: Recommendations, Resolutions plus strategies and policies in own field)*	**Advisory Group** (output*: advise the Director of the Telecommunication Standardisation Bureau, recommend steps towards improved co-operation and co-ordination with other organisations and with the other ITU Sectors)* **Study Groups** (output: *Recommendations, Resolutions plus strategies and policies in own field)*	**Advisory Group** (output*: advise the Director of the Telecommunication Development Bureau, recommend steps towards improved telecommunication development)* **Study Groups** (output: *Recommendations, Resolutions plus strategies and policies in own field)*

General Secretariat

Radiocommunication Bureau (output: *organisation and coordination of ITU-R Sector*)	**Telecommunication Standardisation Bureau** (output: *organisation and coordination of ITU-T Sector*)	**Telecommunication Development Bureau** (output: *organisation and coordination of ITU-D Sector*)

Figure 3.4: Structure of the ITU

ITU-R Study Group	Subject
1	**Spectrum Management** *Working Parties*: *WP1A*: Principles and techniques for the effective use and management of the radio frequency spectrum *WP1B*: Spectrum sharing criteria and methods to enable the efficient use of the spectrum *WP1C*: Techniques for spectrum monitoring and related issues
3	**Radiowave Propagation** *Working Parties*: *WP3J*: Propagation fundamentals *WP3K*: Point-to-area propagation *WP3L*: HF propagation *WP3M*: Point-to-point Earth-space propagation
4	**Fixed-Satellite Service** *Working parties*: *WP4A:* Efficient orbit/spectrum utilisation *WP4B*: Systems, performance, availability and maintenance *JWP4-9S*: Frequency sharing between the Fixed-Satellite Service and the Fixed Service *WP4SNG*: Satellite news gathering (SNG), outside broadcast via satellite *RG WP4B*: performance requirements and asynchronous transfer mode technology (ATM)
6	**Broadcasting Services** *Working Parties*: *WP6B*: Digital Coding *WP6E*: Terrestrial emission *WP6M*: Interactivity and multimedia *WP6P*: Broadcasting systems, production, baseband signals, etc. *WP6Q*: Quality assessment *WP6R*: Recording for broadcasting *WP6S*: Satellite Broadcasting
7	**Science Services** *Working Parties*: *WP7A*: Time signals and frequency standard emissions *WP7B*: Space radio systems *WP7C*: Earth exploration satellites systems and meteorological elements *WP7D*: Radio astronomy *WP7E*: Inter-service sharing and compatibility
8	**Mobile, Radiodetermination, Amateur and related Satellite Services** *Working Parties*: *WP8A*: Land Mobile Service excluding IMT-2000; Amateur and Amateur-Satellite Service *WP8B*: Maritime Mobile Service including Global Maritime Distress and Safety Systems (GMDSS); Aeronautical Mobile Service and Radiodetermination Service *WP8D*: All mobile satellite services except the amateur satellite service; and Radiodetermination Satellite Service *WP8F*: IMT-2000 and systems beyond IMT-2000
9	**Fixed Service** *Working Parties*: *WP9A*: Performance and availability, interference objectives and analysis, effects of propagation, and terminology *WP9B*: Radio-frequency channel arrangements, radio systems characteristics, interconnection, maintenance and various applications *WP9C*: HF systems *WP9D*: Sharing with other services (except for the fixed-satellite service)
SC	Special Committee on Regulatory/Procedural Matters
CCV	Coordination Committee for Vocabulary
CPM	Conference Preparatory Meeting

Figure 3.5: Study Groups of ITU-R Sector

In addition, a series of *Conference Preparatory Meetings*, CPMs, have been established to focus the work of the Study Groups in preparation for each WRC. The pattern is that a first CPM will be held soon after each WRC to ensure that the work programme of the Study Groups takes into account the needs of the next WRC as set by its agenda. Some time before the next WRC takes place, a second CPM will be held to synthesise the Study Group's work into a report which Administrations and others can take into account in making proposals to the WRC. The CPM itself is not expected to carry out technical studies. The final report of the CPM provides the technical basis for the WRC.

The duties of the Radio Regulations Board, RRB, consist of:

- the approval of Rules of Procedure, which include technical criteria, in accordance with the ITU Radio Regulations and with any decision which may be taken by competent radiocommunication conferences;
- the consideration of any other matter that cannot be resolved through the application of the Rules of Procedure;
- the performance of any additional duties, concerned with the assignment and utilisation of frequencies, in conformity with the function of the ITU-R Sector.

3.1.4.2. The ITU-T Sector

The functions of the Telecommunication Standardisation Sector are to fulfil the purposes of the Union relating to telecommunication standardisation by studying technical, operating and tariff questions and adopting recommendations on them with a view to standardising telecommunications on a worldwide basis. In addition, the Telecommunication Sector has responsibility for operations and technical standards in many radio fields. Steps have been taken to ensure that the process is kept under review and that there is adequate coordination between the Sectors. It should be noted that although the Telecommunication Standardisation and Telecommunication Development Sectors both have World Conferences, these conferences do not have treaty-making responsibility but equate in authority to Radiocommunication Assemblies. Only the Radiocommunication Sector’s WRCs (and of course the Plenipotentiary Conference) have the authority to produce internationally binding regulations.

The Study Groups of the ITU-T Sector are responsible for carrying out the work in each area of activity. Figure 3.6 reviews the different Study Groups of this Sector. This work includes the study of questions and the preparation of draft Recommendations on the matters referred to them. Those draft Recommendations are submitted for approval to a World Telecommunication Standardisation Conference, and between such conferences, by correspondence to Administrations.

Between World Telecommunication Standardisation Conferences, WTSCs, a broadly accessible Technical Standardisation Advisory Group, TSAG, works on urgent problems in the standardisation process. One of the tasks of the TSAG is to improve the efficiency of the ITU-T sector. TSAG decides also on the set-up and work of Study Groups in the standardisation sector: it has the mandate to modify the operations of ITU-T to retain efficient and flexible working methods.

ITU-T Study Group	Subject
2	Operational aspects of service provision, networks and performance. Lead Study Group for service definition, numbering and routing
3	Tariff and accounting principles including related telecommunication, economic and policy issues
4	Telecommunication management, including TMN. Lead Study Group on TMN.
5	Protection against electromagnetic environment effects
6	Outside plant
7	Data networks and open system communications. Lead Study Group on frame relay and for communication system security
9	Integrated broadband cable networks and television and sound transmission. Lead Study Group on integrated broadband cable and television networks
10	Languages and general software aspects for telecommunication systems. Lead Study Group on languages and description techniques
11	Signalling requirements and protocols. Lead Study Group on intelligent networks
12	End-to-end transmission performance of networks
13	Multi-protocol and IP-based networks and their internetworking. Lead Study Group for IP-related matters, B-ISDN, global information infrastructure and satellite matters
15	Optical and other transport networks. Lead Study Group on access network transport and on optical technology
16	Multimedia services, systems and terminals. Lead Study Group in this area
Special Study Group on IMT-2000 and beyond	Studies relating to network aspects of International Mobile Telecommunications-2000 (IMT-2000) and beyond, including wireless Internet, convergence of mobile and fixed networks, mobility management, mobile multimedia functions, internetworking, interoperability. Lead Study Group for overall network aspects of IMT-2000 and beyond

Figure 3.6: Study Groups of ITU-T Sector

3.1.4.3. The ITU-D Sector

The functions of the Telecommunication Development Sector are to fulfil the purposes of the Union and to discharge the Union's responsibility as a United Nations specialised agency and executing agency for implementing projects under the United Nations development system or other funding arrangements so as to facilitate and enhance telecommunication development by offering, organising and coordinating technical cooperation and assistance activities.

The Study Groups of the ITU-D Sector deal with specific telecommunication questions of general interest of the least developed countries. Figure 3.7 reviews the different Study Groups of this Sector.

ITU-D Study Group	Subject
1	Telecommunication Development, Strategies and Policies
2	Development, Harmonisation, Management and Maintenance of Telecommunication Neworks and Services including Spectrum Management

Figure 3.7: Study Groups of ITU-D Sector

3.1.5. World Telecommunication Policy Forum

A *World Telecommunication Policy Forum*, WTPF, is a conference where ITU Members as well as entities and organisations other than Administrations can discuss and exchange views and information on telecommunication policy and regulatory matters. The WTPF does not produce prescriptive regulatory outcomes or outputs with binding force, but rather reports and opinions for consideration by the ITU Members and relevant ITU meetings.

The first WTPF was held in 1996 and debated key issues surrounding the development and implementation of global mobile personal communications by satellite, GMPCS. The second WTPF was held in 1998 and dealt with accounting rates as key issue.

3.2. Regional organisations

3.2.1. Introduction

Between the broad framework established at the global level by the ITU and the detailed frequency planning necessary for national Administrations, there has always been, in several other parts of the world, a need for regional coordination. The widespread introduction of pan-regional radio services depends on harmonisation of the radio frequency allocations, the adoption of common approaches to the conformity assessment of radio equipment and agreement on mutually acceptable procedures for cross-border licensing. Even when radio services are not intended for operation on a pan-regional basis, there are advantages for users, manufacturers and regulators in harmonising frequency usage and radio regulatory regimes. The forum for achieving such harmonisation in Europe is the *Electronic Communications Committee*, ECC, of the CEPT, the *Conference of European Posts and Telecommunications Administrations*. In the Americas it is CITEL and in the Asia Pacific region, the Asia Pacific Telecommunity (APT). In other regions of the world similar organisations are emerging. At the time of writing, the regional organisations have developed most in Europe.

3.2.2. Europe: The CEPT, its structure and its role

The *Conference of European Posts and Telecommunications Administrations*, CEPT, was formed in 1959 to bring together the posts and telecommunications Administrations of Western Europe. In the course of the 1980s, as the movement away from the traditional national PTT as a government body providing a monopoly of posts and telecommunications services became clear, a major review of the telecommunications arm of CEPT, the Telecommunications Commission, was initiated. From the early 1990s, the CEPT has two committees on telecommunication issues: the *European Radiocommunications Committee*, ERC, established in 1991 and the *European Committee on Telecommunication Regulatory Affairs*, ECTRA. It also has one committee on postal matters: the *European Committee on Postal Regulation*, CERP. In 2001 the *Electronic Communications Committee*, ECC, was established as a body of radio Regulatory Authorities. The ECC resulted from the merging of the two CEPT telecommunication committees, ERC and ECTRA. Together many of the national operating companies founded a new body, the *European Telecommunication Network Operators Organisation*, ETNO. Though the CEPT committees come under the CEPT *Plenary Assembly*, in practice they have a great deal of autonomy. CEPT now brings together 44 countries of Western, Central and Eastern Europe, and its membership continues to grow. Only European Administrations that are members of the ITU or of the *Universal Postal Union*, UPU, can become a member of CEPT.

3.2.2.1. The Electronic Communications Committee

Based on the following proposed definition of Electronic Communications: *"'electronic communications' means transmission, and, where applicable, switching or routing, which permits the conveyance of signals by wire, radio, optical or other electromagnetic means, irrespective of the type of information conveyed"*, the terms of reference for the ECC are to:

- consider and develop policies on electronic communications activities in a European context, taking account of European and international legislation and regulations;
- develop European common positions and proposals, as appropriate, for use in the framework of international and regional bodies;
- forward plan and harmonise the efficient use of the radio spectrum, satellite orbit, and numbering resources in Europe, so as to satisfy the requirements of European users and industry;
- approve Decisions and other deliverables;
- implement the strategic decisions of the Assembly;
- seek guidance from the CEPT Assembly as and when necessary, and propose issues for consideration by the Assembly;
- the ECC should also establish contacts with equivalent organisations outside Europe.

In carrying out these activities the ECC shall establish close cooperation and consultation with relevant European bodies, in particular the European Commission, EC, and the European Free Trade Association, EFTA.

3.2.2.2. ECC Structure

The structural elements of the ECC relevant to the scientist are shown in Figure 3.8. The ECC has six permanent *Working Groups* which report to the Committee:

- CPG (*Conference Preparatory Group*) which develops European policy and positions concerning WRC agenda items;
- Working Group FM which deals with *Frequency Management* aspects;
- Working Group RR which deals with *Radio Regulatory* aspects;
- Working Group SE which deals with *Spectrum Engineering* aspects;
- Working Group ITU which deals with ITU-specific aspects, such as coordination of CEPT actions for the preparation and the course of ITU activities;
- Working Group GMR, which deals with the *General Milestone Review* aspects for satellite systems.

These working groups may also establish their own project teams to work on specific issues.

The task of the *Conference Preparatory Group*, CPG, is the preparation of common European proposals for the World Radiocommunication Conferences and Radiocommunication Assemblies of the ITU. Its principal role is to prepare a set of European Common Proposals for the relevant conference so that CEPT can approach the conference with a united set of objectives, proposals and briefs.

Of the ‘sector’-working groups, the FM Working Group concentrates on frequency allocation matters. Its objective is to harmonise frequency usage in Europe wherever desirable and feasible and it is proving to be a very effective forum for the frequency managers of Europe to discuss a wide range of problems of common interest, for example the accommodation of new radio systems in the radio spectrum.

The RR Working Group is concerned with legal, regulatory and Administrative matters associated with the use of the radio spectrum and it played a significant role in establishing the international regime necessary for the accommodation of pan-European mobile services, such as GSM (Global System for Mobile communication). It has responsibility for facilitating matters, harmonising licensing regimes and studying economic and market surveillance matters.

The SE Working Group concentrates on technical issues. Its importance is increasing with the multiplicity of frequency-sharing arrangements being contemplated and the complexity of the techniques being used or planned for new radiocommunication systems. It also provides interface with the *European Standardisation Institute*, ETSI, on certain technical standards matters.

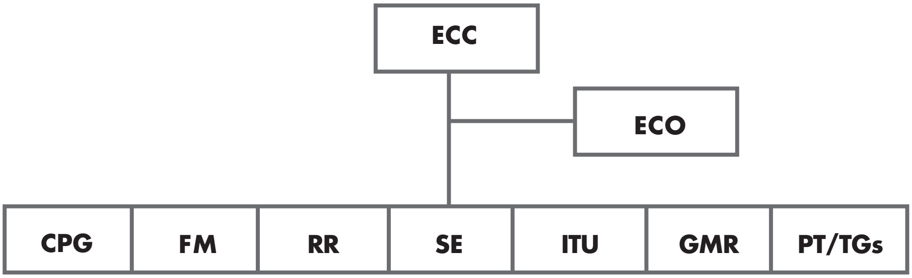

Figure 3.8: CEPT – ECC Structure

The ITU Working Group organises the coordination of CEPT actions for the preparation of and course of the following ITU activities: Meetings of the Council, Plenipotentiary Conferences, World Telecommunication Development Conferences, World Telecommunication Standardisation Assemblies and other meetings as appropriate. It develops European Common Proposals (ECPs) for the work of these ITU meetings and the relevant briefs for the members of CEPT national delegations in order to present the European position at these ITU meetings. Moreover, it consults with various bodies and organisations inside or outside the CEPT, or Administrations outside the CEPT, with the principal aim of collecting information and broadening the support of CEPT positions.

In addition to these working groups, the ERC established in 1997 a *Milestone Review Committee*, MRC, which later developed into the *General Milestone Review Committee*, GMR. The GMR deals with facilitating the licensing process and the distinction between paper and real S-PCS systems. Furthermore, it contributes to a realistic estimation of the spectrum demand for S-PCS and to a consistency in granting of spectrum across Europe. The GMR procedures can in principle be applied to all radio frequency bands.

And last but not least, the ECC has its special Task Groups, TGs, and Project Teams, PTs, on specific issues, such as the Universal Mobile Telecommunication System, UMTS, Technical Regulations and Standards Requirements for Interconnection, General Authorisation and Individual Licences and Satellite Communications.

Throughout the overall structure of the ECC the variety of topics dealt with is enormous. All uses of the radio spectrum are embraced by the terms of reference of the Committee and its Working Groups. At a single meeting it would not be unusual to be dealing with frequency allocations for new broadcasting services, the harmonisation of licensing regimes for radio amateurs, common examination syllabuses for maritime radio operators, and compatibility between low power devices and radar systems.

3.2.2.3. European Communications Office

The *European Communications Office*, ECO, forms the permanent nucleus of staff to support the work of the ECC. This support is essential for the progress of the work of the ECC, which has as major tasks to identify and prepare strategies to meet future demands for the radio spectrum. Some strategies have to be developed on a long-term basis. This volume of work is beyond the scope of the relatively short and infrequent meetings of the ECC and its Working Groups. The ECO is located in Copenhagen, Denmark. The ECO does not have any authority to take decisions in spectrum management in Europe but it provides a centre of expertise to develop proposals for long-term plans for use of the frequency spectrum at a European level. In addition, the ECO acts as a focal point for consultations with industry, including users, manufacturers, operators and service providers.

3.2.2.4. Consultation

In the regulatory process, the interests of all parties involved in radiocommunication have to be ensured. Therefore, various consultation mechanisms have been introduced in order that interested parties can express their views that will be taken into consideration in the decision making process of the ECC.

This consultation process includes an annual CEPT *Radio Conference*, where topical subjects of frequency management and a regulatory nature are presented and discussed. The consultation process further includes direct input to the ECO activities by industry etc. and participation by international organisations in the work of the ECC and its Working Groups. Representatives of the European Commission, EC, and the *European Free Trade Association*, EFTA, may participate as councillors at the Working Groups and also at the meetings of the ECC.

A key activity in this area is the process of *Detailed Spectrum Investigations*, DSI, which is the building block for a Table of *European Common Allocations*, ECA, to come into effect by the year 2008. This table will include all frequencies between 29.7 MHz and 105 GHz and forms a major instrument in the spectrum harmonisation in Europe.

3.2.2.5. Output from the ECC

The basis of most conclusions on harmonisation measures is formed by the ECC Decisions. In addition the ECC has the authority to adopt CEPT-ECC *Recommendations*, which are less binding conclusions. These Decisions commit the specified Administrations to the action agreed in the Decision. Decisions are published with an indication of the Administrations that have committed themselves. The production of Decisions in certain areas of frequency harmonisation has meant that proposed EC Directives have not been necessary. The ECC also produces *Reports*, which describe the state of progress in certain areas or provide the results of technical compatibility studies.

3.2.2.6. Relations with other European Organisations

Within Europe, the *European Commission* maintains responsibility for broad policies including those in the fields of telecommunications, trade and transport. Radiocommunication plays a vital role in all of these areas and so the European Commission takes a keen interest in the work of the ECC. There are in existence three EC Directives that specifically cover frequency harmonisation, and others covering conformity assessment etc. With the development of ECC Decisions, further Directives have not been necessary to date but the position is being kept under review. Reference has already been made to the participation of the EC in the work of the ECC. The formal procedures for coordination between the European Commission and the ECC are given in a Memorandum of Understanding, MoU, between the European Commission and the ECC. In addition a Framework Contract has been agreed which forms the basis for the EC contracting the ECO to carry out studies in radiocommunication.

Telecommunications equipment standards are generally the responsibility of the *European Telecommunications Standards Institute*, ETSI. For radio equipment it is necessary to ensure that the spectrum is used effectively and that mutual interference is minimised, not only between equipment in the same frequency band but also between frequency bands. In addition ETSI cannot develop specifications for radio equipment without knowledge of the frequency spectrum that will be made available. Thus there is a need for close cooperation between the ECC and ETSI. This is specified in an MoU between the ECC and ETSI. This provides for close consultation during the development of frequency plans and the associated equipment specifications. Members of ETSI may participate in the meetings of the ECC Working Groups.

Several other international organisations, such as the *European Broadcasting Union*, EBU, Inmarsat, Eutelsat, and also the *Committee on Radio Astronomy Frequencies of the European Science Foundation*, CRAF, participate in Working Groups and especially in the work of the CPG.

3.2.3. Europe: Standardisation

Internationally, worldwide, standardisation is performed at present by the following standards bodies:

- **ISO** the International Organisation for Standardisation
- **IEC** the International Electrotechnical Commission
- **ITU** the International Telecommunication Union

The corresponding standards bodies in Europe are:

- **CEN** the European Committee for Standardisation
- **CENELEC** the European Committee for Electrotechnical Standardisation
- **ETSI** the European Telecommunications Standards Institute

Many national standards bodies can be identified within Europe. All these bodies make an important contribution to European regional standardisation. When talking about telecommunications standards, the ITU is globally the responsible body. Within Europe, the *European Telecommunications Standards Institute*, ETSI, plays this role. The more focus on European standards, the more ETSI comes into play.

Although the parties in the field of telecommunications in Europe unanimously recognise that worldwide standards are the final prize, the time schedules for completing worldwide standards are, in general, very long. Furthermore, national positions are rigid and it is impossible to reach agreement on one common standard. In such cases, ITU-T Recommendations very often contain options and/or are not detailed enough in order to allow, for example, end-to-end compatibility of terminal equipment.

Against this background, the European standardisation in ETSI plays a key role in the development of voluntary harmonised standards within the EU and serves worldwide standards development. This is done through the construction of a coordinated European solution, which can be offered as a European contribution to the international standardisation body, i.e. the ITU, and adopted as a European standard.

The European standardisation process does not represent an obstacle or a reason to delay international standardisation as such. On the contrary, it constitutes a useful instrument for speeding-up the work at a European level.

The creation of ETSI was aimed at the common European goals to:
- facilitate the integration of the telecommunications infrastructure;
- assure the proper inter-working of future telecommunications services;
- achieve the compatibility of terminal equipment;
- create new pan-European telecommunications networks.

These objectives can be achieved by the timely establishment of clear, European-wide technical standards in the field of telecommunications, and the overlapping areas of broadcasting and office information technologies, by the independent standards body of ETSI.

The guidelines of the European standardisation process in ETSI can be considered as follows:
- To prepare a common European position for the work in worldwide standardisation bodies (ITU, IEC, ISO, etc.) and to support in the aforementioned bodies the adopted European standards. In fact, daily efforts are being made in order to reduce overlap in the standardisation work and thus to lower the global cost of the standards. From the ITU perspective, fixing a regional position is often an obstacle to achieving a worldwide agreement.
- To complete the standards according to the European requirements, defining one option only.
- To anticipate, when useful and necessary, the activity of the worldwide standards bodies through the adoption of European standards.

It is ETSI's ambition to meet the standardisation needs of the whole of Europe, i.e. the whole of Western, Central and Eastern Europe's telecommunications market requirements. ETSI is open for Central and Eastern Europe and has already established closer contacts with Administrations, network operators and manufacturers in the telecommunications field of the former eastern block in order to fulfil this objective.

ETSI's standardisation efforts go beyond European frontiers. ETSI's activities build upon worldwide standards, existing or in preparation, and furthermore will contribute to the production of harmonised new worldwide standards to promote, whenever possible, the worldwide standardisation effort. ETSI begins its standardisation process by looking to the particular projects in hand and builds on them. In cases where no appropriate standard exists, ETSI will create one and the resulting standard is proposed to other international standards organisations for incorporation in their standardisation efforts.

ETSI was founded on the principle of openness, i.e. that any organisation having an interest in the creation of European Telecommunications Standards should be entitled to sit at the table and directly represent that interest. Standards from ETSI therefore result from a partnership between all those concerned in the European Telecommunications sector and constitute the optimal representation of the market's needs.

ETSI is based on the concept of individual Members. Entities join ETSI under one of the five classes of membership:

- Administrations, Administrative Bodies and National Standards Organisations;
- Public Network Operators;
- Manufacturers;
- Users;
- Private Service Providers, Research Bodies, Consultancy Companies/Partnerships and others.

ETSI is therefore a forum bringing together the different economic interest groups in the market. This "one table concept" has been well received by the European Telecommunications sector. Through its membership, ETSI covers the countries of the European Commission, the countries of the European Free Trade Association, and a number of East European countries. Furthermore, the CEPT countries Turkey, Cyprus and Malta are members of ETSI.

The CEPT is the founding organisation of ETSI. An ETSI Member must come from a CEPT member country. Representatives from other bodies involved in telecommunications may attend the Technical and General Assemblies of ETSI as guests, with the right to speak but not to vote. Counsellors represent the European Commission and the EFTA secretariat.

ETSI also has a category of Associate Members for those organisations that have a useful contribution to make to ETSI's work but which, for various reasons, do not qualify for full membership.

It should, however, be noted that the large majority of ETSI Members is from industry. Not more than about 30% of ETSI membership is from Administrations.

3.2.4. North and South America: CITEL and its structure

The *Inter-American Telecommunication Commission*, CITEL, is an entity of the *Organisation of American States*, OAS, and its purpose is to use all the means at its disposal to facilitate and further the development of telecommunications in the Americas to contribute to the development of the region. CITEL aims to provide a forum for discussion and coordination on developing technical, operational, and service standards for global systems and for preparing for international conferences which allocate spectrum to these services. At present, there is no forum in CITEL for harmonising other elements of policy and regulation that would normally be expected to govern the operations of these systems (e.g. licensing, interconnection, competition policy, tariffs, etc.). CITEL now brings together 34 nations of North, Central and South America and the Caribbean. The headquarters of the OAS and the executive secretariat of CITEL are in Washington.

Until now, CITEL's fundamental mission has been technical. CITEL is the only regional organisation open to all OAS Member States with a thorough technical knowledge of telecommunications, not only because Member countries are represented by telecommunication Administrations, but because recently the door has been opened to active participation by the private sector, which can participate in CITEL as Associate Members. CITEL's goal is to continue to develop and strengthen its role in standards coordination, in radiocommunication, and in telecommunication development activities, bearing in mind the differences between the ITU and CITEL. The ITU is a global telecommunication body and as such it addresses problems from a global perspective. CITEL on the other hand was established to address regional issues as they impact and are impacted by global issues.

To obtain these objectives in CITEL, the Administrations work in close collaboration with the private sector and coordinating with regional and international organisations. CITEL provides the private sector with the opportunity to participate in the definition and execution of its programme of activities. CITEL is actually providing the telecommunications industry and member countries with a forum where they can take an active role in establishing standards in the Americas, harmonising equipment certification procedures, liberalising regulatory structures in member countries, promoting competition and privatisation and coordinating spectrum allocation and use. Participation in CIEL also provides the private sector with additional access to the markets within the Americas.

CITEL fulfils its objectives through the following organs: the CITEL Assembly, the Permanent Executive Committee (COM/CITEL), the Permanent Consultative Committees (PCCs), and the Secretariat. The organs shall include such committees, sub-committees, working groups and *ad hoc* groups as may be established when required.

The CITEL Assembly establishes the Permanent Consultative Committees (PCCs) that it considers necessary to attain the CITEL objectives together with specific terms of reference for each PCC. A PCC shall continue in force until such time as the CITEL Assembly itself, or COM/CITEL deems its functions and purpose to be concluded.

3.2.4.1. CITEL Committees

At present, CITEL has four Committees: COM/CITEL, PCC.I, PCC.II, and PCC.III. The objectives and mandates of these PCCs are in summary as follows:

PCC.I: Public Telecommunications services
PCC.I acts as a technical advisory body within the Inter-American Telecommunication Commission with respect to standards coordination, planning, financing, construction, operations, maintenance, technical assistance, equipment certification processes, rate principles, and other matters related to the use, implementation, and operation of public telecommunications services in the CITEL Member States.

In accordance with the ITU Regulations PCC.I undertakes the coordination of regional preparations for major ITU Conferences and meetings, including the preparation of common regional proposals (IAP) and positions when deemed appropriate.

PCC.II: Broadcasting
PCC.II acts as a technical advisory body within the Inter-American Telecommunication Commission with respect to standards coordination, planning, operation, and technical assistance for the broadcasting service in its different forms.

PCC.III: Radiocommunications

PCC.III acts as a technical advisory body within the Inter-American Telecommunication Commission with respect to standards coordination, planning, and full and efficient use of the radio spectrum and satellite orbits, as well as matters pertaining to the operation of radiocommunication services in the Member States.

In accordance with the ITU Radio Regulations and taking into account ITU Recommendations, PCC.III has the mandate to:

- promote harmonisation in the utilisation of the radio-frequency spectrum and the operation of radiocommunication services in the Member States, bearing especially in mind the need to prevent and avoid, as far as possible, harmful interference in radiocommunication services;
- foster the development and implementation of modern technologies and new services in the field of radiocommunication to meet the needs of Member States, in conjunction with a more efficient utilisation of the spectrum;
- undertake a coordinated effort with the different CITEL Groups in those areas that by their very nature lends themselves to joint action;
- undertake the coordination of regional preparations for major ITU Conferences and meetings, including the preparation of common regional proposals (IAP) and positions when deemed appropriate.

3.2.4.2 CITEL and standardisation

CITEL has a *Working Group on Standards Coordination*, WGSC. This working group is not a standards-making body. Instead, the terms of reference for the WGSG are to facilitate network interconnectivity and interoperability on a regional as well as on a global basis.

Recently, ETSI has offered to establish a Memorandum of Understanding, MoU, with CITEL on cooperation between the two organisations. A decision of the Assembly of CITEL on this issue was deferred because of strong opposition by the USA. The USA considered a formal structural relationship between CITEL and ETSI unnecessary and stated that the mandate of the WGSG allows them to consider standards from all recognised standards bodies with a preference for ITU standards.

3.2.5. Asia-Pacific Region: Asia Pacific Telecommunity

The *Asia Pacific Telecommunity* (APT) established 1979, is a Regional Telecommunication Organisation established by an Inter-governmental agreement. Membership in the Asia Pacific Telecommunity is open to any state within the Asia-Pacific region, which is a member of the United Nations or the *Economic and Social Commission for Asia and the Pacific* (ESCAP). Associate membership in the Asia Pacific Telecommunity is open to any associate member of the ESCAP. In addition, affiliate membership in the Asia Pacific Telecommunity is open to any provider of telecommunication services to the public within the region that is nominated for affiliate membership by a member or associate member. The APT now has a strength of 32 members, 4 associate members and 47 affiliate members.

In accordance with a resolution of its General Assembly, APT invites the private sector and government owned companies, academia, research organisations, consulting companies, etc. to participate in the activities of APT such as seminars, fora, exhibitions, study groups activities. Under this resolution, 45 companies/organisations have joined APT since 1993.

In the past few years, the APT has very successfully facilitated the representation of the Asia-Pacific region at international fora. It has effectively expressed and represented the collective views of the region. As a consequence, the APT's profile and stature has been raised considerably in recent years at events such as the ITU-R World Radiocommunication Conference, the World Telecommunication Policy Forum and the ITU Plenipotentiary Conference. The APT will strengthen its role as coordinator of regional positions for major ITU meetings and processes and serve as a valuable information resource for member countries as well as coordinating regional issues on developments in the international arena.

Within the region, the APT will coordinate policy issues relating to the development of the Asia-Pacific Information Infrastructure.

In May 2000, the APT and CEPT reached a cooperation agreement in the spirit of the purposes of the ITU in promoting and providing a framework for:

- exchange of information and documentation
- coordination of positions
- strengthening the relations between APT and CEPT and with the ITU
- the exchange of views during preparations for ITU Conferences and Meetings
- development of telecommunications in the two regions.

3.2.5.1. Objectives of APT

Among the objectives of the Telecommunity the following items are noted:

14317. To Correlate Planning, Programming and Development of Telecommunication Networks;

14318. To Promote the Implementation of all Agreed Networks;

14319. To Assist in Development of National Components of Efficient Networks;

14320. To Foster Coordination within the Region of Technical Standards and Routing Plans;

14321. To Seek Adoption of Efficient Operating Methods in Regional Telecommunication Service.

In furtherance thereof, the Telecommunity may:

14332. Undertake, in coordination with the International Telecommunication Union, when pertinent, technical and other studies relating to developments in telecommunication technology of common interest to its members and associate members;

14333. Encourage the exchange of information, technical experts and other specialised personnel amongst the telecommunication organisations of its members and associate members;

14334. Study the feasibility of transfer of technology in the field of telecommunications amongst its members and associate members;

14335. Arrange the provision of short-term technical assistance to its members and associate members, when so required;

14336. Advise its members and associate members in the assessment of their needs with respect to telecommunication personnel and programmes for training;

14337. Promote, in cooperation with appropriate international organisations concerned with telecommunications in the region, the establishment within the region of telecommunication training institutes of a regional and multinational character;

14338. Promote and assist in the formulation and implementation of bilateral or multilateral telecommunication programmes within the region in cooperation with appropriate international or regional organisations.

3.2.5.2. The general principles and policies for the fulfilment of the objectives of the Asia Pacific Telecommunity

The Telecommunity aims to be a vehicle for the sharing of information and for giving support to governments in the process of deregulation and liberalisation, expanding telecommunication networks, development of information technologies and changing policies to accommodate global trading and commerce initiatives in which telecommunications is increasingly a part of or at the centre. The Telecommunity can be the vehicle for clarifying international telecommunications issues, forming regional policies and advancing these positions in global fora.

An active APT role in the interchange of information and experiences, the development and distribution of techniques via seminars, dialogues, courses, databases, compendia and expert systems will assist these developments throughout the region. The need to tap the expertise and resources of the private sector will be a key mechanism in this process of transition. The development of monitoring techniques is part of this process.

APT will continue to promote APT standardisation, research and development efforts and technology development in the APT region accompanied by technology transfer and joint projects for telecom equipment production, consultative services and execution of telecom projects. There are possibilities of considerable cooperation amongst APT countries in meeting technical challenges and many other issues associated with software development and software modifications. This cooperation is seen in the active participation of the private sector in the recently created *Asia-Pacific Telecommunity Standardisation Program* (ASTAP) forum. Since standardisation is essential for realising the interoperability of any information networks, the APT would:

- strengthen its standardisation activities through promoting research and development collaborative activity, joint projects and joint research among members including industry members with a view to promoting the integration of the research results into global standards;
- make every effort to encourage industry members to participate more actively and at the same time take full advantage of the know-how they have to offer.

Technology transfer and human resources development are important activities in order to ensure a balanced development of telecommunication services in the Asia-Pacific region. The APT should pursue such activities including holding seminars and meetings taking account of the real needs of developing member countries.

3.2.5.3. APT work programme

The APT General Assembly instructs the APT Management Committee to plan and implement the APT work programme focusing on the distinguished priorities to deliver the maximum benefits to its members. In addition, the General Assembly instructs the Management Committee to develop guidelines in relation to the level of contributions of the industry members in the on-going analysis of the financial viability of the Telecommunity.

The APT pays special attention in promoting and facilitating the development of the telecommunication and information infrastructure in the Asia-Pacific region. Several AII pilot projects have been initiated, which are expected to encourage the development and promotion of Asia-Pacific Information Infrastructure (AII). Thus, AII envisioned the promotion of construction of high quality network infrastructure through the National Information Infrastructure (NII) initiatives by the members, the advancement of applications for supporting various information and multimedia systems, the development of technologies for developing human resources, and greater information dissemination to APT members by publishing the AII Compendium. The recent selection of new AII Pilot Projects for implementation was conducted by the AII Expert Group of the APT. As of now, there are 29 AII pilot projects that involve telecommunication application, multimedia and online services of commerce, education, health and socio-political issues.

Another special interest of APT is the Industry and Users' Forum. There is a dramatic change of telecommunication industry and user scenario since the birth of APT in 1979. The service provider originally owned by the Member State has largely been liberalised and privatised giving way to affiliate members and leaving the state as either a regulator or a political representative. The actual players of telecommunications are the private entities or the affiliate members. The ITU has a Private Sector Forum in the ITU-D to recognise the role played by Sector Members (see section 3.1.4). APT, with similar foresight, has formed an Industry and Users' Forum in line with Rule 23 of the Management Committee Rules of Procedures.

The APT has currently the four study groups that together with the key subjects are:

Study Group 1: Policy & Regulation
Study Group 2: Network
Study Group 3: New Services towards Business Creation
Study Group 4: Internet & E-Commerce

Questions dealing with a large variety of issues ranging from market liberalisation via network technology and multimedia services to E-commerce issues are addressed in these study groups.

3.2.6. Asia-Pacific region: Pacific Telecommunications Council

The Pacific Telecommunications Council (PTC) occupies a unique place in the dynamic, rapidly growing world of Pacific hemisphere and global communications. Founded in 1980, PTC serves the communication world by organising a major annual conference, regional seminars, research activities, special issue-specific topic groups; by publishing the *Pacific Telecommunications Review* and a variety of other publications, and through various other activities.

The Council is an international, non-profit, non-governmental membership organisation that brings together in a single forum both the providers and users of communication services, as well as policy-makers, technologists, lawyers, scientists and academics.

PTC's members are found worldwide, and membership is open to all those who share an interest in the development and beneficial use of telecommunications and related disciplines in the Pacific hemisphere. This area includes North, Central, and South America, all of Asia, and Oceania.

According to the PTC Charter, the Council's objectives are to:

- provide a forum for discussion and interchange of information, ideas, and the expression of views regarding telecommunications in the Pacific for a multifaceted, diverse body that includes users, planners and providers of equipment and services;
- promote the general awareness of the varied telecommunication requirements of the Pacific area;
- organise conferences and seminars to promote the free flow and interchange of the varied views and requirements of the Pacific area and to address specific issues in telecommunications to assist in solving current and future issues;
- communicate viewpoints and Recommendations of the Council to the established national, regional, and international organisations responsible for policies in telecommunications.

PTC is first and foremost an organisation of people. As a membership organisation, individuals from diverse backgrounds, competing entities, varied technologies, and every part of the world share the common bonds of PTC membership. Membership has grown steadily over the past 12 years, with a rapid boost of 20.5% in 1992 and 18.5% in 1993. The Council now boasts more than 650 members. The people who comprise PTC cover every aspect of communications: carriers, communication satellite service providers, cable entities, broadcasters, equipment manufacturers, users of telecom services, universities, law firms, consultancies, government ministries and agencies, and a wide variety of individuals encompassing other aspects of telecommunications and information services. The personal contacts formed through the Council, usually in the informal and amicable environment of the annual conference and seminars, is a primary benefit of PTC membership. Members find PTC helps them get to know the communications priorities, issues, and people throughout the region and the world. That wider perspective is vital in today's quickly changing global telecommunications environment. PTC provides a unique opportunity to gain and maintain that perspective.

To reach its objectives, PTC organises an annual conference and mid-year seminars. The annual conference has developed into a meeting that is recognised worldwide as the most important conference on telecommunications in the Pacific hemisphere, covering the latest developments and issues in the field. The scope and quality of the conference are unparalleled. The conference attracted in the late 1990s, in excess of 1 000 participants from more than 50 countries and territories. The annual conference has become an essential meeting place for anyone interested in or involved with telecommunication issues. The annual conference provides detailed information and discussion in a conducive, informal setting. Each PTC forum is noted for its diverse content, the high quality of the presentations, and a wide variety of hosted conference social events. Every year, the conference plenary speakers are the top people in the field, from secretary-generals to company presidents to government ministers and directors-general.

PTC mid-year seminars are held in a different country each year at the invitation of a sponsoring PTC member. They are two-day events that examine regional and domestic issues and developments, and provide means for PTC members to immerse themselves in a particular country of interest. For the seminar host country, the mid-year seminar provides a showcase for its development as well as an opportunity to become more involved in the wider world of PTC.

3.3. Administrations

The ITU Radio Regulation defines an Administration as "*any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations*" (ITU Constitution – Annex 1002).

Each sovereign state has in some way or another its own Administration with the mandate to use all means possible to facilitate and regulate radiocommunication in that country. The possible structure of such a regulatory body within the country's Administration are reviewed in Figure 3.9. Except in dual structures, the regulatory authorities regulate and coordinate the radiocommunication interests of both public and private entities. As public entities we consider radio frequency use as fundamental for the safety of the country (the country's defence system), for adequate operation of public services (e.g. public telecommunication facilities), for public safety and interest (police and fire brigade), for education and general cultural purposes (publicly funded scientific research, public broadcasting). Private entities can be companies active as telecommunication operators, private broadcasting facilities, private safety organisations, general public using non-licensed devices (remote control devices, microwave ovens, etc.).

The mandate and terms of reference of a regulatory authority are usually regulated by national telecommunication law, which, in EC member states and affiliated countries is within the framework of EC telecommunication Directives. This national law also includes a national frequency allocation table, which is the national articulation of the ITU Radio Regulations.

Location in administration	Description	Country example
Department under Ministry (single Organisation)	Radiocommunication authority	European countries
Department under Ministry (dual structure)	a. addressing private radiocommunication issues; b. addressing public radiocommunication issues	USA
State Commission (same level as a Ministry)	"State Commission for Regulatory Affairs"	China

Figure 3.9: Location of a radiocommunication regulatory body in a national administration

However, the process of privatising public facilities causes differences in a way this privatisation is realised in different countries. Usually radio frequency management and regulation is retained as a public interest under the responsibility of a public administration. But in some countries this task is delegated to private organisations with immediate radio frequency interests. When this happens care must be taken that the interests of entities with different interests and requirements are properly managed.

3.4. Global regulation

On a global scale the key role in spectrum management lies with the ITU as explained above. Other regulatory organisations must follow the Resolutions, Recommendations and other guidance from the ITU. However, it should be noted that the World Trade Organisation's role in this respect is developing strongly, but this does not replace the ITU position. The interest of the WTO in radio frequency issues is related to the commercial relevance of radio frequencies since the WTO is the international organisation dealing with global rules of trade between nations. Its main function is to ensure that trade flows as smoothly, predictable and freely as possible, with the goal to improve the welfare of the people of the member countries.

3.5. Regional regulation

At a regional level, organisations such as the CEPT play a key role in spectrum management. Among other items mentioned above (see section 3.2.2), the work of the CEPT on a European Common Table of Allocations is a major effort in frequency management. In sum, one can say that the CEPT provides European Administrations with a multitude of management elements in a framework reflecting from the ITU Radio Regulations, and these national Administrations can tailor them to their national requirements.

In the legal sense, the CEPT Recommendations and Decisions have more or less the same status. The CEPT makes political agreements, Decisions and Recommendations. In the CEPT/ECC the national representatives have a status as delegated by the minister of the respective state.

Nevertheless, this status does not strengthen the legal status of the CEPT Decisions, because the CEPT community of countries is not bound by a treaty regulating the legal status of Decisions and Directives, such as in the case of the European Union.

If the CEPT makes a Decision or a Recommendation, there is a chance that different National Regulatory Authorities, NRAs, will apply it in different ways. In a case of dispute where an action is before a national court against licensing conditions that are imposed, the outcome will most likely be that different conditions will apply in different CEPT member states.

The role of the European Commission is, as indicate above (see section 3.2.2.6) different. For European telecommunication regulation, CEPT Decisions are binding only for those Administrations that committed to them. EU Directives are stronger and are legally binding for all EU member states (because of the EU treaty). If national legislation is not in harmony with EU law, this incompatibility has to be removed in due course. On the other hand, CEPT Decisions and Recommendations also must not be incompatible with EU law. EU Directives and CEPT Decisions must be seen as instruments serving the interests of the Community.

As far as the European Economic Area, EEA, and EC members are concerned, a CEPT Decision or Recommendation would have to be implemented and applied in accordance with EU law, including the Licensing Directive, 97/13/EC (EC, 1997a), and Council and Parliament Decision 710/97/EC (EC, 1997b), as a yardstick. In addition, also other documents such as the EC EMC Directive, which deals with harm caused by "unwanted emissions", are applicable. The same must be noted for the EU Directive 99/5/EC of the European Parliament (EC, 1999) that states in paragraph 2 of Article 7, which deals with "*Putting into service and right to connect",* that *"Notwithstanding paragraph 1, and without prejudice to conditions attached to authorisations for the provisions of the service concerned in conformity with Community law, Member States may restrict the putting into service of radio equipment only for reasons related to the effective and appropriate use of the radio spectrum, avoidance of harmful interference or matters relating to public health*". This clause indicates on what basis an Administration can still ask for a licence for the use of radio. Such a respect for national sovereignty follows also from Articles 30-36 of the EU Treaty and articles of the Treaty on free traffic of services.

These legal instruments allow national regulatory authorities to impose licensing conditions if they are linked to the efficient use of radio frequencies. Any condition must be justifiable and is subject to the principle of proportionality. Regulators always have to use the least restrictive regulatory means to achieve the required conditions.

Given the different mandates of the CEPT and the EC, the views on spectrum management and policy of these organisations are different.

To improve the strategic profile of the EC, it published in 1999 a Green Paper on European spectrum policy, which was meant to serve as a discussion document and to improve the influence of the Commission on European spectrum policy issues and to bring attention to the relevance of a debate on the current European spectrum policy. Unfortunately, several important issues, especially a coherent strategic view on public and scientific usage of radio frequencies, are not well developed. Also, the Green Paper does not include an analysis of strong versus weak aspects of the current practice. It is also observed that the EC overlooked relevant CEPT positions and publications in the preparation of the document, although the Council of Europe invited the Commission in its Resolution 92/C318/01 of November 19th, 1992, "to give full consideration in future to the mechanism of ERC Decisions as the primary method of ensuring the provisions of the necessary frequencies for Europe-wide radio services".

The proposed EC spectrum policy is expressed primarily in terms of interests and requirements for the active radiocommunication services. A strategic view on the specific interests and requirements of the passive (i.e. receive-only) services and applications compared with those of the active services is, however, lacking. Such one-sidedness, in our view, reduces the balance of the spectrum policy, since the requirements and characteristics of active and passive services are significantly different. An explanation for this is easily found in the priority the EC gives to commercial and industrial interest.

The EC policy is clear in its views on spectrum availability for each of the radiocommunication services, i.e. on telecommunications, broadcasting, transport and also on research and development (research is understood in a generic way and applies to industrial as well as scientific research). However, availability in a regulatory sense is different from availability at a quality level sufficient for radiocommunication's requirements. Spectrum impurity degrades spectrum efficiency and reduces spectrum availability significantly, especially when inadequate spread-spectrum modulation techniques are used. Technological cooperation between the users in these different radiocommunication services may well lead to a significant alleviation of the problem. The results of such a cooperation can be considered as beneficial for all users of the radio spectrum. The cooperation between active and passive users of the radio spectrum needs special attention because of the different requirements for the active and passive services.

For the benefit of the active and passive services, industry, operators and users of the provided facilities, cooperation between active and passive services could be improved and the European Commission could play an important and stimulating role in this respect.

The need for such a cooperation could be more clearly articulated as a strategic goal of the European Commission.

Another observation is that the spectrum policy of the EC is developed primarily from the perspective of terrestrial use of radio. Coordination and regulatory procedures for terrestrial radiocommunication applications already exist to a great extent. This holds also for defective systems that have a harmful impact on other radiocommunication services. But a clear opinion of the EC on space issues is lacking in this respect. At the present time, about half a dozen defective space systems can already be identified. In many respects the ITU Radio Regulations are not adequate to give guidance to the Administrations in managing such situations. These systems defects may originate from (1) malfunction of a system; (2) ignorance in the design and construction phase of the system; or (3) plain bad system design. These defects are known because they generate harmful interference or produce some other negative impact on other systems. But nonetheless, at present, operators of such systems meet no constraints.

A strategic position of the European Commission on this issue is urgent and needs to be developed in close cooperation with the CEPT. Such a strategy would be of great help to Administrations, especially when it is known that there are reasons to expect that the extent and impact of this problem on other applications of radio (space based or terrestrial) is rapidly increasing.

A strategy on defective space systems is complicated by the fact that some operators of space applications do not pay adequate attention to system quality if, in their view, this is not commercially justified.

The CRAF contribution to the public consultation process on the Green Paper is reproduced in Appendix 1.

3.6. Local regulation at national level

National telecommunication legislation is developing rapidly in some countries while it hardly exists in other countries. In Europe, national telecommunication legislation finds a framework in legislative instruments such as the EU Directives which are addressed to and binding upon the EU Member States, and require implementation by national law. In other regions, the legislative role of regional organisations is weaker or even absent.

National sovereignty implies a specific national articulation of the telecommunication legislation (Scherer, 1995).

3.7. Management and enforcement

Radio spectrum management, i.e. the efficient operation of radiocommunication equipment and services without causing harmful interference, is the combination of administrative, scientific and technical procedures. Monitoring radio frequency usage and its characteristics is an ancillary function to administrative frequency management and regulatory effort.

The commercial-economic impact of (radio)-telecommunication is steadily increasing. This development has major consequences for the scope and work of National Regulatory Authorities. Operators are paying large amounts of money for access to parts of the radio spectrum with the intention of providing services to the public. Auctions, beauty contests or other means are often used by Administrations to further this purpose. In most cases, the financial revenues from these actions will flow to the State budget and can be seen as an extra income for the government. Because spectrum use is highly priced, it is obvious that telecom-operators demand a clean and usable spectrum. This means that the National Regulatory Authority being the body responsible for proper administrative management of the radio spectrum must be ready and able to perform this task. Today, National Regulatory Authorities or Radio Communications Agencies are made liable for taking care of the spectrum.

To achieve high-quality spectrum management, theoretical frequency planning is not sufficient; adequate information about the actual use of radio spectrum is needed to achieve successful spectrum management. This information can be obtained only by specific monitoring.

It is obvious that besides Administrations various other users of the radio spectrum also deploy monitoring activities. A special case relates to passive radio frequency use: the characteristic of all its measurement activity is a special kind of monitoring. When we mention monitoring in this section, we refer to an activity performed by a National Regulatory Authority or Administration.

3.7.1. Role of monitoring in the past

The ITU-R *Handbook on National Spectrum Management* (ITU, 1995b) describes monitoring as a tool to:

- ensure compliance with national spectrum management rules and regulations through the verification of proper technical and operational characteristics of transmitted signals, and the detection and identification of unauthorised transmitters;
- locate and resolve interference problems;
- determine channel and band usage, including assessment of channel availability and verification of the efficacy of the frequency assignment process and spectrum analytical methods.

From the *Handbook on Spectrum Monitoring* (ITU, 1995c) "monitoring" serves as "the eyes and ears of the spectrum management process". Until today, in many countries hardly any work was done to assist the frequency management department of the national Administration and almost all monitoring activities were related to enforcement purposes. Handling interference issues was one of the main activities carried out in the daily monitoring work. If activities were carried out at the request of the frequency management department it was mostly done on an *ad hoc* basis.

3.7.2. Role of monitoring in the future

The changing radiocommunication requirements and usage of radio frequencies, the technological development, changing user demands and regulatory developments imply that radio frequency monitoring must adequately cope with these developments.

We consider that monitoring has a wide variety of aspects and should not be limited to criteria described by the ITU-R *Handbook on National Spectrum Management* (see above).

Because of the sometimes very high licence-fees for telecom-operators, the regulatory authority wants to be informed whether licence-holders are working in conformity with the licence-conditions. In the past, such verification could often be done by listening and simple measurements. Today sometimes more than one service is emitted within one transmission. For this reason it is necessary to look into the spectrum of such a transmission. In this respect specific transmissions such as in Digital Audio Broadcasting, in Digital Video Broadcasting, by cellular networks or by satellite systems can be identified.

The monitoring technique to enable such a task is Signal-analysis, which will be one of the most important monitoring tools for the future development of the monitoring function.

Due to the increasing use of (mobile) satellite systems, sharing of satellite services with terrestrial services and compatibility issues between space and terrestrial systems, the monitoring function becomes more and more important.

3.7.3. Administrative relationship between frequency management and monitoring facilities

Purely theoretical frequency planning is not sufficient for spectrum management. A well-structured relationship between the frequency management and monitoring departments is needed to accomplish high quality spectrum management by the National Regulatory Authority.

The Regulatory Authority's responsibility in controlling the radio spectrum via both the Frequency Management and Monitoring Departments is changing and growing in a structured relationship to each other. While in the past, 70% of activities were carried out by the Monitoring Service and 30% were enforcement activities, nowadays the proportions are reversed.

The relationship between the Monitoring and Frequency Management Departments can be simply illustrated by Figure 3.10.

This figure illustrates that:

- The spectrum is used for all kinds of radio transmissions. Frequency Management is of overriding importance for the efficient and effective use of the radio spectrum. International and national authorities are setting the rules for the use of the radio spectrum via assignments, licence parameters, etc.
- The Monitoring Service observes the radio spectrum and the monitoring operators have the duty to compare whether the use of the radio spectrum matches the policy of Frequency Management. Via this loop, the Monitoring Service provides *feedback* to Frequency Management.
- In observing the radio spectrum, the Monitoring Service can also provide information to Frequency Management on (hitherto) unknown or new use of the radio spectrum. When Spectrum Management sets up an experiment for new services before a policy concerning that new service has been developed, the Monitoring Service can observe the experiment and advise on it. That is why a *feed-forward loop* is appropriate.
- The Monitoring Service can also address radio spectrum users directly in case of interference. The monitoring operators can give guidelines to the users to avoid interference, etc. This is called *Enforcement*. In this case, no direct relation to Spectrum Management is needed.

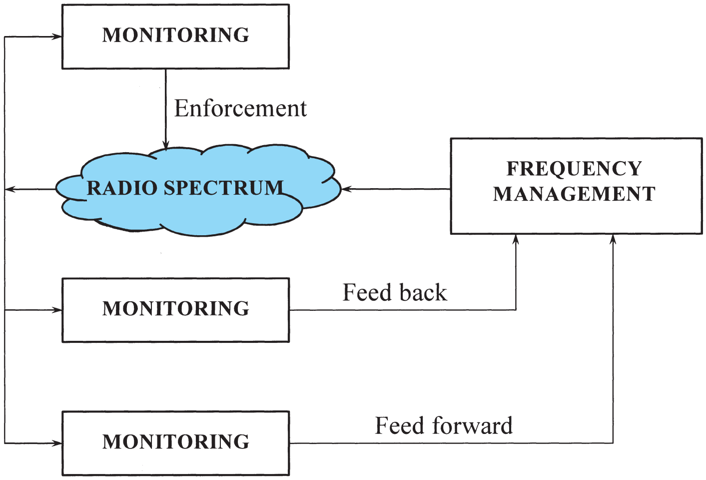

Figure 3.10: Spectrum management cycle

3.7.4. Global and regional activities on monitoring issues

At a global level, the ITU Radiocommunication Sector addresses the issue of monitoring in its Working Party 1C – see Figure 3.5. Within this working party, representatives of Administrations and manufacturers of monitoring equipment collaborate intensively. WP1C develops measuring protocols, working procedures between monitoring services etc., which are laid down in ITU-R Recommendations.

At a regional level, a CEPT project team works on monitoring matters in support of CEPT Working Group Frequency Management, to solve mutual European enforcement problems, to carry out monitoring campaigns to serve the CEPT and the ITU, and to develop European Recommendations in the area of monitoring.

3.7.5. Monitoring as a key element in spectrum management complying with the ITU Radio Regulations

The ITU Radio Regulations contain several footnotes and tables giving power flux density levels, which must not be exceeded for a specified amount of time and in certain directions or area. Administration radio frequency monitoring is one of the instruments in spectrum management complying with these regulations otherwise Administrations choose to work on a nice revision of the ITU Radio Regulations in WRCs, while acknowledging at the same time that given these regulations, it is debatable whether the requirements can be met. This makes the radiocommunication services that are in a victim position regulatory outlaws by definition and puts a consequential burden on Administrations. This cannot be in the mandate of an Administration.

3.8. Other organisations with related interests

Besides the public management organisations discussed so far, various other international and national organisations deploy spectrum management activities within the regulatory framework provided by the ITU Radio Regulations, and regional and national regulations. Among these are organisations such as the *North Atlantic Treaty Organisation*, NATO, the *European Broadcasting Union*, EBU, and the *International Civil Aviation Organisation*, ICAO. Space organisations such as ESA (Europe), NASA (USA) and NADSA (Japan), and intergovernmental operators of space systems such as INTELSAT and EUTELSAT have their own frequency management facilities for managing the frequencies assigned to these organisations. Scientific organisations such as the *Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science* of UNESCO, IUCAF. And the *Committee on Radio Astronomy Frequencies* CRAF of the European Science Foundation, ESF, and the *International Union of Radio Amateurs*, IARU, work on the preservation of the frequencies allocated to the radiocommunication services they represent. Each of these organisations has internally a specific spectrum management responsibility resulting from the characteristics of this organisation. In addition, by means of intensive communication and coordination with public spectrum management organisations and their participation in ITU-R and public regional activities, they can exploit the possibilities of making their case clear in the international and national spectrum management process.

4. Definitions and criteria

The ITU Radio Regulations supply definitions for the terms that play an important role in spectrum management. Several of them are given below. In addition, some other terms are explained. Comments have been made to some key issues .

***Definitions*:**

Administration Any governmental department or service responsible for discharging the obligations undertaken in the Constitution of the International Telecommunication Union, in the Convention of the International Telecommunication Union and in the Administrative Regulations (ITU Constitution - Annex 1002).

Allocation (of a frequency band): Entry in the Table of Frequency Allocations of a given frequency band for the purpose of its use by one or more terrestrial or space radiocommunication services or the radio astronomy service under specified conditions. This term shall also be applied to the frequency band concerned (ITU Radio Regulations, Article S1.16).

Allotment (of a radio frequency or a radio frequency channel): Entry of a designated frequency channel in an agreed plan, adopted by a competent conference, for use by one or more Administrations for a terrestrial or space radiocommunication service in one or more identified countries or geographical areas and under specified conditions concerned (ITU Radio Regulations, Article S1.17).

Assignment (of a radio frequency or radio frequency channel): Authorisation given by an Administration for a radio station to use a radio frequency or radio frequency channel under specified conditions concerned (ITU Radio Regulations, Article S1.18).

Coordination (of frequency assignments): The process, undertaken between Administrations, for ensuring that proposed frequency assignments may be brought into use in a manner which is compatible with existing assignments, or with other proposed assignments; the process may involve the adjustment of technical characteristics and a detailed evaluation of the propagation conditions using methods agreed by the Administrations concerned (from ITU-R TG1/6 and CEPT studies).

Coordination area The area associated with an earth station outside of which a terrestrial station sharing the same frequency band neither causes nor is subject to interfering emissions greater than a permissible level (ITU Radio Regulations, Article S1.171).

Coordination contour The line enclosing the coordination area (ITU Radio Regulations, Article S1.172).

Coordination distance Distance on a given azimuth from an earth station beyond which a terrestrial station sharing the same frequency band neither causes nor is subject to interfering emissions greater than a permissible level (ITU Radio Regulations, Article S1.173).

Emission Radiation produced, or the production of radiation, by a radio transmitting station. For example, the energy radiated by the local oscillator of a radio receiver would not be an emission but radiation (URSI XXVIIth General Assembly)

Earth exploration satellite service A radiocommunication service between earth stations and one or more space stations, which may include links between space stations, in which:

- information relating to the characteristics of the Earth and its natural phenomena is obtained from active sensors or passive sensors on Earth satellites;
- similar information is collected from air-borne or earth-based platforms;
- such information may be distributed to earth stations within the system concerned;
- platform interrogation may be included (ITU Radio Regulations, Article S1.51).

Frequency sharing Occurs when a frequency band is allocated to more than one radiocommunication service, or station or space station. This condition implies a potential threat of harmful interference *(definition inferred from other ITU-R definitions by author)*.

Harmful interference Interference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with the ITU Radio Regulations (ITU Radio Regulations, Article S1.169).

Harmful interference to the radio astronomy service Interference levels are considered to be harmful to the Radio Astronomy Service when the rms fluctuations of the system noise increase at the receiver output by 10% due to the presence of interference (ITU-R *Handbook on Radio Astronomy*). Note that a continuous process as well as an intermittent interference can be harmful.

Interference The effect of unwanted energy due to one or a combination of emissions, radiations, or inductions upon reception in a radiocommunication system, or loss of information which could be extracted in the absence of such unwanted energy (ITU Radio Regulations, Article S1.166).

Notification To bring to the attention of another entity the parameters which must be considered in coordination matters.

Out-of-band emisssion An emission on a frequency or frequencies immediately outside the necessary bandwidth which results from the modulation process, but excluding spurious emissions (ITU Radio Regulations, Article S1.144).

Necessary bandwidth For a given class of emission, the width of the frequency band which is just sufficient to ensure the transmission of information at the rate and with the quality required under specified conditions (ITU Radio Regulations, Article S1.152).

Protection against interference

- *radio astronomy service:*

For the purpose of resolving cases of harmful interference, the radio astronomy service shall be treated as a radiocommunication service. However, protection from services in other bands shall be afforded to the radio astronomy service only to the extent that such services are afforded protection from each other (ITU Radio Regulations, Article S4.6).

- *space research (passive) service and earth exploration-satellite (passive) service:*

For the purpose of resolving cases of harmful interference, the space research (passive) service and earth exploration-satellite (passive) service shall be afforded protection from different services in other bands only to the extent that such services are afforded protection from each other (ITU Radio Regulations, Article S4.7).

Monitoring Experimental/theoretical tool to ensure compliance with national spectrum management rules and regulations

Radiation The outward flow of energy from any source in the form of radio waves (ITU Radio Regulations, Article S1.137).

Radio astronomy Astronomy based on the reception of radio waves of cosmic origin (ITU Radio Regulations, Article S1.13).

Radio astronomy service A radiocommunication service involving the use of radio astronomy (ITU Radio Regulations, Article S1.58). Note that ITU Radio Regulations Article S29 provides general regulations concerning the radio astronomy service.

Radio astronomy station A station in the radio astronomy service (ITU Radio Regulations, Article S1.97).

Radio - communication Service A service involving the transmission, emission and/or reception of radio waves for specific telecommunication purposes (ITU Radio Regulations, Article S1.19)

Sharing see: Frequency sharing.

Space research service	A radionavigation service in which spacecraft or other objects in space are used for scientific or technological research purposes (ITU Radio Regulations, Article S1.55).
Spectrum management	Embraces all activities related to planning, allocation, use, and control of the radio frequency spectrum (and satellite orbits) *(see this document section 2.1 as formulated by R.G.Struzak).*
Spurious emission	Emission on a frequency or frequencies which are outside the necessary bandwidth and the level of which may be reduced without affecting the corresponding transmission of information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products, but exclude out-of-band emissions (ITU Radio Regulations, Article S1.145).

***Comments on the definitions*:**

No ITU-R view on passive radiocommunication services

From the definitions we note that in the perspective of the ITU Radio Regulations the radio astronomy service is to be treated as a radiocommunication service (ITU Radio Regulations, Article S4.6). Furthermore, the passive services are protected only to the extent that active services are afforded protection from each other (ITU Radio Regulations, Articles 4.6 and 4.7). This implies that these regulations do not consider the fundamental difference in characteristics between active and passive services. Because of this lack of understanding, the protection of passive services remains a difficult issue. As has already been noted in section 3.1.2, passive services measure natural radiation, sometimes of very low levels and therefore they need protection in absolute terms. This does not match the concept of protection of active services: for these, protection is achieved in relative terms.

The lack of a clear definition of a passive radiocommunication service in the ITU Radio Regulations, is therefore the crux of the difficulties encountered by scientific users of radio frequencies. This is especially relevant for the radio astronomy service, which is treated as a radiocommunication service, i.e. in terms of an active service, in protection issues – also in any coordination process. It is obvious that this view comes into play when radio astronomy is in the position of an interference victim service, since a passive service can never cause interference. Therefore, this lack places passive services *a priori* in a victim position in protection issues and an adequate coordination process must be achieved to ensure that the passive service operations are not degraded by radio interference.

The ITU Radio Regulations are not a suitable means to adequately addressing the protection requirements of passive services and therefore many footnotes have been introduced in the regulations to resolve this lack. The special requirements for radio astronomy are given in these regulations as guidance for Administrations (Article S29 – see Appendix 2 to this document). No such article yet exists for other science services.

5. Frequently asked questions

In discussions between scientists and other users of radio frequencies, the following questions are often asked:

***Questions raised by active non-scientific users or Administrations to scientists*:**

Question 1: **How much time you need at frequency F to do your experiments?**

Answer 1: The time needed to have the instrument operating at a certain frequency F depends on various aspects and parameters. One may address the question as related to the integration time for a scientific measurement/experiment. Secondly, the time requested may refer to the total calendar time needed to complete the measurement/experiment. Therefore, before answering the question, it has to be clear what is meant by “time”. As soon as that is known, the answer can be formulated considering aspects such as:

- instrument characteristics, such as sensitivity reached per second integration time;
- signal to noise ratio necessary to address the scientific question;
- availability of possible alternative frequencies.

Question 2: **When will you use frequency F, tomorrow, after a month or next year?**

Answer 2: The answer depends on the specific scientific case. Scientific applications, which take place as continuous daily operations such as measurements for weather forecasting, can relatively easily be planned and scheduled. Because discovery by its nature can not be scheduled and planned, research experiments cannot be scheduled and are done as soon as the discovery event occurs.

Question 3: **When will you no longer need this frequency F?**

Answer 3: Scientifically speaking, an answer to this question can be given only when the frequency is no longer required on scientific grounds . The reasons for this can be:

- an alternative frequency is preferred;
- the object of research ceases to exist.

It should be noted, however, that the question also implies the validity of the case that a new frequency which was until now of no interest, is urgently needed. The questioner should then be ready to satisfy the scientific criteria.

If the background to the question is merely to "take away" frequencies from scientific applications of the radio spectrum, it cannot be a valid question since the questioner has no consideration of the basic requirements of the scientific user of the spectrum.

However, if a radio frequency band is no longer needed for a particular scientific application and for scientific reasons, e.g. physical, an alternative frequency is preferred or needed to obtain the data to answer scientific question, that particular scientific community must inform the Regulatory Authority and expert organisations such as IUCAF (section 6.3.1) which work on behalf of that community on spectrum management issues, so that this spectrum can be freed for other purposes.

Before any answer is given, IUCAF must be consulted.

Question 4: **It is obvious that scientists do not always use the frequency F and since no interference is experienced when no measurements are done, we need to protect you only when you do actual measurements. Can you provide us with details of your measurement schedule, so that we guarantee protection on demonstrated need?**

Answer 4: One may consider that as soon as an allocation is given to a radiocommunication service for a particular frequency band, it has been adequately publicly demonstrated that this radiocommunication service needs this frequency band. Without such a demonstration no allocation is given. This is obvious because the radio frequency spectrum is a scarce resource. After this allocation has been given, the ITU Constitution, neither the ITU Convention nor the ITU Radio Regulations support the view that a radiocommunication service can enjoy protection only when additional details on need for its operations are demonstrated.

The ITU Radio Regulations and regional and national frequency plans as allocation plans do not deal with the characteristics of the factual operational status of an application in a radiocommunication service; this is part of the responsibility and sovereignty of the individual radiocommunication service. The protection arguments could be different when these regulations concern assignment planning to specific applications. Secondly, if it is accepted that a radiocommunication service may consider protecting another service only when that latter has additionally demonstrated its needs to this first service, other questions arise which are related to the criteria for this demonstration, for this need, and why the other service asking for proof of this need has the mandate to demand this. Thirdly, if this kind of demonstration of need is accepted, the difference in allocation status between radiocommunication services becomes arbitrary and relies on pressure brought by private (usually commercial) entities. If such a practice is accepted the status of the regulations is significantly weakened.

Therefore, the reply to such a question must be in the negative, and users acknowledging the validity of the question create precedents for other users in the same radiocommunication service, which are difficult to correct at a later stage.

This answer sounds contradictory to the general rule of "cooperation". However, on various occasions when radio astronomy stations provided the requested information on the assumption that adequate protection for the observations would be provided, the active user could not provide this protection because of commercial arguments. Usually, the scientific community is in favour of cooperation, but that must mean cooperation between parties that respect and help each other.

Question 5: **Does ITU Radio Regulations footnote S5.372 which says that harmful interference shall not be caused to stations of the radio astronomy service using the band 1610.6–1613.8 MHz by stations of the radiodetermination-satellite and mobile-satellite service not invite the interpretation that protection is required only during actual operations in the affected radiocommunication service since it uses the word "using"?**

Answer 5: The interpretation of this footnote is that a radiocommunication service to which a specific radio frequency band has been allocated must be protected under the conditions of the regulations. Once an allocation is made the need for the allocation should not be re-discussed. The word "using" implies that the affected radiocommunication service has the legal right to use this band since it has been allocated to this service. The characteristics of this usage depend on the nature of the specified radiocommunication service that has to be protected, which can be very different from the characteristics of the usage within the service having the obligation for protection. The word "using" does not imply that in order to be protected, the victim service must demonstrate that it really needs to operate in the particular frequency band and that it can enjoy this protection only during these actual operations. Such an interpretation leads to much confusion and dispute. And also, the word "using" must not be read with the idea that an arbitrator has checked whether the conditions for use have been fulfilled within the scope of an as yet developing framework of legal concepts. If there are reasons to think that a need has to be demonstrated, the obvious way is by periodic reassessments made by ITU WRCs.

Question 6: **When protection criteria need to be determined, to what extent can an ITU-R Recommendation such as ITU-R RA769 be used for the Radio Astronomy Service?**

Answer 6: ITU Recommendations do not have a binding status. As recommendations they provide only guidance to Administrations. However, within the ITU Radio Regulations an ITU-R Recommendation may be "incorporated by reference" e.g. in a footnote to a frequency allocation. In such a case the status of the contents of the Recommendation has the same force, as the ITU Radio Regulations is stronger than just a Recommendation and Administrations must take it properly into account.

Recommendation ITU-R RA769 which provides information on levels for interference detrimental to the Radio Astronomy Service, is an interesting example:

This Recommendation has been developed for terrestrial sources of interference due to variable propagation conditions only. It does give guidance to determine protection criteria for transmissions from geostationary satellites. However, it must be noted that this Recommendation mentions neither non-geostationary satellites nor aeronautical transmitters. Nevertheless, it has become the practice to use Recommendation ITU-R RA769 in cases when the protection criteria for other than terrestrial or geo-stationary sources of interference have to be determined. In such an event, one must consider that the levels published in this Recommendation do apply only for emission received by the sidelobes of the radio telescopes, i.e. outside an area of 19º from boresight. This implies that when one applies this Recommendation to the non-terrestrial and non-geostationary sources of interference, emissions received by the main beam of the telescope have to be considered as well, which results in much more stringent protection criteria (e.g. the main beam gain of a radio telescope is of the order of 70dB).

***Questions raised by scientists*:**

Question A: **When an Administration asks an opinion concerning coordination with another user of the radio spectrum, what should be the answer?**

Answer A: The answer and conclusion depend very much on the situation: coordination of frequency assignments is required only when one is dealing with an application operating within the same frequency band as the scientist is using. The coordination process and details depend on what is called “the sharing situation” (*see chapter 12*).

When coordination with a local user is requested and it is certain that the coordination conclusions will have no impact on scientific research abroad, this can be discussed at the local, i.e. national level. If the scientist belongs to a community which has an organisation working on frequency management issues on behalf of his particular science, he must inform his community about the coordination discussions and conclusions as any coordination analyses may be used by other countries or in different situations *(see section 6.4.3)*.

When coordination is requested with an internationally operating user and/or the coordination results may have an impact on scientific research abroad, the scientist must first adequately consult his colleagues before proceeding to discussion with his Administration. He must explain that a decision in his country could have a significant impact on scientific operations in other countries *(see section 6.4.3 and chapter 12)*.

Part 2

Issues in the scientific use of radio technology

6. What should we do today?

This chapter gives an overview of strategies that scientific users of the spectrum should be aware of today. This chapter is particularly aimed at scientific policy makers and for scientific users of radio who have responsibilities in spectrum management or system design when, for example, frequency selection is an issue. Most of the explanations given relate to radio astronomy, but similarities are easily found in other sciences.

6.1. The observation

The observation is done at a radio observatory, a "radio astronomy station" in ITU terminology. A radio telescope tracks a celestial radio source for some time and its receiver collects information on various aspects of the radio waves emitted by this source. These aspects can be the frequency dependence of the intensity (for spectral analysis), broadband/continuum characteristics, narrow band/spectral line characteristics, polarisation characteristics, variability of these aspects as a function of time, frequency or celestial coordinates. The radio telescope can be a single dish instrument, an antenna array or an interferometer. The mutual distances between interferometer elements range from a few tens of metres to thousands of kilometres (in the case of Very Long Baseline Interferometry). Since 12 February 1997, the VLBI networks have been extended into space with the Japanese HALCA satellite, which carries a radio telescope for VLBI operations.

The scientific question determines at which frequency the observations are made, with which instrument these observations are made and also the integration time and duration of these observations. The integration and observation duration depend on the sensitivity required to address the scientific issue. Usually, astronomers working at a university pose the scientific question. They are the "customers" of the radio observatory.

It is common practice, that initially it is the *radio observatory staff* who is concerned about the quality of the observation in the technical sense to serve the scientific community as a whole in the best way considering state-of-the-art technology. Usually the radio astronomer, for whom the observation is done, is interested only in high quality data to serve his own individual scientific goal. This is referred to as "scientific quality", which will also depend on the technical and data manipulation skills of the scientist. Radio astronomers are often satisfied with the removal of "bad" data (e.g. due to harmful interference) to improve this scientific quality. If after this operation the data quality is too low, the observation has to be repeated for reparation. This also holds for interference effects in observations.

At present, hardly any hardware or software tools exist to filter harmful interference adequately from the scientific data without data loss. Furthermore, the feasibility of such a technique depends totally on the characteristics of the instrument, the data processing methodology which is intimately connected with the scientific case, and also on the characteristics of the scientific question (for one question the harm has less impact on the result than for another question). An example related to the technical characteristics of the instrument is: interference removal techniques applicable to radio interferometers which make use of the fact that the interferometer fringe pattern for a celestial source is different from that for a terrestrial source, cannot be applied to single-dish telescopes.

From a management and technical point of view one may consider that interference excision techniques based on data editing is an inadequate procedure. Which funding agency will support an instrument knowing that inevitably a certain amount of data will be lost? Good arguments must be found to defend an investment with intrinsic loss of value due to effects beyond the operator's control and without the option of a replacement under different conditions.

The nature of the scientific activity implies that the question of frequency protection is not only relevant to present day problems but in particular to guarantee the high quality of this activity for future generations of scientists. In order to achieve this, clarity has to exist about a number of questions rising from the simple and "naive" statement:

> *"Radio astronomy is only possible when it can use frequency bands which are sufficiently free of interference considered harmful to radio astronomical observations".*

However, before formulating the question of what we should do to make radio astronomy possible to the extent necessary for each scientific case, clarity has to exist about the following:

- The radio astronomy station suffering the harmful interference should have made it clear that the interfering source is external to that station. If not or if the interference is due to insufficient protection built into the telescope system, the radio astronomy station must improve its own instrumentation before starting any further action. This is in fact a key issue, since scientists must make and maintain their instruments in a state-of-the-art condition as much as possible.
- When radio astronomers explain to non-radio astronomers (either in a technical or an astronomical sense) that they are working hard on interference "rejection"/"removal" techniques, they should bear in mind that these techniques should have been incorporated in their systems in any case: such an explanation could invoke the impression in non-radio astronomers that these radio astronomers have not done their work properly.

In all discussions on the protection of scientific research and investigations to reduce the vulnerability of scientific experiments to interference, one should consider that state-of-the-art scientific research is often only possible with equipment which is not commercially available but has been built for a special scientific requirement. Furthermore, quite often such equipment has been built with technology not yet commercially available since the scientist uses radio frequencies that are as yet commercially inaccessible to the non-scientific user. This holds especially for radio astronomy. Therefore, each radio astronomy station can be considered to be its own prototype. Measurements with a scientific instrument must always be taken with the highest possible sensitivity, since it is vital for scientific research to obtain data of the best possible quality. Defective data result in faulty scientific results.

Because radio astronomy and various remote sensing investigations require measurements at such high frequencies for which no equipment is commercially available but has to be individually designed to satisfy the specific scientific requirements, it is in most cases not possible to design and build the instrument according to existing standards and regulations since these are usually not suited to the technical specifications needed for the scientific instrument. If measurements need to be done in a radio frequency range for which the technology is still very much under development, regulations or guidelines will not exist for a long time and non-scientific users are not yet deploying activities (see e.g. sections 2.2.3 and 2.2.4), scientists cannot take these obviously unknown criteria into account in the design and construction of their instruments. Another issue is that in many radio frequency bands, radio astronomy instruments and other scientific equipment have already existed for a long time – usually for several decades – and came into operation often before the aforementioned technical standards were developed. This implies that many radio astronomy and other scientific instruments do not have adequate capabilities to suppress or remove harmful interference. Studies related to interference-robust equipment are therefore in first instance applicable only to newly designed equipment and can currently be undertaken only for those radio frequency domains for which supporting knowledge and technology already exists, e.g. below 20 GHz. It is a waste of effort to develop interference-robust equipment for operations in a frequency range where nobody has any idea how this could be achieved and for which currently no test equipment exists, e.g. at frequencies above 100 GHz.

Nevertheless, scientists must develop their instrumentation according to available regulations and technical standards. Administrations and active users must understand that scientists develop their instrumentation to a state-of-the-art condition and understand that everyone is served by obtaining the highest possible quality and the most feasible interference-robust equipment. By its nature, scientific research is continuously developing and therefore the instrumentation is regularly adjusted to the changing scientific questions and upgraded accordingly.

Given the available instrumentation, scientists in general and radio astronomers in particular must be able to address the following questions raised by the statement given above:

1. what determines whether scientific research is *possible* in this context?
2. what is the criterion for *sufficiently free of interference*?
3. what is considered to be *harmful to a radio astronomical observation*?
4. what is the meaning of *guarantee of data quality* in the context of action to be performed?
5. what is the criterion for *scientific priority* of a specific frequency band?

These questions can be answered in many different ways. Their answers depend on:

a) a knowledge of radiation mechanisms in relation to the physics in and around the celestial radio source. Astrophysics and fundamental astronomy should provide the motivation to claim protection in a specific frequency band;
b) a knowledge of the state-of-the-art and limitations of hardware and software technology to serve matters of instrumentation, data processing for obtaining relevant and adequate information of the object of interest;
c) a knowledge of development trends in both active and passive frequency use and in receiver development (what is harmful today may be harmful tomorrow or not harmful at all);

d) a knowledge of the state-of-the-art and limitations of technology to extract this information from data distorted by e.g. interference by unwanted natural or man-made emissions;
e) the availability and implementation of this knowledge;
f) the view on the priorities in the development of astronomy as a science both at a national and international level;
g) the research priorities in the different astronomical institutes; these are many different (often incoherent) opinions and interests;
h) the local/national science policy.

Figure 6.1 shows the relationship between these five questions and the eight reply parameters:

	1. possibility of research	2. interference free	3. harmful	4. guaranteed quality	5. priority
a. physics	+				+
b. limitations	+	+	+	+	
c. trends	+			+	
d. technology	+	+	+	+	
e. implementation	+	+	+	+	
f. view on development					+
g. priorities					+
h. policy					+

Figure 6.1: Relations between aspects and considerations relevant to answer the five questions.

Given these considerations we will undertake an attempt to answer the questions just raised:

- **the *possibility* of radio astronomy:**
  Assuming that radio astronomy at a certain frequency is theoretically possible, the practical possibility of radio astronomy depends entirely on the achievable quality of the measurements. Radio astronomy is possible when the quality of the observation data is adequate to understand the physical conditions of, inside or surrounding, the celestial radio source. This data quality determines whether the scientist is able to improve his understanding of the physical processes maintaining the structure of this celestial object.

- **what does *sufficiently free of interference* mean?**
  One of the most difficult questions is, how can one identify a signal as interference, since scientific instruments are not usually built to do so. The scientist notices that "something is wrong with his data but he cannot proceed to understand the real cause further". Interference can be manifest as for example, impulsive interference or an increase of the root mean square, rms, noise in the data (possibly as a function of frequency and polarisation). An increase of the rms noise in the data must be distinguished from the system noise: but how? This becomes

more complicated when the interference is manifest in the same way as the characteristics of the signal of interest, e.g. in spectral line observations.

Radio astronomical measurements are always done at the limit of what is technically achievable. Sensitivity levels can be calculated theoretically and radio astronomers accept that an observation is sufficiently free of interference when the sensitivity achieved in the final radio astronomical result is at the level of what is theoretically achievable with the instrument used. This criterion may be understood as an ideal that one wants to reach. It should be recognised, however, that in real life external situations such as anomalous propagation conditions play a role. But by all means, radio astronomy receivers are made state-of-the-art in the sense that the ultimate physical limitations are approached as close as possible. External effects, which have a non-man made origin have to be accepted as being unavoidable. For some radio telescopes using receivers cooled at cryogenic temperatures, the sensitivity is determined for a large part by the thermal noise in the system.

These notes imply that it is generally not possible to explain whether an observation is sufficiently free from interference. Therefore, for practical reasons, radio astronomers consider that an observation in which the interference is below a specified threshold, i.e. as specified Recommendation ITU-R RA769 (see however chapter 5 question 5), it is sufficiently free from interference. However, radio astronomers should have already prepared their case carefully by choosing sites as free as possible from interference. It should furthermore be recommended that when proposing frequency allocations, Administrations take into account that it is very difficult for the radio astronomy service to share frequencies with any other service in which direct line-of-sight paths from the transmitters to the observatories are involved. Above 40 MHz sharing may be practicable with services in which the transmitters are not in direct line-of-sight of the observatories, but coordination may be necessary, particularly if the transmitters are of high power: for this reason Recommendation ITU-R RA769 was developed.

- **what is considered to be *harmful to radio astronomical observations*?**
  As a criterion for the intensity at which an interfering signal is considered harmful, the level which causes an increase of 10% in the measurement errors, relative to the errors due to the system noise alone, is used (ITU-R *Handbook on Radio Astronomy*, 1995a, p.16). This definition implies that in interference calculations the usual practice is to assume that this interference level is the same as that which causes an increase in the receiver output by no more than 10% of the rms output fluctuations due to the system noise. It is assumed that with this criterion the minimal data quality necessary to make the science of radio astronomy possible is guaranteed. This criterion is also used in the determination of the levels of detrimental interference as published in Recommendation ITU-R RA769.

- **how can freedom from harmful interference to radio astronomical observations be *guaranteed*?**

  The guarantee of freedom from harmful interference can be achieved by regulatory measures by a national Administration and by technical measures at the interfering transmitter and at the radio astronomical receiver.

  The regulatory measures can be various, such as setting up an exclusion or coordination area around the radio astronomy station, limiting power levels for the transmitter, definition of antenna pattern constraints to the transmitter, or even a kind of time sharing scenario (when it is feasible and acceptable).

  The transmitting side of the signal path could be engineered in such a way that unwanted emissions are adequately filtered and the transmitting spectrum is properly shaped to avoid interference. Filtering must be implemented in all cases when the passive service does not operate in the same frequency band as the active service, since when the passive service suffers interference, it is due to spectrum pollution and energy waste, which should be avoided.

  The receiving side of the signal path could be subject to adequate filtering if that does not degrade the performance of the system. It should be noted that only when the active and passive application enjoy an allocation of the same frequency band, arguments can be given to look for such filtering. *(see also chapter 11).*

- **what is the criterion for *scientific priority* of a specific frequency band?**

  The physical conditions and the characteristics of the object of interest determine the priority of a specific radio frequency band for scientific observation purposes. However, various other arguments and interests also play a role. It is impossible for each institute to work in all fields of scientific research, therefore, choices have to be made. Such choices are based on various arguments: such as the qualities of some particular scientist without which modern radio astronomy is unthinkable (i.e. due to the work of J.H.Oort and H.C.van de Hulst in the Netherlands in the mid-20th century, leading to strong stimulation of hydrogen line research and studies of galaxies), financial reasons (e.g. solar research is in many respects less expensive than mm-wave radio astronomy with its study of interstellar molecules), personal preferences. In addition the views developed within the scientific community enhance or reduce the noted priorities.

  Priorities developed within the scientific community are translated by the responsible national ministers into a national science policy with its own priorities.

  In conclusion, the priority of a specific frequency band is primarily scientific, but it must not be forgotten that other elements also play an important role.

6.2. Keys to a strategy

We now know that in principle radio astronomy is possible if it can use frequency bands which are sufficiently free of interference considered harmful to radio astronomical observations. Such a happy statement can also be developed for other sciences using the radio frequency spectrum.

However, the pressure on the radio spectrum from various spectrum users and radiocommunication services shows that much work must be done to translate this possibility into reality. In the past such a translation appeared to be unnecessary since scientists could use their radio frequencies without any conflict with other users of the radio spectrum. Of course the scientists knew that frequency bands used for broadcasting and military applications had to be avoided but until about 1980 the radio spectrum was relatively free (also for frequencies below 1 GHz).

6.2.1. Education

The new situation of rapidly increasing pressure on radio frequencies indicates the need for adequate and appropriate answers and information in reply to the questions these non-scientific frequency users raise since these users often do not understand why scientists need to use a particular radio frequency band. But in practice, one cannot simply take the all necessary or wanted time to "educate" or study the problem in a "scientific way" when urgent, adequate and appropriate action is required: the time scales set by the new situation and the developments of telecommunication technology, do not allow for this. Besides, the non-scientific users of radio frequencies request support by the Administrations for their cases and ask for access to radio frequencies to which their radiocommunication service has an allocation (although possibly not used for a long time). These Administrations also request scientists for information and cooperation in coordination issues.

It becomes, therefore, urgent to understand what strategy scientists should follow regarding such requests for information and education. To answer these questions they face three major situations:

- Increasingly, scientists are facing degradation of their observations due to man-made interference and also re-allocations of frequencies which may be a threat for existing and future frequency bands needed for passive frequency use. Therefore, the scientist must provide a clear opinion and evaluation of the current situation. From that he must develop unambiguous answers to the questions raised by non-scientific users of the radio spectrum. However, besides the need for answers and education, usually each individual scientific user of the radio spectrum has almost exclusively or primarily knowledge of his own research interests and he considers therefore the frequency bands which he uses as the most important ones. An example is in the remote sensing field; meteorologists have their own specific interests and priorities, which may be very different from those of aeronomy or atmospheric research. A consequence is that scientists have difficulty in finding a single coherent answer to the questions asked by an Administration or the non-scientific user of the radio spectrum. In his response the scientist must make this clear or refer the questioner to a colleague or organisation which is more qualified to reply.

- At stations of scientific research not many people are working on frequency management issues. Usually not more than one person and this is generally on part-time or voluntary basis in an environment which hardly understands the issues. (It should be noted that usually none of these people is adequately trained at university or any other educational institute). The time scale of the learning curve for this job is long: usually of the order of more than five years.

- In Administrations and related bodies the tenure of appointment in a certain position is typically of the order of about 2.5 years. This implies that at this time-scale the "education" and "provision of information" by the scientist has to be repeated regularly as an ongoing process. This tenure is usually short in relation to that of satellite programmes (when we consider that the typical schedule of a satellite programme is 7 years design phase, 5 years construction phase, 15 years operations phase).

The scientist educating the non-scientific user of radio frequencies or the Administration must be aware of a number of issues of the whole spectrum management mechanism as well as the non-scientific applications and needs, plus possible ways and means of solving problems in a constructive manner:

To this end and as far as reasonably possible the scientist should:

- know and understand the nature and characteristics of the current and expected developments and problems in his own field;
- know and understand the developments in active services and passive frequency use, such as technical developments, standardisation process, (potential) threats or compatibility problems;
- know the national/international frequency regulatory process. This knowledge helps significantly in responding in a straightforward manner to the questions and uncertainties of the non-scientific user of the radio spectrum or the Administration. This knowledge elevates the discussion level between the parties;
- know and understand the frequency allocation and management process to avoid mistakes;
- know and understand the unwritten policies in this process to avoid or escape pitfalls. Therefore, it is important that when one enters this education process one should consult colleagues who already have experienced it;
- have adequate communication with the national authorities. These could be the ministry responsible for science policy and support, the national Administration responsible for frequency management and spectrum engineering or military authorities since several frequency bands allocated to radio astronomy are also used by military applications;
- be aware of the relevant internal communication and decision making paths within these authorities;

- participate in decision making processes (local and regional). This is particularly important in cases of sharing and protection studies or in work in preparation of e.g. ITU-R World Radiocommunication Conferences;
- on all occasions present one single opinion/one single voice (local, regional and global) since fragmentation in opinions, diverging views and conflicts may have irremedial consequences;
- indicate priorities for their scientific research (at a local, regional and global scale). This issue may sound logical and evident, but in practice scientists usually consider their favourite frequency band to be the most important. When in frequency management discussions it is claimed that every frequency band is very important or the most important for a particular issue, the conclusion can only be that no frequency band is really important;
- indicate what fraction of science is lost if a frequency band is lost. But note that losing data because of interference other than due to variable propagation conditions (ITU-R Recommendation RA769), may lead to erroneous conclusions or even cut off a whole new development (see also chapter 10). Examples of such degrading effects can be found in meteorology;
- give the right comment at the right moment to the right body. But is he/she prepared to do so?
- inform and educate his/her scientific community about the "frequency" world problems. Until today, the scientific community has ignored the developments in the real world and has considered frequency management as a non-scientific activity and therefore a waste of the resources needed to "develop the marvellous world of science". This attitude must change, since scientific frequency management is a fundamental requirement for a scientific institute, just as much as paying the electricity bill;
- inform and educate directors of institutes about the global frequency problems. Directors must be able to give adequate guidance to their respective institutes and when political and management issues are discussed, they have to give the right answers. Education of colleagues and directors is also important because a key issue is training of new experts in frequency management issues;
- maintain adequate, accurate and appropriate interaction and exchange of information within the scientific community and bodies to actively protect radio frequencies important for research, such as the *Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science* of UNESCO, IUCAF, and CRAF (section 6.3.1).

These are merely keys for a "strategy under construction". However, in order to act adequately, much information, communication, listening and reading is mandatory to decide on the correct criteria. The key problem is to be active and seek solutions to the challenges in cooperation with relevant partners and services. Scientists should not wait until space communication people come to them to ask for their scheduling information, etc.: that will be too late, and furthermore, giving such information is wrong (see chapter 7). The scientist should actively approach Administrations and non-scientific users of radio frequencies as soon as he knows that they are planning activities that potentially may be harmful to radio astronomy: this could be seen as an assertive anticipatory attitude. Scientists should develop and maintain a review of the global, regional and local interference pressure as a function of frequency band, radiocommunication service and radio stations on the WorldWideWeb.

In summary, scientists must generate a general awareness in society of the pressures they meet in the deployment of their research due to pressure on radio frequencies. The educational process must start with students in schools.

6.2.2. Communication

In order to acknowledge the reality of an interference or electromagnetic compatibility problem the Administrations and active spectrum users need to be informed about the nature and (quantitative) characteristics of notified and expected interference problems. This information has to be transferred to a community, which usually does not have the slightest idea of passive spectrum use, the nature of a passive service and the characteristics of scientific use of radio frequencies. "Tools" have to be developed to answer this need for specific education. This education is a major element in communication with non-scientific users of the radio spectrum and Administration.

Such communication can either be directly with the non-scientific spectrum user or the Administration, or through conferences or lecture series. In conferences one could have sessions dedicated to special subjects relevant to scientific interests. One could also consider lectures during meetings – how fruitful these might be – these presentations should not only be addressed to, be relevant for and of interest to the "already converted". All contacts must be aimed at making "converts". In an aggressive but accurate and informative way the scientific community has to present its case at such conferences, like conferences on EMC problems, studies on frequency allocation techniques, frequency management meetings, etc.

The following communication channels seem important:

- with local Administrations to keep them up-to-date on the scientific spectrum issues;
- with regional and global public bodies involved in the regulatory and standardisation process to keep them aware of the scientific requirements;
- with organisations of active spectrum users to make them aware of the requirements and needs of scientific usage of radio frequencies;
- with scientific organisations, such as the International Union of Radio Science, URSI, to involve them in support of scientific radio frequency matters;
- with directors of observatories, since they have to represent their institutes and set priorities for the different activities in these institutes;
- with space agencies (US, European, Russian, Chinese, Japanese) to keep them up-to-date so that they take the requirements of scientific usage of radio frequencies into consideration in their planning and design activities;
- with industry to make it aware of the specific unusual requirements which scientists must explain to them as being vital for scientific progress.

But it must be noted, the Administrations cannot provide a miraculous solution for everything. Furthermore, we should recognise the fact that they are under pressure from those who need access to the spectrum and in some countries Administrations are under the pressure to generate income by different spectrum pricing methods. The Administrations are facing new and previously unknown issues related to the various telecommunication developments already mentioned, space issues especially contribute significantly to this. Although it is obvious that education of Administration officials is important, education of those who need access to the spectrum might be even more important. The process of education, communication and promotion should address key professional and social groups with emphasis on those who prepare the background to decisions and who make decisions.

6.3. Methodology

6.3.1. International Scientific Organisations

One of the weakest points among scientists relating to the handling of interference problems, influencing frequency management and spectrum engineering is their *individualism*. Nevertheless, scientists have organised themselves into a couple of organisations that work on spectrum management issues. At a global level, the efforts in scientific frequency management are coordinated by the *Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science* of UNESCO, IUCAF. The parent organisations of IUCAF are URSI, the *International Astronomical Union*, IAU, and the *Committee on Space Research*, COSPAR. IUCAF is the channel through which the scientific unions, URSI, IAU and COSPAR provide expertise and information in ITU-R Study Group 7. At a regional level the radio astronomy community in Europe is organised in CRAF, while in the Americas, the interests of scientific frequency users are covered by the *Committee on Radio Frequencies* of the US National Research Council, CORF, currently representing scientists in the USA, Canada and Mexico. IUCAF and CRAF are ITU-R Sector Members and in this position, they collaborate at ITU-R level to take care of the interests of radio astronomy and passive scientific use of radio frequencies.

Coordinated by IUCAF, regional and local committees like CRAF and CORF, should continuously put pressure on the international scientific community, e.g. the URSI, to stimulate discussions and (where possible) to achieve harmonisation of opinion among scientists to form a single clear and concerted view on a specific topic. The scientific unions, such as the URSI, should actively initiate these discussions and trigger studies, the results of which could help IUCAF and the related regional and local committees in their efforts.

If it is seen that the international scientific organisations do not actively deploy these activities sufficiently well, a regional organisation such as CRAF should inform IUCAF, which should bring this observation to the attention of the scientific organisation concerned e.g. during its General Assembly, by communication to its Executive Council or by input to its Information Bulletins. This action of IUCAF and regional and local committees such as CRAF and CORF, should be a well-coordinated joint effort.

During General Assemblies of the scientific unions, IUCAF supported by regional or local organisations could organise sessions during which the following subjects could be discussed:

- the nature and characteristics of the problem field: development of spectrum demand, development of telecommunication applications and their impact on the radio frequency spectrum;
- short-term, medium-term and long-term developments;
- how to trigger scientists and the unions to make clear statements on research priorities;
- IUCAF: its structure, membership, correspondence, how is the work done and by whom? (review activities, if possible quantitatively).

6.3.2. Local Scientific Community

The "scientific individualism" mentioned above is often too clearly visible in the attitude of individual radio astronomers, staff of radio astronomy stations and observatory directors. On many occasions their opinion is required on various topics in relation to the protection of frequencies for radio astronomical research. However, nobody can be a specialist in all fields. Experience shows that the areas of frequency regulation, protection, management are very complex and most people need several years to become familiar with all aspects. Therefore, given the existence and activities of IUCAF, CRAF and CORF, radio astronomers, staff of radio astronomy stations and directors should coordinate all activity in this field with these bodies. Besides their experience, another important reason is that IUCAF, CRAF and CORF are well-known bodies to Administrations and several international private and public organisations. Working outside these three bodies would confuse and spoil the radio astronomy case.

Furthermore, where IUCAF and organisations like CRAF or CORF make recommendations contrary to the hopes of the individual radio astronomer, radio observatory staff and observatory director, these people should follow the recommendation unless they are able to prove that IUCAF, CRAF or CORF has come to an incorrect conclusion. This methodology does not imply that the mandate of the individual radio astronomer, observatory staff member or observatory director is restricted, but that the bodies who have been created for this job and to which this specialised activity has been referred, are able to fulfil their job properly.

Similar cases can be extrapolated for other scientific communities.

6.4. Collaborative attitude

Scientists are usually funded by public money and their interests are outlined in a governmental strategy on research and development. This public aspect and the fact that, with some exceptions, scientific research depends on support from the Administration, mean that the scientific communities must maintain good relations and interact with these Administrations at a national level. At an international level, similar good relations and interactions are required.

IUCAF and regional organisations like CRAF are ITU-R Sector members. This improved the interaction with the ITU-R and the participation in ITU-R(-related) activities. In Europe, CRAF has developed to become the European radio astronomy discussion partner of the CEPT. Organisations such as IUCAF, CRAF and CORF participate actively in many working groups, study groups and project teams devoted to spectrum engineering and regulatory issues.

Under the auspices of the ITU-R much work is done (e.g. in WP7C by remote sensing scientists and in WP7D by radio astronomers) on definitions and criteria for sharing conditions. However, it cannot be assumed that the colleagues in this activity do have complete and sufficient knowledge of specific scientific needs and problems. Organisations such as IUCAF and CRAF should cooperate closely with the chairmen of the relevant ITU commissions/working groups. IUCAF and CRAF should initiate studies in support of the ITU-R WP activities. When necessary and possible these work programmes should be used as subjects for discussions under the auspices of the international scientific community, i.e. URSI.

The structure of this activity is basically reactive and addressing issues which arose on this side of the horizon. However, a clear perspective for the mid-term future must be available and regularly be updated. An essential element of such a plan is that it is related to science policy in those countries supporting scientific research. Politically speaking, relations with organisations, e.g. in Europe the *European Commission,* should be improved where relevant.

This item must be on the agenda of all scientific users of the radio frequency spectrum.

In addition to good relations with regulatory and political organisations, scientific communities should collaborate actively with space agencies, telecommunication operators, broadcasting organisations and other active users. The aeronautical and space projects may especially cause major problems relating to the process of frequency selection and development of protection tools, where the considerations and requirements of the science service have not been taken into account properly. Protection of science services against space-to-Earth or Earth-to-space transmissions need special attention (depending on the specific scientific interest, of course).

Collaboration with industry should be developed as much as possible. A good example of where such a collaboration can lead is the joint project of the European Space Agency, ESA, the Swiss-Italian company Oerlikon-Contraves and CRAF to develop adequate filter technology to protect radio astronomy receivers' operation in the frequency range around 95 GHz against harmful interference and physical destruction by signals from a space-based cloud radar system planned to operate in the band 94.0-94.1 GHz. The result of this collaboration was that such a filter technology was developed in 1997.

6.5. Specific events of harmful interference

Events of harmful interference have of course an origin. This origin can be *local, regional* or *global* (*CRAF Handbook for Radio Astronomy*, 1997, p. 93). When scientists addressing the protection of radio frequencies important for scientific research, that specific local, regional or global organisation must be kept informed of the interference events to be able to give adequate guidance and support to the affected scientific community. This is a major role for CORF, CRAF and IUCAF and other similar organisations when they come into existence.

Local questions and problems have to be dealt with locally, i.e. in bilateral communication with the national, civil or military administration and the radio observatory involved. In such communication, usually the following information is needed:

- place, date and time of interference observed
- frequency band within which the interference occurred
- frequency at which the interference occurred
- allocation status for the specific frequency band
- characteristics (when known) of the interfering signal: strength, direction, modulation (if possible).

All questions and problems need to be communicated to the organisation working on spectrum management for scientific research. The information on interference events should continuously be registered, collected and documented in a WWW-accessible database. Organisations such as IUCAF should produce a common public domain and Web-accessible software tool-kit for that purpose. If necessary and proper, this organisation or IUCAF may provide additional support in necessary communications with the relevant Administrations.

Regional questions and problems have to be dealt with regionally. In Europe, CRAF, as the European body concerned with the protection of frequency bands allocated to radio astronomy in Europe, has to communicate with national Administrations, the CEPT, the EC and ESA. The required information is the same as provided to local Administrations. It is mandatory that in Europe the radio astronomers follow the line taken by CRAF or improve their scientific case via CRAF only. Such a position holds for other scientific communities and regions as well.

It is also important that regional organisations for the protection of radio astronomy frequencies are established in other regions. Some activity is currently being developed in the Asia-Pacific region, but that needs further attention. CRAF and IUCAF can play a supporting role.

Global questions and problems have to be dealt with globally. IUCAF is the body to take the initiative and to give guidance. However, CRAF and its American sister CORF should provide IUCAF with timely, proper and adequate information. ITU-R members such as IUCAF and CRAF could also inform the ITU-R Radiocommunication Bureau directly about any issue.

In cases of specific events of harmful interference, scientists should follow the following action path:

- If possible the scientific station should determine whether the source of interference is local, regional or global. In any case, it must be sure that the interference is not internal to the station.
- If the scientific station is connected with an organisation dealing with spectrum management and frequency protection issues, this station should bring the event to the attention of this

organisation. This communication helps to build a database of events which after some analysis enables the organisation to address the frequency protection issue adequately to a regional Administrative organisation or, if necessary and the organisation is Sector Member of the ITU, to the ITU-R Radiocommunication Bureau. An organisation such as CRAF or IUCAF may be able to advise and may provide support.

- The scientific station suffering the harmful interference checks the allocation status of the frequency band in which the interference is experienced. The bases for this are the ITU Radio Regulations and the local national frequency distribution plan. In case the scientific service has no or a secondary allocation in the band, one may discuss the issue with the national Administration of the country in which the station is located, but then the case is a local problem which has to be solved locally, i.e. with the national Administration.
- If the interference is experienced in a frequency band allocated to the science service suffering this interference, the interference event should be well documented and discussed with the national Administration. The latter may need an independent confirmation of the harm. This confirmation is usually performed by one of the monitoring stations operated by an Administration, e.g. the satellite monitoring station of the German Administration in Leeheim, Germany. If no adequate monitoring facility is available, the local Administration should be asked to request assistance from a facility elsewhere.
- After independent confirmation the radio astronomer who contacted the Administration, requests this Administration for advice and help. In practice, such an Administrative action may imply that a formal statement of complaint is sent to the “operator” whose system is causing interference, or any other adequate action may be taken. If the transmitting source is outside the country and the location of the source is known, the Administration can be requested to inform the Administration of the country in which the transmitter is operating. It is also strongly recommended to inform the ITU-R Radiocommunication Bureau about specific interference cases, or request its assistance in solving the problem. The ITU Radio Regulations Board may also be requested to solve the interference problems according to ITU Convention No. 140.

Hopefully, these supportive Administrative actions may be sufficient to solve or alleviate the problem.

6.6. Work

On a global scale, scientists enjoy only two full-time frequency managers: one located in Washington, USA, and working for the US National Science Foundation; the other located in Dwingeloo, the Netherlands, being the European frequency manager of the ESF Committee on Radio Astronomy Frequencies, CRAF. Besides these full-time frequency managers several other members of the scientific community work on a voluntary basis on frequency management issues (with their own experience and know-how of course) but they are not always available. Given the large variety of issues that require attention, the members of organisations such as IUCAF, CRAF and CORF should be dedicated to specific tasks on a continuous level. In this way they would build group know-how within the community and support the frequency managers in their work. Using modern means of communication the physical non-availability of IUCAF, CRAF and CORF members could often be alleviated.

6.6.1. Meetings

The number of meetings where a scientist competent to discuss spectrum management issues needs to participate is growing rapidly. A single frequency manager is physically not able to attend all such meetings. Furthermore, in various meetings such as those of the CEPT and the ITU more than one representative of the scientific community is often needed. This is due to the structure of the meeting when various drafting groups work simultaneously. When required, the frequency manager needs to be assisted by other scientists; the first option is assistance by a colleague of the country in which an event takes place, if available. Experts for specific issues should be available to assist as well.

If studies of specific questions are required, the scientific community and especially its organisation dealing with spectrum management and protection issues should organise dedicated workshops to address these.

6.7. Agreements between scientists and non-scientific radio spectrum users

In some cases regulatory imperfections exist which must be resolved before completion of a coordination process is possible. To satisfy the needs of various radio spectrum users, private agreements have been made and are being made with the aim of filling regulatory gaps or to solve a problem that Administrations cannot solve because of these inadequate regulations or because of political reasons. Reference to such private agreements may be incorporated in Administrative regulatory procedures but such agreements may also develop into precedents to undermine current spectrum regulation and respect for these regulations. This process may be exacerbated by economic and political pressures.

A complicating factor in Europe is that the telecommunication legislation in some European countries does not allow for reference to or attachment of a CEPT Recommendation as an authorisation. Other countries may have another different legislation. This implies that bilateral agreements of such private entities with other private legal entities are considered very probably the best way out for the private parties involved.

In some cases, scientists are asked to enter an agreement with non-scientific radio spectrum users. The reasons for such a request can be various, but often such an agreement helps an Administration to solve its problem when no adequate regulation for a case exists yet. Such agreements are often an option in coordination issues between different users of the radio spectrum.

If it seems that scientific organisations or stations are urged to come to agreements with active users, it is of major importance that sister organisations and IUCAF are consulted properly and adequately, and that their opinion is taken into account. In all cases one should first investigate whether the requested agreement is necessary. The reason for this is that any agreement may create a precedent and may also put constraints on sister organisations/stations.

It must be noted that in cases of radio frequency matters, a national Administration has only the authority to request an agreement from the considered scientific community. Where unexpected problems occur and an Administration has no immediate opportunity or method of solving the issue, an agreement could be made between the scientific community and the operator under the condition of full compliance with the ITU Radio Regulations. No private legal entity has the right to ask an agreement for any other purpose. This is particularly obvious where the local, regional or global use of a frequency band is changed (often reduced for scientific applications): the national government of a sovereign state can make decisions which set only the political priorities, such as "science or telecom". If the national priority to science is not to be degraded but the scientific frequency use has been restricted, adequate action is required. In this case, expert organisations like IUCAF, CRAF or CORF may play an active role in guidance and support.

When agreements cannot be avoided, one should carefully evaluate under which conditions the idea of an agreement can be accepted and when it should be rejected. An agreement should not be accepted for the simple reason that the station involved in this agreement is not interested in that particular frequency band or that it is considered to have local relevance only. A case that is considered to have local relevance only may at a later stage develop into one with global importance. Often such an agreement has severe implications for sister organisations, which may be extremely difficult to modify or correct.

If agreements are needed, the framework for these can only be international and national legislation. International legislation is formulated in the ITU Radio Regulations (e.g. its table of frequency allocations and related footnotes and Article S29 that describes the characteristics of radio astronomy as a radiocommunication service and its protection). No agreement must be accepted which does not fully comply with these legal frames. Furthermore, one must avoid the situation that agreements become a substitute for the international and national regulations, because this development degrades the status of (inter-)national legal structures.

7. What should we not do today?

The issue of agreements mentioned in the previous chapter brings us to the question of what we should not do today. We, as scientists, must be aware of actions to avoid because of the increasing pressure of use on the radio frequency spectrum.

Commercial users of radio frequencies, especially those working in the field of telecommunication by satellite, are eager to enter the radio frequency spectrum as soon as the system they want to operate enters its test phase. Of course they then have to go through the whole process of ITU-R notification and coordination with national Administrations, but once this process has been completed and frequency band(s) have been assigned to this system, the design phase of the system has to be completed in such a way that guarantees can be given that other users of that part of the radio spectrum will not suffer from unwanted emissions. If everything runs well, and if in the system design and construction all necessary precautions have been taken to eliminate spectrum pollution, and if all regulations on standards and electromagnetic compatibility have been obeyed, no problems should occur.

However, daily practice often does not comply with this ideal situation. For commercial and competition reasons, industry prefers quick and cheap solutions rather than the implementation of results of thorough technological and scientific research. This industrial practice often results in badly designed or defective systems [we call a *defective* system any system that technologically avoidably pollutes the radio frequency spectrum and causes harmful interference to another radiocommunication service]. The result of this is that on a number of occasions the final system may not be as perfect as anticipated, requiring the operator to enter a coordination process with a possible victim service. Such a process is usually performed under Administrative auspices. At that point the Administrations face the situation that the new system exists in such an already advanced state that refusing its operations may have an unacceptable impact on the operator. Although in the strict regulatory sense the frequency Regulatory Authority must refuse operation of any such defective system, political arguments can and, in practice, do overrule such a regulative action.

So far, examples of defective systems which have caused significant and irremediable damage to scientific research using radio frequencies are:

- the Russian system for radionavigation by satellite GLONASS at 1.6 GHz;
- the US based satellite system for mobile communication by satellite Iridium at 1.6 GHz and 23 GHz;
- the US military satellite TEX at 328 MHz;
- the fixed-satellite system ASTRA-1D operated by a Luxembourg-based operator at 10.7 GHz.

Of these systems, the GLONASS system is being improved to protect passive radio usage: this improvement will be completed by the year 2006.

The Iridium satellite system is a clear example of bad design in which no protection of other radiocommunication services was built in.

The TEX satellite is an example of a system which is no longer operational but which, since it has no OFF-switch built in, cannot be switched off, resulting in harmful interference due to malfunctioning of the system. In order to keep it silent, the company responsible for the system must continue to allocate manpower and a tracking station and keep providing the system with the proper commands.

Another example is the ASTRA-1D satellite, which causes out-of-band emissions far above the acceptable levels of harmful interference in an adjacent frequency band due to the wrong design or malfunctioning of system components. Since the satellite is in a geostationary orbit, it will take a long time before a better, non-polluting, one will replace it. The issue has been brought to the attention of the German Administration, which confirmed the observed interference by observations at its Leeheim Satellite Monitoring Station and, supported by this evidence, also to the attention of the operator. The operator, *Société Européenne des Satellites* in Luxembourg, did improve the system to some extent but a complete cure of this problem has not yet turned out to be possible.

The system is heavily used in Europe for direct to home broadcasting and therefore, political arguments oppose the shutting down of the system in the frequency range it is polluting.

These examples help us to understand the limited applicability of agreements.

The solution reached in the case of the GLONASS problem is the result of an agreement between the GLONASS administration and IUCAF concluded in 1993. The GLONASS system had been causing harmful interference to radio astronomy since it started operations in 1987. Radio astronomy stations were the first to notice this initially military Russian system since it operated partly in a band allocated to the Radio Astronomy Service; in fact the GLONASS designers were not aware they were causing harmful interference to radio astronomy. The agreement between GLONASS and IUCAF foresaw the move of the frequency channels of the GLONASS system outside the radio astronomy frequency band. Furthermore, this agreement also included a time path for this modification.

Since it was too late to start a coordination process for the already operational GLONASS system and since it was highly unlikely that the Russian authorities would switch off the system, GLONASS and IUCAF reached the aforementioned agreement in order to solve the problem in the not too distant future while at the same time allowing both radiocommunication services, i.e. GLONASS under radionavigation by satellite on the one hand and radio astronomy on the other hand to continue their operations. It was out of the question to demand filtering of the radio astronomy receivers, as radio astronomy enjoyed a primary allocation in the affected frequency band of 1610.6-1613.8 MHz.

We note that the GLONASS-IUCAF agreement has its roots in the ITU Radio Regulations: the adopted modifications are in compliance with the obligation of the GLONASS system not to cause harmful interference to the radio astronomy service, which was initially caused by the space-to-Earth transmissions of this system in the band 1610.6-1613.8 MHz.

The situation is different for the TEX satellite; because of malfunctioning of the system, the operator is not able to switch it off or to bring it into a different attitude to prevent the reception of its emission on Earth. The case has been well known since 1992, when Dutch and Indian radio astronomers discovered the interfering source. The satellite operator has been known to the Radio Astronomy Service since 1998 and he has acted according to the regulatory criteria. Radio astronomers will need to wait until the satellite finally 'dies'. However, with the necessary continuing effort of the operator, its interference has been effectively removed.

In this specific case scientists did not conclude an agreement with the operator. The Administration of the Netherlands informed the ITU-R Radiocommunication Bureau of the problem, which then notified the US, Russian and Chinese Administrations. The Russian and Chinese Administrations responded that the satellite was not theirs. After several years of investigation, the US Administration admitted in 1998 that the interfering satellite was a US military satellite, which was supposed to have ended operation in 1991. The US took the responsibility of acting against the operator, who has since then taken measures to keep the satellite quiet.

Also in the ASTRA 1-D case, it is unlikely that an agreement can be reached which will lead to anything acceptable for scientists. At the moment of writing, the frequency band 10.6-10.7 GHz therefore simply cannot be used for scientific research due to spectrum pollution from the satellite which operates just above 10.7 GHz. In the regulatory sense this issue is not yet closed and discussions at European level are continuing.

7.1. Mistakes with agreements

7.1.1. The Iridium lesson

The Iridium satellite system caused a lot of trouble for the Radio Astronomy Service since, despite guarantees to protect radio astronomy, no precautions to realise this have been built in into the system. Furthermore, other defects were noticed in the meantime.

An analysis of the history of the Iridium tragedy shows a number of avoidable mistakes made by scientists at the time, which had a large impact on the coordination process elsewhere.

The situation is as follows:

The WARC 1992 allocated the band 1610.6-1613.8 MHz to the Radio Astronomy Service on a primary basis. It also allocated the band 1610-1626.5 MHz to the Mobile-Satellite Service, MSS (Earth-to-space) on a primary basis, and MSS (space-to-Earth) got a secondary status in the band 1613.8-1626.5 MHz. Furthermore, footnote S5.372 was added to the band 1610-1626.5 MHz which says that *harmful interference shall not be caused to stations of the radio* *astronomy service using the band 1610.6 - 1613.8 MHz by stations of the radiodetermination-satellite and mobile-satellite services*. These allocations and the footnote hold for all three ITU-R Regions (see Figure 3.3).

The band 1610-1626.5 MHz is used by several MSS operators for the Earth-to-space transmission path. The Iridium Satellite System wanted to use the band 1621.35-1626.5 MHz for space-to-Earth transmissions (conforming its USA licence and allocation). The Iridium Satellite System consisting of 66 satellites in Low Earth Orbits flying at an altitude of 780 km was designed and built by Motorola Inc.

Already soon after the first specifications of the Iridium system became known, the radio astronomy community (represented by IUCAF) discussed with Motorola Inc/Iridium LLC the protection of radio astronomy observations in the frequency band 1610.6-1613.8 MHz against possible harmful interference from its MSS stations. By letter of October 9th, 1991, to the chairman of IUCAF, Motorola Inc stated "*Motorola's goal is to share frequencies in a manner that will not interfere with radio astronomy or other MSS/RDSS services*."

In Europe, CRAF tried to have technical discussions with Iridium LLC on the protection of radio astronomy from unwanted emissions from the space-to-Earth transmissions of the Iridium Satellite System into the frequency band 1610.6-1613.8 MHz. However, before 1998, Iridium LLC was not inclined to have such discussions.

In the course of time it became clear that Motorola had not implemented any proper measure in the Iridium system to protect radio astronomy or any other radiocommunication service, as the system design showed. Instead, Motorola Inc proposed some possible operational solutions to radio astronomy stations. However, these would affect radio astronomy observations only without having any impact on Iridium system's operations. Furthermore, Motorola Inc showed that their space-to-Earth transmissions in the band 1621.35-1626.5 MHz would cause harmful interference of up to 30 dB above the levels permitted as given in ITU-R Recommendation RA.769, as was eventually confirmed by radio astronomical observations.

At no time, was either Motorola Inc or Iridium LLC willing to have *technical discussions* with IUCAF or CRAF in order to seek a solution for this problem. Iridium LLC only wanted to discuss its view on operational solutions with radio astronomy stations on a site-by-site basis, which soon turned out to be a divide and rule policy with respect to radio astronomy stations by this operator.

Mistake 1: The GLONASS-IUCAF agreement complies fully with the ITU Radio Regulations and provides the radio astronomy service with the guarantee that, according to a specified time path the space-to-Earth transmissions of the GLONASS system will be moved outside the band 1610.6-1613.8 MHz in which the radio astronomy service has a primary allocation and that through adequate technical means the harmful interference to the radio astronomy service will be suppressed. The agreements concerning the Iridium system are of a quite different nature: they are meant to ‘regulate’ the harmful interference from spurious emissions from the transmissions of the Iridium system (space-to-Earth). While the GLONASS-IUCAF agreement is made to solve an issue of spectrum pollution, the agreements with Iridium LLC *regulate* the pollution that the victim service must accept. Therefore, these agreements are fundamentally of a different nature and the existence of the GLONASS-IUCAF agreement must not be accepted as an argument to conclude the kind of agreement as made subsequently with Iridium LLC.

Mistake 2: In 1994, the US National Radio Astronomy Observatory, NRAO, signed a Memorandum of Understanding, MoU, with Motorola Inc in which NRAO accepted that radio astronomy observations at its stations in the band 1610.6-1613.8 MHz would be done, to the greatest extent possible, during low traffic hours of the Iridium system, i.e. during 4 night hours. In addition some other obligations of a technical nature were accepted by NRAO. Although a MoU is a common enough kind of agreement, as such it is not legally binding. Furthermore, this MoU put burdens only on radio astronomy while neither Motorola Inc nor Iridium LLC had to accept any constraint or obligation. Nor does the agreement contain any time-path, milestones or an arbitration procedure in case of conflict. In addition, NRAO accepted a non-disclosure agreement concerning technicalities, which could arise from the Iridium case.

The tragic aspect of the NRAO-Motorola Inc MoU is that NRAO entered it in good faith, without apparently being aware of the far-reaching consequences of precedents for sister organisations: Motorola Inc used this MoU by stating publicly outside the USA, that *“the radio astronomers agreed”* without explaining that it was reached with one institute in the world only. Had NRAO been aware of the potential implications elsewhere, it would certainly have consulted the radio astronomy community outside the USA – which was not done, however. Only if on the other hand, the issue could have been considered as a truly local one with no consequences whatsoever for radio astronomy operations outside the USA, then NRAO would have been correct in treating it as a local issue. One could conclude that NRAO had simply overlooked the consequences, but even a basic analysis of the Iridium system parameters would have revealed that the footprint of the satellites has such dimensions that its transmissions cannot remain confined within the USA alone.

On the issue of the non-disclosure agreement signed, we will make some comments below in section 7.2.

Mistake 3: In 1997, the US National Astronomy and Ionospheric Centre, NAIC, operating the Arecibo (Puerto Rico) Radio Astronomy Station accepted a similar agreement with Iridium LLC which states that for about 8 hours per night the Iridium interference will be below the level allowed for detrimental interference for radio astronomy. It also accepted a non-disclosure agreement with Iridium LLC, like NRAO had done. Furthermore, NAIC accepted that they would notify Iridium LLC when exactly it wants to do observations in the frequency band 1610.6-1613.8 MHz.

On the notification or demonstration-of-need issue we will make some comments below in section 7.3.

***Consequences of mistakes 2 and 3*:**

These mistakes put pressure on radio astronomers outside the USA to enter into similar agreements with Iridium LLC. In Europe, the CEPT and the EC put pressure on CRAF to accept an agreement with Iridium LLC because of the conditions included in the licensing of the Iridium system in European countries to guarantee protection of radio astronomy in Europe.

The guidance of the CEPT resulted in a Europe-wide agreement signed in 1999 between the European Science Foundation on behalf of CRAF and Iridium LLC, obliging Iridium LLC to remain for 7 hours per day and a number of full weekend days below a specified power flux level. The agreement states explicitly that it is legally binding on both the ESF/CRAF and Iridium LLC, as well as to the successor of each of the parties, in the event that this might occur. It does also state that by 1 January 2006, the Iridium system must cease to cause interference above a specified power flux density level. The agreement also foresees an arbitration procedure in the case of any legal dispute. Until now, dispute handling has not been covered by agreements outside Europe.

Throughout the negotiation process towards the ESF-Iridium LLC agreement, CRAF cooperated intensively with IUCAF which gave strong supportive guidance.

Elements of this agreement have also been taken into account in Canada and India. In Australia, no agreement between radio astronomers and Iridium LLC has yet been reached.

The events in the USA show clearly where failing to consider precautions properly may lead. In Europe, the existence of an MoU between NRAO and Motorola was *the* argument to make European radio astronomers negotiate their own agreement which, after all, is nothing more than an agreement to time share with the radio waste of a defective satellite system and thus a precedent was established that such an agreement could be reached regardless of the view of the ITU Radio Regulations. For the NRAO case, the ITU Radio Regulations have limited status, since local legislation has priority over local issues. In Europe, however, the situation was different, since a Europe-wide solution was sought. Therefore, one may question whether an agreement as such was the proper solution given the legal status of the ITU Radio Regulations.

However, European licensing Directives and the difference between national legislation in the individual European countries, called for a swift and pragmatic solution to break the deadlock.

Lesson 1: The GLONASS-IUCAF agreement proves that in the case of unforeseen difficulties the public legal context of the ITU Radio Regulations provides an adequate framework for full cooperation and good faith in how to solve the problem. This attitude is essential for mutual coexistence and cooperation in the use of radio frequencies.

Lesson 2: While the GLONASS-IUCAF agreement was made to *solve* an issue of spectrum pollution, the agreements made with Iridium LLC *regulate the pollution that the victim service must accept*. Therefore, these agreements are fundamentally of a different nature and the GLONASS-IUCAF agreement should never have been used as an argument to force the conclusion of an agreement on an other kind of issue, as made in the case of Iridium LLC or any other future issue.

In both cases, the existing regulations and legislation proved inadequate to solve the issue at hand. Nevertheless, the GLONASS-IUCAF agreement set a precedent, and has found its way into national rule making, and has in this sense integrated into the national regulatory processes.

The same occurred with the various agreements with Iridium LLC. However, it must be noted that as far as is currently known, private agreements between radio astronomy communities and Iridium LLC were required to fill an evident regulatory inadequacy regarding the protection of a radiocommunication service from plain pollution, despite the various articles and clauses in the ITU Radio Regulations addressing this issue.

Agreements like that signed between GLONASS and IUCAF comply fully with the public legal regulatory framework. However, if it becomes publicly accepted that victims can be forced to sign agreements accepting pollution regulation, as happened in the Iridium case, and if this becomes common practice for any purpose, this will weaken the public regulatory process and the legal status of an international treaty. Administrations should prevent such agreements rather than suggesting, or even asking for them in order to solve an issue.

Also, the pollution victim should not accept an agreement. For, in doing so, he contributes to the creation of precedents showing that private agreements can be made to regulate pollution, quite separate from the already available legislation, simply to make life easier for the polluter alone.

Lesson 3: Another lesson to be learned from the Iridium story is that individual scientific radio stations must adequately coordinate all their frequency management efforts with the expert organisations working on the issue, e.g. IUCAF, CORF and CRAF. When questions are asked on coordination issues and their impact transcends the borders of the country where the station is located, agreements between only that specific station and the non-scientific user must be avoided by all means. The reason is that separate or site-by-site agreements generate site-specific or scientist-specific characteristics which may not apply elsewhere, but the most advantageous of which will be used by the non-scientific user in the attempt to reach his goal.

Mistake 4: When it is necessary for scientists to enter into an agreement with a non-scientific entity, the scientists must be careful that the correct legal context and concepts are used in the agreement. The frequency regulation is of a *public legal* nature, while an agreement between a scientific organisation and a non-scientific entity arises in a *private legal* context that must comply with the public legal framework. The ITU Radio Regulations have this public legal status, as do national frequency regulations and telecommunication legislation: agreements between private legal entities typically cover private legal issues. Therefore, an agreement must comply with the proper public legal context, and may neither modify the legal interpretations for the benefit of one private party, nor contain language taken from a public legal text that is not adequately defined in a private legal context.

This issue was raised in the discussions between CRAF and Iridium LLC when Iridium LLC tried to introduce public legal language taken from EC Directives into the anticipated agreement, such as the need to comply with the so-called 'proportionality principle'. The proportionality principle implies that the lightest possible restrictive regulatory measures should be imposed on the parties to the agreement. From this Iridium LLC inferred that protection needs to be granted only on demonstrated need. This interpretation was disputed by CRAF as improper legal reasoning. When non-private language and concepts find their way into clauses in a legally binding agreement between two private legal entities, the execution of the agreement may well have negative consequences for one of them.

Lesson 4: When it comes to discussions on agreements, scientists must seek legal support. In a region like Europe this is not easy, since legal questions contain elements of international and national law, both public and private. Scientists must be extremely cautious that their good faith is not abused.

Mistake 5: When an Administration asks scientists to enter an into agreement with a non-scientific entity, in their good faith the scientists may consider that once a number of clauses on operational or technical issues have been agreed upon, the agreement is complete. The mistake is that when the agreement does not explicitly state that it is legally binding, each party still has the freedom to act in any way it likes. In itself the issue of making an agreement legally binding is important, but as in daily practice conflicts and disputes cannot be avoided, the scientists must not be satisfied with an agreement in which dispute arbitration is not included, despite the fact that the agreement is, of course, made in good faith.

Lesson 5: Any formal agreement between a scientific and a non-scientific private organisation must include a clear statement to make the agreement legally binding as well as clauses regulating dispute resolution. Disputes cannot always be resolved via arbitration, and one has to verify if the agreement contains adequate parameters within which arbitration is possible. Furthermore, when dispute resolution becomes necessary, one has to state under which law this has to be performed and one has to make clear that adequate jurisprudence related to the subject of the dispute actually exists.

Therefore, also in this case, adequate legal support and guidance is essential. To generalise this conclusion, scientists must be aware of the legal impact of their discussions and cooperation with non-scientific parties. Usually this is not a problem, but scientists must avoid any unwanted difficulty.

7.2. Non-disclosure agreements

In discussions with industry and operators, the issue of an agreement not to disclose confidential information to third parties not involved in the discussion is frequently raised. Such confidentiality may relate to technological items or to commercial issues, knowledge of which may be of great importance to each of the parties entering such an agreement. Therefore, non-disclosure agreements are a well-known practice in industrial and commercial collaboration and discussions.

However, by its nature, science has no real use for specific commercial information provided by the other party. This implies that any non-disclosure agreement on commercial issues can only be an empty binding agreement. Only where the scientific question is directly related to a specific technological solution of which the other party has the patent or cannot disclose information for obvious and explained reasons, a non-disclosure agreement could be considered. However, in this case, it must be clearly stated to what exactly the agreement applies and no vague or unspecified terms must be accepted in the agreement. The root of this position is that the nature of science is different from the characteristics of a commercial-industrial enterprise. Also the scientific culture of freedom of information exchange does not comply with a non-disclosure agreement. Therefore, non-disclosure agreements cannot support the progress of science.

If a scientist accepts a non-disclosure agreement without a clear guarantee that it is not a void agreement, he binds himself to the other party in the sense that he accepts not to disclose information received within the scope of the terms of the agreement. This may have the nasty consequence that the scientist's mouth is sealed while the other party is under no obligation to provide him with even the smallest bit of useful information.

For this reason, *non-disclosure agreements driven by commercial motives must be avoided by all means* unless this would hamper the very progress of the particular scientific context relating to the agreement. A specific case in which a non-disclosure agreement is preferred concerns the coordination of the operations of transmitting stations with radio astronomy stations. The agreement between the operator of these stations and the other (scientific) party could be subject to a non-disclosure agreement if there is a real threat that other operators could abuse elements of this coordination agreement. In any case, great care must be exercised and warnings should not be underestimated.

7.3. Providing scheduling/planning information

Some operators support the interpretation that *protection of another radiocommunication service is needed only during actual operations of the victim service*.

It must be noted that such an opinion is not supported by the ITU Radio Regulations and the ITU Constitution (see also chapter 5 answer 4). The ITU Radio Regulations and regional and national frequency plans have a public legal status, i.e. as *allocation* plans they are not dealing with the factual operational status of an application in a radiocommunication service after an allocation has been given on publicly demonstrated need. The protection arguments would be different if these regulations concerned *assignment* planning for specific applications to which specific conditions might apply.

Secondly, if it is accepted that one radiocommunication service is protected only on its demonstrated need, then other questions arise, related to the criteria used for this demonstration and to why the service asking for a demonstration of this need has the mandate to demand this at all. Furthermore, it is far from clear what arbitration process is adequate to resolve conflicts.

Thirdly, if accepted, the difference in allocation status between radiocommunication services becomes arbitrary and dependent on the pressure and power of private (usually commercial) entities. If such a practice is accepted the status of the regulations is significantly weakened.

Therefore, the reply to the question *does scheduling/planning information needs to be provided* cannot be answered in the positive. Furthermore, if the answer were to be positive, other questions arise relating to the criteria for the justification to schedule/plan a specific observation or an experiment. Users agreeing to respond to the question run the danger of entering into unsolvable disputes since the other party is usually not competent in the necessary evaluation. Furthermore, precedents for other users in the same radiocommunication service can be created which are bound to be difficult to remedy at a later stage.

In the vein of the faulty interpretation of protection touched upon above, the USA agreements between US radio astronomers, and Motorola Inc and Iridium LLC contain clauses stating that radio astronomy observations should be scheduled avoiding peak traffic periods of the Iridium system. The NAIC has even accepted an obligation to show Iridium LLC its observing schedules to demonstrate to Iridium LLC that the requested observing time is indeed necessary. The European agreement between the ESF and Iridium LLC does not contain such a clause, as it would violate the internal sovereignty of each individual radio astronomy station to do the observations at the time it considers best to achieve the scientific goal.

When non-scientific users ask the scientists to specify when a particular frequency band will be used, the *answer must also be a categorical refusal to respond*. The reasons are as follows:

- Such a request is in conflict with the ITU opinion on protection of a radiocommunication service, as indicated above.
- A notification of demonstrated need is not related to the protection of the notifying radiocommunication service, since the protection concerns the *prevention* of interference detrimental to the victim service by technical and operational measures which must be taken by the interfering service, and not by *regulation* of the interference.
- No private user of the radio spectrum has the authority to ask another user to show when a particular radio frequency band is needed, since in simple terms, it is none of his business. The background to this is the role of the Administration in the coordination process (see definition in chapter 4). When a radiocommunication service enjoys the allocation of a particular frequency band, the very fact of this allocation shows that the international community accepted that the need to use this band by that service has been justified sufficiently.
- Such a notification procedure places the notifying radiocommunication service in the victim position and in a secondary status with respect to the service to which the notification is made, since it relieves the interfering service from the obligation to take appropriate measures to prevent interference (e.g. ITU Radio Regulations S0.2 and S0.3).

7.4. Monitoring

When harmful interference is experienced in scientific projects, it is important to know what exactly the characteristics of the interfering source(s) are. This information is important background information when the interference issue is discussed with a Regulatory Authority. In many cases it is not possible for the scientist to derive this important information from the interference noted in the data resulting from his experiment/measurement. In such an event it seems attractive to the operator of the scientific radio station to install a monitoring facility on a vehicle and to drive this around in order to obtain dedicated measurements of the interfering signal.

Warning 1: It must be noted that not every country's national Administration will be happy with such a monitoring experiment performed on the initiative of the scientific radio station. On the contrary, even the publication of monitoring data from such an experiment may actually be forbidden by law, as is the case in the Netherlands and in France. When there is a need for such a monitoring experiment, adequate consultation with the Administration must be undertaken to find ways to obtain the desired information.

Some scientific stations have installed instruments dedicated to monitoring particular radio frequency domains. It is recommended that the National Regulatory Authority is consulted beforehand in such projects. It has been known on some occasions that this Authority has had an active interest in the construction of such a facility, as it is important for a Regulatory Authority to have adequate knowledge of what is going on in the radio frequency spectrum in its territory. The scientist's special interest in monitoring this information concerns, for instance, scheduling reasons, the establishment of a frequency plan for his experiment.

Warning 2: The scientist must note that the data obtained with such a monitoring facility do not provide information on interference but rather on spectrum occupancy. Therefore, these data are not pertinent to provide support for a specific interference complaint to a Regulatory Authority, since interference corrupts scientific measurement data and no scientific measurement data are degraded in this monitoring facility. Furthermore, the scientist must be aware of the need to keep the monitoring information to himself or interested colleagues in his institute only, as in many countries it is not allowed to show such information to third parties or to make it public. The reason for this is obvious, since information on spectrum occupancy reveals to other users of the radio spectrum where the spectrum is unused and to what degree. Such information could have high commercial value.

CRAF maintains a database for spectrum occupancy monitoring data and has a facility to query this database and to manipulate its contents accessible on the World Wide Web under password protection. In order to serve the scientific community and other authorised entities, all astronomical monitoring station are urged to send the data with a defined data format to CRAF (for address information, see chapter 19).

8. How are we operating scientific radio projects after 25 years?

The way sciences are able to use the radio frequency spectrum after 25 years, depends on parameters such as the development in radio spectrum usage, technological developments on the transmitter and on the receiver side and various other developments such as in the social and economic fields. Before outlining the perspective for scientific radio frequency use after 25 years, we need to make comments on these developments.

The development of science proceeds in an unavoidably intensive relationship and cooperation with other technological developments, especially in the field of the so-called "information technology industry". Advances in information systems and communication networks are driven by digital technology. These developments have brought and are bringing new challenges to the regulatory and legislative regimes, and have begun to blur traditional regulatory definitions and jurisdictional boundaries (ITU, 1999). Universal Access and Interconnection are key factors in the development of competition in the telecommunication industry. This will as far as we understand not change in the next decades but be enhanced.

8.1. Spectrum development

Telecommunication developments depend on the possible capacity of communication channels per Hertz and the costs to deploy a service per Hertz. It is a well-known fact that this capacity for satellite-based mobile and fixed services is more than an order of magnitude lower than the capacity for terrestrial systems and even declining (conform the status at the time of writing this document). It is therefore not certain that communication by satellite is *the* future development for telecommunication. This development will heavily depend on the telecommunication infrastructure in the regions where it is applied. In Europe, for instance, the terrestrial wired and wireless telecommunication is very well developed. In other areas of the world this can be much less: e.g. in the USA or many remote areas, this Earth-based telecommunication system is less advanced and therefore the interest in space-based systems can be greater in these areas than in Europe.

Recently constructed long distance optical fibre cable systems between e.g. Germany and China, and a newly planned transatlantic high capacity cable system show that space systems are not an obvious route for telecommunication development (observation at the time of writing this document). The fraction of overseas telephone traffic carried on satellites has declined to an amount of about 30%, while in the 1960s a single satellite could have a capacity almost equal to that of all of the RF/coaxial cables laid under the Atlantic Ocean up to that time. In the year 2000, satellites are the prime means of distributing television pictures around the globe, either to cable head ends or directly to subscribers. Satellites are, at the end of the 20th century, also increasingly being used to provide private data networks for companies (such as banks) that have widely distributed offices. This service usually involves a central large (hub-)station linked to many very small aperture terminals (Evans, 1999).

The full blending of broadcasting, internet, telecommunication and computing facilities and the merging of the Broadcasting-Satellite and Fixed-Satellite Services, indicate that satellite applications are likely to remain for broadcasting since by that the other functions mentioned can be provided. Geostationary satellite systems are preferred for broadcasting direct to the home because of technological simplicity. Satellite radiocommunication is likely to remain important for navigation and surveying purposes and for safety-of-life services.

From this perspective, it is likely that spectrum can be freed by reducing the allocations to space services, i.e. the Mobile-Satellite and Fixed-Satellite Services.

The blending of Fixed and Mobile Service applications will also lead to more efficient spectrum allocation, which is enhanced by increasing the communication capacity per Hertz due to the improvement of transmission and reception techniques.

Other developments are the increasing use of very wide band systems which may have bandwidths of about 50% of the frequency of operation. This shows that the bandwidth requirements per application may change. This development may lead to an increase of incompatibilities between different services since the bandwidth usage characteristics and requirements are different for different radiocommunication services. Efficient frequency allocation management must be applied to avoid sharing between incompatible services in this regard.

The increasing demand for the aforementioned new broadcasting applications require, on the basis of current technology, an increase of high-density applications. This development adds to the demand for exclusive use of spectrum because of sharing difficulties for these high-density applications. However, we may not dwell too long on this consideration since technological development will certainly find a solution for this.

Given the nature of scientific research and physics, it is not likely that the spectrum demand for scientific applications will reduce significantly. However, it is not impossible that some scientific application may prefer different frequencies than are now used. That this perspective on spectrum development differs from non-scientific applications, is due to the fact that for most of the non-scientific services the frequency choice is much less critical than for scientific research: the latter must select the radio frequencies because of the scientific question and the laws of Nature.

These developments in radio frequency requirements must lead to a reduction of the fragmentation of spectrum allocation.

Furthermore, it can easily be noted that the telecommunication development in developing countries is different from that in the well-developed countries. The reason for this is obvious: the developing countries will certainly lack money for the implementation of expensive telecommunication infrastructure and systems, while on the other hand areas of very low population density make any such implementation commercially not attractive (not even for satellite-based communication systems). In mid-1999, the number of telephone connections per 1 000 inhabitants in developing countries was about 0.5% of that in the developed countries.

A similar ratio is observed for television sets or newspapers, as statistics provided by the World Health Organisation and the World bank show. This imbalance between developing and developed countries is recognised by the ITU, but it is unlikely that within 25 years the discrepancy between these two cultural levels will decrease: on the contrary, the noted gap appears to become bigger and may even change geographically.

Such regional differences in telecommunication development imply that the characteristics of scientific interest in radio frequencies will also show regional differences.

In summary, our perspective on the situation after 25 years is the following:

- significantly less radio spectrum is allocated to the Mobile-Satellite Service and to the Fixed-Satellite Service;
- the spectrum demand of the Fixed-Satellite Service is significantly reduced;
- terrestrial services remain well-developed but some are blended, such as the Fixed and the Mobile Services, which implies reduction of spectrum allocated to these services individually with respect to the situation in 2000;
- there are more exclusive radio frequency allocations;
- the fragmentation of the frequency allocations is reduced, leading to a more efficient use of the radio spectrum;
- regional difference between the requirements and use of radio frequencies remain, which is reflected in the ITU Radio Regulations table of allocations. However, the geographical distinction of radiocommunication regions may have changed since the economic-political characteristics are intrinsically dynamic.

8.2. Technological development

Superficially, one may note that non-scientific users of the radio frequency spectrum are apparently more concerned about the quality of their signal channel from transmitter to receiver than scientists, because of the significant commercial implications. This quality includes the spectrum efficiency and purity of the signal. For commercial companies and industrial enterprises this quality can be a matter of survival of the organisation in the battlefield of hard competition. Scientists on the other hand consider themselves much less under such pressure because their motivation and interest is driven by the scientific question they explore. However, real life does also affect their view on system development, design, construction and operations.

8.2.1. Outside science

Current commercial pressure and hard competition lead to a practice of priority for a specific industry regardless of other users of radio frequencies. This is especially noticeable in the current practice that for space systems operating in the fixed-satellite and mobile-satellite services no mitigation factors are considered and all the burden of compatibility issues is put on the terrestrial services. The next decades will see more regulations to address electromagnetic compatibility issues. Regulations for space systems will especially require more attention because interference experiences by industry implies that the current regulatory gaps providing relative freedom for the mobile-satellite and fixed-satellite industry need to be filled. The telecommunication industry is becoming adequate mitigation techniques to provide a reliable service to the end user. At the time of writing, this aspect has hardly taken hold, but industry cannot avoid developing of its products to be less vulnerable to interference. Such a development may well lead to a product quality with the level of safety margins of e.g. airplanes, because spectrum pollution implies direct impact on the quality of life: pollution means that essential communication systems and applications using radio frequencies become unreliable and related malfunctioning of equipment may well have great impact on the cultural, health and social aspects of society.

8.2.2. Scientific applications

Scientists, and radio astronomers in particular, intensively study new directions in system design to build instruments which are more interference robust. However, the driving force for this work is not the changing radio environment but the scientific need for systems with much better sensitivity and better angular resolution. The physics of the Universe implies that besides research within radio frequency bands allocated to the radio astronomy service much work must be done outside these bands in an environment with much interference. Research in interference-free frequency bands remains a matter of the highest priority to achieve maximum sensitivity and to ensure the adequate calibration of the instrument used.

This view on the development of scientific instruments is not new and in fact has been in daily practice for decades. However, the pressure on the radio spectrum urges scientists to consider questions such as how can one build an instrument and at the same time address the question of how one is supposed to discover what has to be rejected experimentally when building the equipment?

Much research is in progress on new antenna systems for scientific instruments and improvement of calibration technology. However, the research on techniques to suppress RFI in frequency-, time-, space-, and multi-interferer domain is still in its infancy. Methods must be found to answer the following questions:

- how can one determine the characteristics of the interference with an instrument that has been built for a different purpose?
- if one knows the modulation scheme of the interfering source, is one able to remove the interfering signal? If that is the case indeed, how can one determine from the observed characteristics the modulation scheme?

At the time of writing this document, the author considers that the answers to these questions are still far away.

Before any adequate answers are found to the questions just mentioned, any real research on mitigation techniques is premature. Nevertheless, it is urgent that mitigation techniques for experiments outside radio frequency bands allocated to a science service are developed. However, before doing so, one has to consider what is meant by ‘mitigation technique’ (section 13.1.2).

It is obvious that these considerations are fed by the situation at the time of writing this document and that research is inevitably progressing. However, one conclusion should probably be made in any case:
Scientific research faces in the year 2025 an environment with more harmful interference and scientists do not have the tools to avoid or remove this.

The simple reason for this is that technological development outside the realm of science is also advancing but not in coordination with scientific development. It is impossible to design and build instruments that are robust against all harm, i.e. unknown or unanticipated at the time of design and construction.

We believe that the comments on radio astronomy apply to other scientific applications using radio frequencies.

8.3. Administrative development or the ratio between public and private sectors

A significant development, which began in the 1990s, was the changing telecommunication legislation to stimulate privatisation and competition. To a large extent this process goes hand-in-hand with a process of de-regulation and convergence in regulation, such as the grouping of different industries into one industry with one regulator (e.g. Malaysia Act 1999). New legislation has given rise to new, separate telecommunication regulatory agencies. The governing structure of the new separate regulators, despite significant national and regional diversity, seems to point to a new model for telecommunication regulatory bodies.

While in the view of the ITU (ITU, 1999) the increase in regulators and legislative reform is certainly encouraging, new technologies and services are moving faster than the bodies that regulate them. Convergence is not a simple issue for telecommunication regulators. The challenge is to determine ways in which to regulate technologies that are continuously evolving and, more importantly, to determine the role of the regulator in a converged sector. The challenge for regulators is to develop consistent and relevant regulation that does not inhibit the growth of the sector, but rather encourages technological innovation.

This ITU perspective complies with the view on radio frequency management restricted to the commercial, monetary and industrial aspects of the radio frequency spectrum (section 2.1). It is noticeable that many Administrations adhere to this point of view. However, one may also consider that the ITU perspective reflects the common view of its members and their governments.

8.4. Science in 2025

During the next decades, scientists will increasingly face a view on radio frequency management restricted to the commercial, monetary and industrial aspects of the radio frequency spectrum. They will have to explain that the radio frequency spectrum is *not* limited to these aspects, although they certainly are of major importance. As we indicated in section 2.1, the intrinsic meaning of "management" is "*the sparing or frugal mode of administering scarce resources to serve all humankind*" (Dooyeweerd, 1969). This view holds certainly in any case for radio spectrum management.

In the world of commercial force and pressures, the interest of passive use of radio frequencies by science services is expected to be low to negligible.

Scientists should not expect more radio frequency bands to be allocated to science services. They must accept that as with other users of radio frequencies, frequency management – the work to prevent and remove harmful interference – is an expensive and immense effort, which will constitute a much larger part of their work than in the mid-20th century. The cooperation between scientists and Administrations should be intensified and improved since both parties, the user and the Administration, need each other for sound frequency management.

9. What management tools do scientists have?

Scientific users of radio frequencies are private legal entities, which have to obey the law regulating frequency allocations, frequency assignments and frequency allotments. As private legal entities, scientists have no tools to manage the regulatory aspect of frequency management which belongs in fact to the mandate of the Regulatory Authority of a sovereign country.

However, this is only a part of the story.

The other part is that in radio spectrum issues the Administrations having regulatory responsibility also have the facilities to improve the radio frequency situation and environment for the scientist when the circumstances demand this. These circumstances may vary, from the request to remove radio interference to guidance when the project requires the use of a frequency for which no allocation to the science service exist. In countries with a well-profiled scientific community, Administrations are usually very receptive to questions, requests, information and other communications from the scientific community. This is partly related to the fact that scientific research is usually funded only by public money and also that scientific frequency usage is rather vulnerable to interference and the impact of pressure by non-scientific radio spectrum users.

Furthermore, in collaboration with the national and regional Administrative bodies, scientists also have the opportunity to influence the radio frequency environment. In Europe, CRAF is very active in this respect and a number of positive results can be noted.

Another aspect the scientist must not forget is that in designing, building, maintaining and operating his equipment he should take the opportunity to reduce its susceptibility to interference and improve the robustness of the system.

It is highly recommended that in using these tools, scientists cooperate intensively with their expert organisations. In the case of radio astronomy and remote sensing these are e.g. IUCAF, CRAF and CORF.

Besides these Administrative and technical-operational tools, no other management tools are immediately at his disposal. However, when the scientist is using these tool in an optimum way, no more may be needed. One may object that this is not sufficient and that scientists should improve their political profile and influence at national and international level. Although this is very true, such a political action is not spectrum management as such but rather lobbying for a desired objective.

Figure 9.1 summarises the conclusions of this chapter.

Collaboration with national and international Administrative bodies
Improvement of hardware and software of scientific instrumentation
Collaboration with expert organisations, e.g. IUCAF, CRAF, CORF

Figure 9.1: Spectrum management tools for scientists

10. With what harm can we live?

Harmful interference is commonly quantified in terms of the power level, which exceeds a specified level received from a transmitter. However, this parameter is not completely practical in compatibility issues in which interferers with variable time and location must be considered. Separation distances may alleviate this problem, but in coordinating radio astronomy stations statistical methods may be used. Input for such methodologies requires quantification of e.g. the tolerated percentage of data or time loss due to interference. In this chapter some ideas on tolerated losses are given for radio astronomy and other passive services applicable for frequency bands shared with other services.

Some frequency bands are passive exclusive bands, such as the band 1400-1427 MHz which is allocated to the Earth Exploration-Satellite Service (passive), Radio Astronomy Service and Space Research Service (passive). In the ITU Radio Regulations footnote S5.340 is added to such bands which states that for that specific frequency band all emissions are prohibited. This footnote applies to all purely passive bands in the radio frequency spectrum. It does not state that all *transmissions* are prohibited, which would address an assignment/allocation issue, but rather relates to emissions, which is always related to some transmitting station. The ITU Radio Regulations do not provide a definition for transmission nor an explanation of the difference between emission and transmission. Nevertheless, the first conclusion is, that it is forbidden to assign station in a frequency band to which footnote S5.340 applies. In relation to the assignment of frequencies to stations adjacent to the relevant frequency band, the decision below shall apply in conformity with the ITU Rules of Procedure (ITU 1998b, part A1, section ARS4):

"To resolve cases of harmful interference between services in adjacent bands it was decided that, irrespective of the phenomena at the origin of the interference (out-of-band emission, intermodulation products, etc.), the administration responsible for the emission overlapping a non-allocated band shall use appropriate means to eliminate the interference."

10.1. Radio astronomy

An important parameter in sharing the radio spectrum between the radio astronomy service and active services is the percentage of observing time lost to interference. In coordinating radio astronomy stations with active service operations, e.g. by using statistical software tools like the Monte Carlo methodology, Administrations need a quantification of this parameter. Existing limits to time losses tolerated by various other services in ITU-R Study Group 7 are given in Figure 10.1.

Radio telescopes are designed to operate continuously, following a schedule of observing programmes requested by astronomers. As a rule, access to radio telescopes is on a competitive basis, with research proposals often exceeding available telescope time by a factor of two or three. Virtually all radio astronomy installations are operated out of public funds, and must be used very efficiently. Some loss of observing time resulting from maintenance or upgrading of hardware or software, however, cannot be avoided.

Earth Exploration-Satellite Service, 3-D sounding for forecasts	(Rec. ITU-R SA.1029)	0.01%
Earth exploration, near-Earth spacecraft	(Rec. ITU-R SA.514)	0.1%
Meteorological satellite service	(Rec. ITU-R SA.1161)	0.1%
Space operations systems S/N > 20 dB for > 99% of time	(Rec. ITU-R SA.367)	1.0%
Broadband passive sensors in spacecraft (looking down)	(Rec. ITU-R SA.1029 and Rec. ITU-R SA.1166)	1.0 - 5.0%

Figure 10.1: Examples of time losses tolerated by radio services other than radio astronomy in ITU-R Study Group 7

In order to achieve such results, other services will have to design their individual systems and to control their operations to an appropriate fraction of these figures. Prudence dictates that individual systems exhaust only a fraction of the interference budget, depending on factors related to the actual allocation situation, such as band sharing and the interference potential due to unwanted emissions from other services.

The advent of radio services using space stations and high-altitude platforms requires some reassessment of the measures by which the radio astronomy service is protected from interference. Frequency sharing with such services is normally impossible, but potentially negative effects upon the radio astronomy service by services in other bands arise in two ways:

- unwanted emissions falling in bands allocated to the radio astronomy service;
- intermodulation and departures from system linearity in radio telescope systems due to strong signals in adjacent bands.

It is generally assumed that the satellite operators will use all practical means to minimise unwanted emissions, and radio astronomers all practical methods to minimise sensitivity to signals in adjacent bands. Nevertheless, the second problem will be an important consideration when allocating bands adjacent to or close to bands allocated to the radio astronomy service.

The emissions studied in radio astronomy are Gaussian white noise. The measurements are either broad band measurements of integrated flux and polarisation over an entire frequency band allocated to the radio astronomy service, or of spectral structure within that band. In many instances there is little time-variability in the properties of the emission over time-scales shorter than a day. In order to improve the signal-to-noise ratio, observations usually involve integration of the signal over seconds, hours or even days. However, some emissions consist of short pulses or bursts, where simple integration is not appropriate; the radio emissions from pulsars, often of the Sun and of Jupiter are examples. In such cases it can be very difficult to distinguish the desired astronomical signals from impulsive interference. But also in measurements requiring long integration times, it can be very difficult to distinguish the desired astronomical signal from interference, particularly when it is manifest as a low intensity background with little variation in time.

Whenever data loss is mentioned in this document, it refers to data that has to be discarded, because it is contaminated by interference above the levels of Recommendation ITU-R RA.769 from one or several sources. Data loss may result from loss of part of the observing band, or part of the observing time. Both of these can be expressed as loss of effective observing time.

An observing session may consists of a series of shorter observing units of minutes, duration to more than 12 hours depending on the instrument used and on the requirements of the scientific project. After the observing session these units, or fractions of them, are weighted for data quality, or deleted if unusable. If the measurements are of a single position in the sky, as in measuring the strength of a weak, discrete radio source, the usable blocks will then be incorporated into an overall average. Lost observing time then translates into a poorer measurement that might be unusable. If mapping is being done, lost observing time results in lost detail on the map and a possible need to redo part or all of it.

There are two aspects to the issue of loss of observing time due to interference to radio astronomical observations that must be considered. In other radiocommunication services these are the needs of the customers during a budgeting period. The equivalents for a radio astronomy facility are:

- The amount of time during an observing session that is lost due to interference. In the simplest case it is that which is blanked by interference. However, saturation of the receivers and other equipment used to process and record the data obtained can lead to greater loss than just the time interval actually occupied by the interference.
- The amount of available observing time at any observing facility that is negated by interference over an operating year. This may not in all cases be the same as the first point because some interference problems might be avoided through appropriate scheduling of observations and maintenance.

There are two further burdens caused by interference to radio astronomical observations:

- the amount of time and effort spent *after* the observing session exorcising the effects of interference from the data. This often far exceeds the loss of observing time that the interference itself causes during the observations;
- as the amount of interference increases, the probability of weak interference not being identified also increases. In addition, the more processing is needed to make data usable, the greater the risk that erroneous conclusions will be drawn from the data.

10.1.1. Interference due to variable propagation conditions

We consider the following scenarios of interference due to variable propagation conditions:

10.1.1.1. Transmitters beyond the horizon

In cases where the strength of an interfering signal varies as a result of time-varying propagation conditions, a percentage of time must be specified for propagation calculations. A figure of 10% is given in Recommendation ITU-R RA.1031-1. However, this does not automatically lead to a 10% data loss for radio astronomy observations. Propagation conditions vary episodically, typically over a time-scale of days. It should therefore be noted that over periods of weeks at a time, the period for which data are contaminated by interference might be a few days. These effects occur primarily at longer wavelengths. Hence, periods of data loss can be reduced by dynamic rescheduling to about 1%.

10.1.1.2. Transmitters under line-of-sight

For transmitters under line-of-sight, e.g. airborne or space-based transmitters, the variability of propagation conditions is negligible compared to the signal strength, and therefore does not need to be considered.

10.1.2. Interference from transmissions variable in time and location

For the present analysis we identify the consequences of interference from transmissions variable in time and location and quantify the extent to which this harm can be tolerated:

10.1.2.1. Sharing of a frequency band

10.1.2.1.1. Terrestrial transmitters

Radio telescopes are operated continuously. Loss of observing time due to interference is to be avoided. However, some small loss is inevitable. An example is the emissions from mobile (Earth) stations in the mobile (satellite) services, where the location and activity of individual users cannot be fully controlled. An acceptable maximum level of data loss from such a system is 2%. This sharing scenario is dealt with in Recommendation ITU-R M.1316, which also asks for agreed input parameters. This figure of 2% may be used.

10.1.2.1.2. Space-based transmitters

Sharing with satellite downlinks is not possible in bands where the radio astronomy service has a primary allocation. Hence there should be no data loss from this source.

10.1.2.2. Unwanted emissions into a radio astronomy frequency band

10.1.2.2.1. Terrestrial transmitters

In coordinating radio astronomy stations with the stations of other services operating in frequency bands outside a radio astronomy band, filtering of transmitters and geographical separation should be considered to suppress unwanted emissions into the radio astronomy band to below the Recommendation ITU-R RA.769-1 threshold levels at the location of a radio astronomy station. However, there is a potential for interference when the beam of a radio telescope is pointed closer than 19° to a terrestrial source. The levels in Recommendation ITU-R RA.769-1 are based on the assumption that the interfering source is at the 0 dBi contour. As can easily be understood, a terrestrial source on the horizon (elevation = 0°) can cause detrimental interference in up to 1.8% of the visible hemisphere for a telescope that points within 5° of the horizon. Some sources of interference are known and can be avoided. A practical level of 2% data loss can be expected from a terrestrial source on the horizon.

10.1.2.2.2. Space-based transmitters

Space-based transmitters have the potential to cause extensive harmful interference to the radio astronomy service through unwanted emissions into a radio astronomy band. It is extraordinarily difficult to reduce the data loss suffered by the radio astronomy service from unwanted space-based transmissions even in primary radio astronomy bands. For example, even a satellite transmitting at the harmful interference limits defined in Recommendation ITU-R RA.769-1 blocks 5.5 % of the visible hemisphere of the sky. If the orbital elements of the satellite are known, the radio telescope may be scheduled to avoid observations within 19° of the satellite position and data loss can be reduced. This rescheduling, however, results in loss of flexibility of telescope use and loss of observing time due to the additional steering time required, and may not be possible in all cases. Rescheduling of observations may be possible for geostationary orbit and slow moving satellites, but fast-moving satellites pass through a cone of radius of 19° around the observing direction quickly. In practice a lower probability of data loss will result. It is expected that the overall effect is approximately 2%.

The practical assessment reviewed above leads to an acceptable aggregate data loss to the radio astronomy service of 5% from all sources. The existence of multiple overlapping sources of interference is a practical aspect that must be accounted for. To comply with this requirement, 2% per individual system is a practical limit.

10.2. Other science services

Time losses tolerated by radio astronomy have been indicated in section 10.1 in detail. The reason for this amount of detail is that at the time of writing this document, the radio astronomy criteria were developed only in 2000 and have not yet been integrated in many publications. The criteria for radio services other than radio astronomy in ITU-R Study Group 7 has been explained already in more documents and are summarised in Figure 10.1. It should be noted that the structure of the argument is similar for all services in ITU-R Study Group 7 but with their specific articulations.

10.3. Regulating tolerated loss

When a fraction of percentage of time loss is tolerated by a radiocommunication service this should not be interpreted as if this service is happy to accept a regulation in which this time it is unprotected. Just as with road traffic, to prevent the number of accidents exceeding a certain percentage, less stringent precautions need to be taken than when trying to guarantee absolute safety. Therefore, in regulating a tolerated fraction of time lost due to interference one could approach the protection by considering that the interfering transmissions remain below the interference threshold applicable to this service all the time, but that this threshold does not guarantee 100% protection since daily practice within the accepted thresholds implies an already accepted fraction of lost time.

For further details on this issue: see Recommendations ITU-R RA.1513

11. Passive versus active: the sharing problem

According to the terminology of the ITU Radio Regulations, *frequency sharing* occurs when a frequency band is allocated to more than one radiocommunication service both of which have a primary status in that particular frequency band. When a service a secondary status has in that band, it cannot interfere with the primary service nor claim protection and must accept interference from a primary service unless some conditions have been put on that primary service. A situation of a radiocommunication service with a secondary status in a frequency band, in which other services have a primary status, is not called a sharing situation.

It is obvious that a sharing situation implies a potential threat of harmful interference. This is especially true when active and passive radiocommunication services share the same frequency band. The requirements of the passive service and of the active service are usually very different, which adds to the complicated issue of sharing.

Relation between radiocommunication services	**Sharing situation**	**Potential threat of harmful interference**	**Coordination required/recommended**
1. Frequency band allocated to more than one service, i.e. these services have a primary allocation	1. yes	1. yes	1. yes – seek advice of Administration
2. Frequency band is allocated to secondary service	2. yes	2. yes, but secondary service has no right to complain	2. yes – support by Administration depends on good will of these Administrations only
3. Frequency band is not allocated but used by a Radiocommunication service on the basis of an ITU-R footnote	3. no	2. yes, but secondary service has no right to complain	no – support by Administration depends on good will of these Administrations with respect to the victim radiocommunication service
4. Adjacent band is used in which the service has no regulatory status	4. no	4. no, but out-of-band or spurious emissions may occur when systems are not designed properly	4. no – but in case of harmful interference from out-of-band or spurious emissions, the victim may submit a formal complaint to the national Administration.
5. A frequency band is used in which the service has no regulatory status	5. no	5. yes – the victim service has to accept this situation and to try to find a solution	5. no

Figure 11.1: possible mutual relations between radiocommunication services

Figure 11.1 summarises the possible mutual relations between two radiocommunication services and the potential threat of interference. It must be noted that the sharing concept never applies to protection from out-of-band or spurious emissions. It this case the issue is rather a *compatibility issue*. Such an issue should not be solved as if it were a sharing case. If this happens, this solution is a pseudo-solution that may relieve the interfering service from taking adequate measures to protect the victim service and it creates easy precedents and dilutes the public legal nature of the regulations that apply.

In a sharing situation harmful interference of one radiocommunication service with the other with which the frequency band is shared can be avoided when these services are adequately coordinated. Such coordination is usually accomplished by, or under, the auspices of a National Regulatory Authority. In regional coordination issues usually regional Administrative organisations play a role, such as the CEPT for Europe.

Coordination method	Impact on interfering service	Impact on victim service
1. Coordination area – applicable only to terrestrial interference situations.	1. Within the area around the associated Earth station the interfering emissions must not exceed a permissible level. The interfering service must implement the technical means to achieve this.	1. Operations of the victim service unharmed down to the permissible level of emissions from the interfering service.
2. Maximum transmitter spectral power flux density.	2. The interfering emissions from the interfering station must not exceed a specified spectral power flux density. The interfering service must implement the technical means to achieve this.	2. Operations of the victim service unharmed down to the permissible level of emissions from the interfering service.
3. Time sharing between interfering Earth station and the station of the victim service – it should be noted that the time – sharing scenario as such is not defined in the ITU Radio Regulations.	3. Operational constraints for interfering station.	3. Operational constraints for station of the victim service.

Figure 11.2: Possible coordination methods

In the coordination process, operational or regulatory solutions are sought to enable both services to operate in the frequency band, although under certain restrictive conditions. Such conditions may imply the implementation of the coordination area concept. According to the ITU Radio Regulations, a *coordination area* is the area associated with an Earth station outside of which a terrestrial station sharing the same frequency band neither causes nor is subject to interfering emissions greater than those at a permissible level. Another option to solve a sharing problem is to set an *upper spectral power flux density limit* (mask) on the transmissions of the interfering source. It must be noted that this limit must always be an aggregate limit. A third option is *time-sharing*. This means that when two services are incompatible with each other, i.e. they cannot operate simultaneously, the Regulatory Authority specifies when each of them can operate without interference and when one (or more) of them has to cease operation or accept interference.

The following explanatory comments can be made on the sharing scenarios :
Geographical sharing means that a coordination area is defined and installed in such a way that an Earth station outside this area sharing the same frequency band with the station used by the scientific application neither causes nor is subject to interfering emissions greater than those at a permissible level.

Time-sharing means that time constraints are put on the operations of an interfering Earth station and the station used by the scientific application sharing the same frequency band in such a way that each of the stations operating at the same time as the other station, neither causes nor is subject to interfering emissions greater than those at a permissible level. This means in practice that each of the affected scientific stations will blank its reception at the presence of transmissions by the other station, while at other agreed times the transmissions by the active station are prohibited. It is obvious that time-sharing has the potential for many operational difficulties and certainly cannot be applied widely because of the characteristics of the services involved. Time-sharing attempts between a radio astronomy station at Bologna (Italy) in 1992 and nearby broadcasting transmitters show that when the commercial interests are strong, time-sharing is not a practicable option.

The sharing issue is particularly difficult and complicated for space-to-Earth transmissions that interfere with terrestrial stations. In many cases, the satellite operator considers that when the terrestrial station is outside the footprint of the downlink transmissions, the terrestrial station is protected. This may be true for some systems, but certainly not for those using active antennas, because the transmissions through the sidelobes of such systems are beyond control. This implies that a terrestrial station is protected when the space station is not visible from the terrestrial station. Similar arguments apply for high altitude platform stations (HAPS) and aeronautical stations.

Scientists often argue that the number of stations they operate in an affected radio frequency band is small. Apart from the fact that for the radio astronomy service this statements does not need to be made since it is explicitly explained in the ITU Radio Regulations (Article S29.4), it should be noted that it is an irrelevant criterion in the protection of a radiocommunication service to consider whether the number of stations operating in that service in a specific frequency band is large or small. However, this qualitative (i.e. not-quantified) statement may help to add political weight to some arguments. Furthermore, it must be noted that what is true in one part of the world may not be true in another, because of obvious geographical conditions and the uneven geographical distributions of the stations in that service. The argument that the number of radio stations in some service is small may also be converted into the undesirable argument that less protection requirements are necessary for that affected radiocommunication service.

12. Questions and answers

In discussions between scientists and other users of radio frequencies, the following questions are often asked:

Questions raised by active non-scientific users or Administrations to scientists:

Question 1: **Is site-specific coordination with radio astronomy stations a mitigation factor in coordination issues with space systems?**

Answer 1: Dependent on the antenna system of the space station, coordination with radio astronomy stations could be sought considering the footprint of the space station or the visibility of the space station. The usual dimensions of such a footprint imply that emissions from this footprint already shine on several European radio astronomy stations at the same time because of the geographic density of radio astronomy stations in this region. The sensitivity of radio astronomy receivers implies that transmissions through sidelobes of the transmitting antenna of the space station can usually not be neglected, in particular relating to transmission by active antennas. It is therefore not practicable in Europe to coordinate space stations and radio astronomy stations on a site-by-site basis. For other regions similar arguments apply.

Furthermore, VLBI observations require identical coordination for all radio astronomy stations participating in the VLBI network to maintain the VLBI quality.

Therefore, unless other techniques become available, site-specific coordination with radio astronomy stations cannot be a practicable mitigation factor in coordination issues with space systems.

Questions raised by scientists:

Question A: **For scientific reasons, the project requires data obtained at radio frequencies outside a frequency band F allocated to the particular science service. Is this allowed?**

Answer A: When frequencies outside an allocated frequency band must be used, the National Regulatory Authority must be notified and consulted. When this body does not object and it registers the particular frequency usage, the scientific application can proceed. Issues like this occur specifically in broadband experiments that are necessary in for example various projects on solar research.

It must be noted that from the regulatory perspective, observation outside radio frequency bands allocated to the particular scientific service is not usual: in many countries it is tolerated and no objections are made when it is properly coordinated with the Administration. In some countries, however, observing at frequencies not allocated for this application is illegal and scientists must be aware of possible difficulties when they want to make observations outside allocated frequency bands.

Question B: **A scientific station wants to monitor spectrum occupancy, and exchange and discuss the monitoring data with his colleagues elsewhere. Can he do this?**

Answer B: Spectrum occupancy data must not be made public because of the commercial value this information may have for active radiocommunication services. In many countries, it is forbidden by law to publish monitoring data. However, when these monitoring data are used as confidential information for a selected group of colleagues, it may well be acceptable to discuss details and to apply what is learned from them. For this reason, CRAF maintains a radio interference database and a spectrum occupancy database, which can be searched (password protected) via the CRAF website. It is highly recommended that newly obtained monitoring data be included in the CRAF spectrum occupancy database (see section 7.4 for more details)

Question C: **Operator X wants to discuss coordination in frequency band F. What should I do?**

Answer C: Three cases can be distinguished:

(i) the issue has only local meaning:
the scientist can proceed with the discussion. However, he/she should inform his colleagues, sister organisations and the expert organisations relevant to his scientific discipline about these discussions. They may learn from these discussions and also the scientist involved may get guidance for these discussions (which is extremely important). For pitfalls in relation to agreements, see section 7.1.

(ii) the issue appears to have local meaning only but may develop into a regional issue since it is related to applications in neighbouring countries such as a channel plan for broadcasting:
the scientist must not enter in the discussion but inform his colleagues, sister organisations and the expert organisations relevant to his scientific discipline about these discussions. When an issue reaches regional or global importance, the scientist must inform the operator X that a regional or global position will be provided. For this reason he should refer the

operator X to the appropriate regional or global expert organisation. This saves resources for the scientific community involved and also for the operator, since then he needs to only consult one single address.

The background for this approach is to prevent any site-by-site discussion/solution for a specific case, since that can be detrimental for the affected scientific community. For further details, see sections 6.2 and 6.7.

(iii) the issue has immediate regional or global impact:
the answer is the same is in case (ii).

Question D: **The Administration asks to discuss coordination in frequency band F with operator X. What should I do?**

Answer D: Basically an explanatory answer in conformity with answer C can be given. Usually the Administration will understand this and appreciate a regional or global approach because of its potential resolving power. However, if the Administration insists that the scientist or his organisation enters the requested discussions, guidance and support by the expert organisations such as IUCAF, CRAF and CORF must be sought.

13. Misunderstandings

This chapter attempts to answer misunderstandings due to the often very different nature of passive and active frequency use and the very different nature of technical demands of scientific and various other users of the spectrum. For example when in radio astronomy a level of harmful interference of -240 dB ($Wm^{-2}Hz^{-1}$) is understood as a concession to many active users of radio who still see radio astronomy as an art of science fiction, some explanation is needed indeed.

Many misunderstandings exist concerning various aspects of the use of radio frequencies for scientific applications on the one hand and among scientists about the radio frequency spectrum on the other hand. This chapter addresses some of these misunderstandings.

13.1. Misunderstandings among non-scientists

13.1.1. Interpretation of interference levels detrimental to radio astronomy

For the Radio Astronomy Service, the levels of detrimental interference are given in ITU-R Recommendation RA.769. At the time of writing , such criteria do not exist for the other scientific applications of radio. Non-scientists often state that these levels are worst-case parameters and that in actuality radio astronomers can accept higher interference levels. This is heard particularly among representatives of industry. The reason for this misunderstanding is obvious: in industry and the field of telecommunication, these levels are so much lower than in radiocommunication daily practice that it is hard to believe that they are realistic. Even today there are people who consider radio astronomy a science fiction. Such a view results in a large part from ignorance about the science of radio astronomy.

However, it must be noted that the levels of detrimental interference published in the aforementioned mentioned ITU Recommendation, are *not worst-case values* but even more, they are a *major concession* to active users of the radio spectrum since state-of-the-art radio astronomical observations show sensitivities reached at levels which are more than 3 orders of magnitude lower than those published in the ITU Recommendation. The radio astronomy community should consider giving more explanation in this Recommendation on how it should be interpreted and used. Furthermore, the levels given in the ITU Recommendation refer to interference received by the sidelobes of the radio telescope. This indicates the second concession: the interference received by the main beam of the telescope is disregarded, so that radio astronomers give away a part of the sky. According to ITU-R Recommendation RA.769, the sidelobes by which interference is received are outside an angle of 19º from boresight. This implies that for each space- or airborne interfering source visible from a radio astronomy station, about 6.5% of the visible sky is given away to the interfering source. Thirdly, it must be noted that the levels of detrimental interference published in ITU-R RA769 refer to terrestrial sources of interference. The Recommendation gives guidance in considering interference from geo-stationary satellites but not for non-geo-stationary and airborne interfering sources.

13.1.2. Mitigation

When considering the idea of mitigation, the assumption is usually made in the non-scientific community that when appropriate mitigation techniques are implemented at the scientific radio station, the scientific experiment can *effectively* tolerate interference above what is considered to be its level of harmful interference. Furthermore, the conclusion from this assumption is that when mitigation techniques are properly implemented, a scientific application does in fact no longer need an interference-free frequency band.

The concept of mitigation is often misunderstood. In the ITU Radio Regulations, the concept of mitigation is not defined. In an attempt to improve our understanding of mitigation, we make the following observations and assumptions:

- mitigation is considered to be applicable to the *victim radiocommunication service* to reduce its vulnerability to interference.
- *mitigation* means an adjustment of the equipment in such a manner that it is less vulnerable to interference.
- a *mitigation procedure* is a regulatory measure to regulate the interference vulnerability of a victim service. Such a procedure could be applied in a coordination process.
- *mitigation technology* refers to the technical knowledge enabling the development of *mitigation tools* which could be installed in the equipment to reduce its vulnerability to interference.

It should be noted that when a mitigation technique is found for an application which reduces its vulnerability to interference, one may ask why this was not built into this equipment when it should have been designed properly.

Implementation of mitigation techniques does not apply to the victim service only but also to the interfering source.

Mitigation techniques could be adequate filtering at the transmitter and/or receiver, improved modulation schemes for the transmitted signals, improved antenna characteristics at the transmitting and/or receiving side or sophisticated data-processing techniques at the science service side. However, if work has to be done to develop and implement these, it must be noted that the system was improperly designed initially. Therefore, if there is an occasion of implementing mitigation techniques, the user implementing this must be blamed for his inferior initial system design.

A mitigation procedure could be a regulatory measure as discussed in chapter 11 as coordination methods.

When it has been proved that radio equipment has been designed improperly, one might consider looking for techniques to reduce its susceptibility to interference. The user of the defective equipment must take this action. The application causing harmful interference to a scientific application enjoying adequate allocation status in a frequency band must not question whether the victim service could implement mitigation techniques but must search ways to implement mitigation techniques in its own system until the interference has disappeared. Such work complies with the Preamble to the ITU Radio Regulations, S0.4.

13.1.3. Level of harmful interference

Several ITU-R documents contain levels of detrimental or harmful interference for scientific applications. These levels are usually expressed in dBW/m^2 per bandwidth. This bandwidth can be a couple of kHz, MHz or even GHz. The bandwidth is expressed in a unit typical for the scientific application. It is obvious that in cases of interference the characteristics of the victim service are used to quantify the level of detrimental or harmful interference. However, this level expressed in the associated units may still not be adequate to protect the victim service, especially when a large bandwidth is used in the determination of the level.

We explain this as follows:

Suppose that the power flux level, which to protect the victim service must not be exceeded, is *pfd* dBW/m^2 per *x* MHz in the frequency band *f1-f2* MHz. The value of *x* MHz is typical for the application of the victim service in the frequency band. The assumption could well be that the victim service is protected if the level of *pfd* dBW/m^2 is satisfied at a frequency of 0.5x MHz from the band edge. At the band-edges, *f1* MHz and *f2* MHz the victim services is supposed not to complain if the deviation is ± X dB to satisfy the condition that on average the interference does not exceed the specified level within the given bandwidth. It should be noted that the value *pfd* dBW/m^2 has been determined for a reference bandwidth of *x* MHz. Thus the assumption that the victim service is adequately protected if the level of *pfd* dBW/m^2 is satisfied at a frequency of 0.5*x* MHz from the band edge may be correct only if in the application an uninterrupted bandwidth of *x* MHz is used. In practice, the application of this bandwidth may well be divided into several smaller bandwidths, which at a later stage are combined to cover the whole bandwidth of *x* MHz or even *f2-f1* MHz.

Protection of a victim service means in any case protection at the edge of the frequency band. This implies that the reference bandwidth related to the maximum power flux density level to protect the victim service should be optimised to guarantee this protection at the edge of the frequency band. To achieve this, one could consider taking the spectral characteristics of the interfering source, i.e. its bandwidth as the relevant reference bandwidth. Usually the bandwidth for the interfering application is narrower than for a broadband scientific application. If that bandwidth is taken as a reference bandwidth the victim service is better protected possibly even at the edge of the frequency band.

13.2. Misunderstandings among scientists

13.2.1. Monitoring and measuring spectrum occupancy

It is often said that an instrument that is fully dedicated to measuring the intensity as a function of radio frequency, can monitor interference. At some radio astronomy stations such equipment has already been installed and is in operation. This equipment is not used for radio astronomical observations but for spectrum measurements only.

By ITU-R definition, interference is "the effect of unwanted energy due to one or a combination of *emissions*, *radiations*, or inductions upon reception in a radiocommunication system or loss of information, which could be extracted in the absence of such unwanted energy". This implies in the case of scientific applications, that interference is noted in the measurement data of the application as an unwanted signal, which corrupts the information, which must be read from the data. Therefore, dedicated monitoring instruments do not reveal interference harmful to the scientific application but give information on the occupancy of the radio spectrum interval measured by that instrument. From the perspective of the scientist, this monitoring information is, however, very useful, for example for scheduling purposes and experiment planning.

13.2.2. Mitigation

When it has been proved that radio equipment has been designed improperly, one might consider looking for techniques to reduce its susceptibility to interference. It must be noted that some scientific instruments suffer from improper design, and it is a matter of good faith that these defective instruments are improved so that the scientific application can operate interference-free in conformity with allocation status in the radio frequency band used and an obligation to conform with ITU-R Regulations Article S29.7, which states

> *"All practicable technical means shall be adopted at radio astronomy stations to reduce their susceptibility to interference. The development of improved techniques for reducing susceptibility to interference shall be pursued, including participation in cooperative studies through the Radiocommunication Sector".*

A different situation exists when the application is used in a frequency band not allocated to the science service operating it. In that case, mitigation techniques could be sought to enable experiments in such frequency bands.

However, when scientists look for mitigation techniques in a radio frequency band allocated to the particular science service on the assumption that it will help them, they basically relax the level of harmful interference in favour of the service causing interference. Such an action is not needed when with proper collaboration with the National Regulatory Authority the interference issue can be solved. It seems improper to us that scientists publish what they think their mitigation techniques can do for them, without making clear that their system design has already met an adequate state-of-the-art technological level and complies already with ITU Radio Regulations Article S29.7. If scientists are not sufficiently accurate in this respect, Administrations and non-scientific users of the radio spectrum might deduce from this that scientists are incapable instrument-builders and that their published protection requirements are over-demanding. An exception is if the equipment had been designed and built when it was impossible to know that a new application of radio could cause interference (see also section 6.1). This statement holds especially for frequency bands with an exclusive allocation to science services, since that band has a status enabling the particular science to do its experiments at the maximum possible sensitivity and to enable adequate calibration of the scientific instruments.

Part 3

Frequency allocation and management perspective

14. "Modern times"

The assumption made in the previous chapters is that the management of the radio spectrum has a public character because by its nature it is a matter for the public. Spectrum regulation must therefore also have a public character. The public character of spectrum regulation remains unaffected even if a Regulatory Authority refers its execution to a private organisation as happens in some countries. The final regulatory responsibility and enforcement of this law remains by its nature a public issue and an element of the public law of the state.

Since the beginning of the work of the ITU the characteristics of the radio frequency user has changed tremendously. New technologies emerged which were beyond imagination some 75 years ago, space applications were considered science fiction even after the development of rockets at the time of World War II. Radiolocation applications had an impressive development. Since 1932 a new branch of science has been matured: radio astronomy. Atmospheric research uses a variety of new instruments for which access to the radio frequency spectrum is required. Aviation cannot exist today without adequate radio facilities of various kinds. Broadcasting as entertainment developed a quality characteristic similar to other kinds of modern art, both as audio and video. And this list can be extended much further.

14.1. Frequency allocation methodology

The frequency allocation and assignment methodology does not significantly differ from dividing a piece of cake at a birthday party. An ITU-R WRC may allocate a specific frequency band to a service that has adequately demonstrated its need for this band when the operation of other services to which this band might have been allocated are not incompatible with those of the newcomer. This basically simple methodology is fundamentally the same as the one used during the 1930s.

However, the negotiations and discussions in the decision-making process during a WRC become more and more complex and difficult. This shows that modern systems and modern technology add a dimension to this process, which has as yet no proper place in the allocation methodology. Compatibility studies may lead to conclusions that some applications or services may not share the same frequency bands. These conclusions are added to the decision-making process, but usually on an *ad hoc* basis only. In relation to radiocommunication development, the distinctions between the different radiocommunication services are fading but the technological differences between the applications used under these services are becoming more specific. In terms of the birthday cake, the division must not only consider equality of size in the piece partitioning but it must also take the taste and constituents of that potential piece into account to serve the customer properly. The allocation methodology should include consideration of technical/technological characteristics of applications that within the same service might be incompatible with each other, and characteristics of applications in different services that would make sharing more feasible than it was a few decades ago.

Integrated within the whole spectrum management process, the allocation methodology could also include the concept of decay times for allocations. This could enable the development of a structure within which also re-farming of frequencies can find a regulatory place in the ITU Radio Regulations. Such a re-farming process should include an evaluation of the requirements of affected radiocommunication services, plus recommendations from considerations of groups or fora mandated for spectrum management (see section 14.2).

Recognising these aspects, the ITU-R WRC allocation process should consider the allocation of a frequency band to the following parameters on the basis of demonstrated need:

- a radiocommunication service
- a specific technology
- a specific kind of application
- a decay time.

Such a methodology may even develop into a replacement of "radiocommunication service" concept by a "technological category of service".

The ITU-R Study Groups must develop the proper elements for incorporation in such an allocation methodology. The technological elements could ensure the rational, equitable, efficient and economical use of the radio frequency spectrum in the physical and technical sense by all radiocommunication services including the specific case of passive services which would then receive adequate and proper treatment.

14.2. Frequency management for the next 25 years

The changes expected in the radiocommunications environment within the next 25 years call for an in-depth evaluation and improvement of spectrum policy and spectrum management which should include

- changes of policies for spectrum allocations/assignments and consideration of some shortcomings in the existing spectrum management procedures;
- a policy that stimulates the compliance with internal disciplines in user communities, accepted conditions, contract or voluntary soft regulations that could be established by a group or forum of specific categories of radio frequency users;
- the need for transparency in spectrum management can be met by the regulatory society by inviting private entities or forums to participate in organisations such as the ECC.

It is widely recognised that timely access to radio spectrum is crucial to continued growth and success in radiocommunication services.

It is understood that the national and region-wide spectrum policy and spectrum management may need further improvement and development in order to:

- promote spectrum efficiency;
- enhance access to spectrum by a range of users;
- improve the quality of radio frequency use to improve customer satisfaction.

Thereby

- an adequate administration of scarce resource of the radio spectrum, may well lead to:
- facilitating wealth creation;
- broadening competition and choice;
- improving competitiveness.

For non-commercial radio spectrum users it may lead to improved compliance with their requirements and objectives.

The very wide variety of radio frequency users, each with their particular characteristics and requirements which usually cannot be reduced in relation to each other, implies that radio frequency management is by nature a public activity, i.e. serving the public as a matter concerning the public.

Within this public framework, the basis for an efficient use of the spectrum may be an intense competition that is surely reflected in the applications for radio spectrum access to the individual national Administrations or national authorities. It is most important that the national authorities in the decision and licensing process act in such a way that the concerned parties are secured equal opportunities to compete. Therefore, it is important to achieve business fairness for privately funded applications, and for publicly funded radio frequency usage and those for which radio frequency use does not provide financial benefit, a fair judgment during any evaluation or selection process when allocating or assigning spectrum resources.

Business fairness is a necessity, since the imminent convergence of telecommunications services will have an impact on the radiocommunication services. Technical borders between the various radiocommunication services will fade out but significant differentiation may develop within radiocommunication services. Consequently, operators using different networks, such as broadcasting, mobile or fixed multimedia networks together with some of the satellite-related networks will compete in the same or similar market segments. They will be providing the market with a choice of digital information services carried by the available spectrum resource, possibly using similar radiocommunication technologies. Only the contents, availability, interworking possibilities or quality of service may distinguish one service from the other, but this fact calls for equal treatment of the market players.

The same arguments of business fairness can apply to publicly funded radio frequency usage and those for which radio frequency use does not provide financial benefit. Fairness is necessary to give non-commercial users of radio frequencies adequate access to the radio spectrum, which is not overruled by private business interests but handled in a balanced manner.

These new requirements will drive the need for improved regulatory regimes. In such a regime private groups of users or forums could be given a mandate to develop among themselves common positions and views on frequency management issues within clear and adequate guidelines and under the supervision of Administrations. Such groups or forums could be formed by clustering common interests within organisations having spectrum management interests, and a combination of these organisations. In practice guidelines need to exist for both the aforementioned groups/fora, but also for the Administrations/National Regulatory Authorities to provide necessary clarity to strengthen the quality of the management process. National and regional telecommunication legislation and regulation should be adjusted to comply with this new situation.

The telecommunication market is driven by requirements for the free choice of information, entertainment and education and also by requirements for special functions and control systems. The subsequent choice of technology will be determined by a vendor or a group of vendors to meet these particular requirements.

It may well be required that the Regulatory Authority should limit its interventions in the market to a minimum; to monitor the various initiatives; produce the fundamental horizontal framework; and secure business fairness, when allocating and assigning the spectrum resources. The same should apply to non-commercial radiocommunication services. But minimum intervention does not immediately imply that the various parties interested in a radio frequency band should decide amongst themselves who will have access to which part of the spectrum. Only if homogeneous interest groups can be identified may it be necessary/unavoidable that each single group handles the issue itself with guidance given by the Regulatory Authority. Accordingly, one may foresee that the regulatory society will to a greater extent administer large groups of public and private radio systems, and coexistence issues in relation to such groups, rather than the administration of individual independent systems.

14.2.1. Existing spectrum policies

Historically it has been difficult to acquire a share out of the spectrum.

The typical assignment process used to imply:

- that an assignment is free of interference at most times (a noise limited solution);
- a strong reliance on Administrative tools, such as databases containing national spectrum usage;
- a legal framework that is sector specific.

When there are operational deviations from the expected results, in terms of sharing, compatibility and coexistence, subsequent to the assignment, the existing policies lead to difficulties identifying and treating incompatibilities and making corrections; there exist few adequate mechanisms to resolve the uncertainty that occurs.

Spectrum users often find themselves as pawns in a game involving national radiocommunication agencies, the ITU-R, and regional organisations such as the European Commission, CEPT/ECC, ETSI and various other forums. Ambitious spectrum regulators sometimes regard themselves as safeguards for a functioning radio system, or a technology. Such matters should, of course, be left to others devoted to technology and business development and consumer organisations. However, the regulators still have a special responsibility for services related to science, public utilities, emergency and national security, i.e. non-commercial users of radio frequencies. This responsibility must not be put on the back-burner but be given its proper priority.

Internationally, the frequency spectrum is allocated to radio services as given in the ITU Radio Regulations. The historical development of the present Radio Regulations has led to the definition of many service categories and within these categories there are a large number of individual service allocations. It could be asked whether the development of new technologies and variations in demand should lead to a changed framework as these individual allocations tend to restrict flexibility and unnecessarily limit the utilisation of the spectrum.

14.2.2. The shared spectrum environment

In future, coexistence of relatively autonomous operators having access to a common spectrum resource in the space, time or code domains might lead to efficient use, and reuse, of the radio frequency spectrum.

It is argued that manufacturers, operators and other parties concerned have a self-interests in using the natural resource of radio frequency spectrum in an efficient way. However, it is also argued that for these users the commercial interests have higher priority than the *sparing or frugal mode of administering* of radio frequency spectrum. No commercial user of radio frequencies is able to perform this translation. They employ a tremendous effort in developing the business case, involving considerable resources in refining the offered services to meet market expectations. Standard setting, design, field trials, testing and cooperation play a major role in the work to satisfy the various requirements.

With a suitable regulatory framework, adequate EMC Directives and enforcement facilities for Administrations, the work to satisfy the requirements of the end user will improve the efficiency of the actual use of spectrum, without detailed control by the regulators. Industry is far more able than the regulator to judge and respond to the end-user expectations. Efficient use of restricted resources is the key to profitability in every business.

Sharing a common spectrum has traditionally not been possible between services with incompatible requirements, but will become more acceptable through alleviation mechanisms and dynamic spectrum allocation schemes in upcoming technologies. Allowing several applications to share the entire available spectrum, may, under normal conditions, increase the total possible traffic density, since access by everybody to all the locally available spectrum resource will improve the trunking efficiency. The capacity advantage of sharing the spectrum is further amplified when considering effects of typically uneven local traffic distribution within cells and between operators. It is important that technologies and systems are specified in such a way that the individual operators retain their incentive to invest in a denser infrastructure in order to gain capacity.

14.2.3. A voluntary soft regulatory environment

Regulation should be based on a soft regulation policy within a framework that is clear for the user. Such a policy could involve self-assumed ethics (which is often parameterised by commercial interest), agreed conditions, contract or soft regulations that could also be the basis for judging a dispute between the parties concerned. If the self-regulatory system is not capable of resolving a dispute, the parties may subsequently approach the National Regulatory Authority for arbitration.

But how should a self-regulating system work?

Operators and other licence holders selling the same category of services and interested in operating in a shared spectrum, may set up a forum constituted by an agreement according to conditions given by the National Regional Authority for the participating organisations and managed by a management team. Participation in the forum will be stipulated by contractual conditions that state the procedures necessary to safeguard the sharing and operational environment. The agreement will also have to cover the conditions for the right to use the spectrum resources. The involved parties should then be trusted to administrate the operating conditions.

The participating organisations are responsible for developing the conditions, standards or specifications to be used, maintaining the agreement and specifications, correcting errors and improving clarity as the need arises. This forum also handles distribution of relevant information to the authorities. Market structure is undergoing rapid changes in the telecommunications sector, and companies are restructuring to stay competitive. However, the forum conditions should not impose any restrictions on how participating companies organise themselves, nor restrict their opportunities to compete in infrastructure provision or service delivery. Also, the forum conditions should not impose any restrictions on other users of radio frequencies.

Such voluntary soft regulatory systems, as a complement, need agreed procedures to resolve problems, similar to the market surveillance function in the regulatory field. Such problems may involve disputes between the participating organisations or between one of these parties and external entities. Such a dispute-regulation procedure will have to be built upon an agreement between the participating parties. The basis for assessment in a case of operability problems should be the agreed conditions laid down in the contract.

It can be presumed that in most cases of practical operability problems, the parties involved will solve them without delay and without the need of a formal resolution procedure. This has shown to be the case for the Global System for Mobile Communication, GSM, where pragmatic and cost-optimised solutions have been found to solve the problems that have occurred. Where necessary contractual stipulations on how to solve problems may be agreed upon between the parties involved. This may vary depending on the risk potential. Such agreed procedures must be based on fair, balanced and competitive principles – the competitive environment must not be compromised by such arrangements. The parties concerned may find that there is a need to suggest clarifications to the agreement to avoid the problem occurring again.

One should accurately evaluate changed policies for spectrum allocations and assignments that take into consideration some shortcomings in existing procedures. When a party concerned has failed to meet the sharing and coexistence requirements, improved policies able to resolve discrepancies have also been explored.

A changed policy implies that the industry takes on more of the responsibilities, and that there are means to:

- identify cases of incompatibilities;
- resolve incompatibilities;
- propose a course of action.

National Regulatory Authorities should be kept informed either voluntarily by the parties or via a regulated communication process about market development for the parties to enable regulatory authorities 'refarming' of the spectrum under consideration and to adjust the spectrum provided according to customer need.

14.2.4. Changed national and international spectrum policies

With regard to spectrum management the following points may be discussed as a matter of concern between industry and National Regulatory Authorities:

- *transparency:* inviting involved parties, collecting and giving information;
- *openness:* evaluate any opportunity in an unbiased way;
- *business fairness:* impartial and balanced ruling;
- *technology and application neutrality:* standards should be decided by relevant standardisation organisations or by vendors or a group of vendors.

At the European CEPT level the need for transparency can be met by the regulatory body inviting the industry to participate and by placing them on equal footing in the ECC and subordinated working groups on technical and frequency management. However, the CEPT should remain the European regulators body. Accordingly it should be suggested that industry representatives could represent individual companies or organisations. The industry should be allowed full rights and obligations, and should also be sharing the financial burden involved. It is further suggested that industry delegates be allowed the right to vote and to be selected to the chair and secretary positions.

Additional rationales, beyond the need for transparency, would be to have the necessary market and technical expertise available at an early stage in the discussions, so that the consultation procedures may be made more efficient. Regulatory control will still stay with the national Administration that approves the resulting ECC Decision. However, the opportunity for regulators to discuss matters in closed sessions should be retained.

14.3. Managing system defects

A specific aspect of spectrum management is devoted to handling defective systems. Evaluating this, we must distinguish between terrestrial, aeronautical and space systems.

14.3.1. On the meaning of 'defective'

We understand that a defective apparatus is one not satisfying its design objectives or required quality of operation. Defective in the context of radiocommunication systems is defined as generating malfunctioning of other radio systems or system components.

14.3.1.1. Internal system defect

A system is considered to be defective when because of defects, it cannot function according to the requirements set by the design objectives.

14.3.1.2. External system defect

With respect to other systems, a defective system has a degrading impact on the correct functioning of one or more of the other systems. Interpreted in this way, a defective system generates electromagnetic-incompatibility between systems and apparatus.

Following this interpretation, a defective space system is a system that generates electromagnetic-incompatibility with other systems and apparatus. The discussion of defective radiocommunication systems is therefore strictly speaking an analysis of to what extent these application comply with the requirements for electromagnetic compatibility, EMC.

14.3.2. Terrestrial and aeronautical systems

EMC regulation for terrestrial and aeronautical systems is, at the time of writing, well developed. Current practice is that when an application does not comply with this regulation or is electromagnetic-incompatible with other systems or apparatus, action must be taken to solve this issue and clear the noted spectrum pollution.

14.3.3. Space systems

The situation is very different for space systems. The main reasons for this are that reparation of a defect or correcting an electromagnetic-incompatibility of a space application is not possible, and commercial arguments related to the priority given to the survival of the space application operator company. The argument is that new technological development must not be hampered. Nevertheless, it must be noted that with the increasing number of space systems the related EMC issues increase as well (see chapter 7). In designing space stations the radio frequency protection of, and the compatibility with, other systems must be taken into account, as all other radiocommunication systems have to. Commercial and technological limitations may, however, lead to space systems that do not comply with EMC criteria in the same way as they apply to terrestrial systems. One must distinguish the following categories of space systems:

- a space system in which protection of other radio applications has been or will be implemented;
- a space system which is improved to protect other radio applications;

- a space system in which, by design, no protection of other radiocommunication services has been built in;
- a space system which causes harmful interference to other radiocommunication services because of malfunctioning of system components.

It must be noted that electromagnetic-incompatibility between space systems and passive applications, both space and terrestrial are not always due to priorities set by the space industry, but in several cases generated by the allocation status of different space and terrestrial radiocommunication services sharing the same frequency band or in bands adjacent to each other in the ITU Radio Regulations. Another observation that must be made is that, at present, adequate EMC guidelines and regulations are lacking for space systems. This environment harbours a potential for the development of defective space systems. It should furthermore be noted that various spectrum policy positions recently developed by organisations such as the European Commission, EC, have been written primarily from the perspective of terrestrial use of radio (see section 3.5). At international level a view on a regulatory strategy on defective space systems is lacking. In many cases, these defects are known because they generate harmful interference or produce some other negative impact on other systems. We note also that the comments of the ESF Committee in Radio Astronomy Frequencies, CRAF, to the EC spectrum policy document (Appendix 1) have not found any reflection in the final version of the EC Green Paper on this issue.

An adequate strategy for defective space systems and regulatory improvements are of great help to Administrations, especially when there are reasons to expect that the extent and impact of this problem on other applications of radio (space based or terrestrial) is rapidly increasing. In various groups, studies are done to develop technical criteria, which could be fed into EMC regulations. However, a strategy on defective space systems is so complicated that some operators of space applications are reluctant to pay adequate attention to system quality if, in their view, this is not commercially viable. Furthermore, it is general practice that for space systems operating in the fixed-satellite and mobile-satellite services no mitigation factors are considered and the whole burden of compatibility issues is put on the terrestrial services.

As noted in the introduction, a view on a regulatory strategy for defective space systems is lacking. Also, adequate EMC guidelines and regulations for space systems are not available.

In the examples given chapter 7, the acuteness of the impact of the defective systems has been removed by different measures:

- the body currently responsible for the maintenance of the TEX satellite has taken measures to keep the satellite silent by operational action at ground stations;
- GLONASS is improving its system to improve compliance with the ITU Radio Regulations and the protection of the radio astronomy service;
- Motorola Inc and Iridium LLC have made agreements with radio astronomy entities to regulate the pollution generated by the Iridium system. This approach obviously does not comply with the ITU Radio Regulations and generates regretable precedents that may dilute the status

of the ITU Radio Regulations and ultimately of an international treaty (section 3.1.2). However, since a clear view on EMC guidelines and regulations for space systems and a strategy for defective space systems is lacking at entities such as the World Trade Organisation and the European Commission, their national equivalents and regulatory authorities – significantly dominated by industry – such as the US Federal Communication Commission, FCC, and the political pressure on radio astronomers to accept agreements such as those with Motorola Inc and Iridium LLC was tremendous.

- The ASTRA-1D case has not been solved yet in any of the aforementioned ways, and the discussion to address the adjacent band issues for the Fixed-Satellite Service in the frequency band 10.7-12.75 GHz is subject to further consideration within the CEPT. ASTRA-1D continues to transmit as a broadcasting satellite to household TV systems and the assumed customer interests are considered by the operator to have higher priority than international public law, i.e. the ITU Radio Regulations and, moreover, with umbrella treaties such as the UN Outer Space Treaty (United Nations Treaties and Principles on Outer Space, 1994).

These examples show very clearly the consequences of the lack of a view, strategy and regulation for defective space systems. It must be said that the ITU Radio Regulations contain some articles that address space system operations and their cessation, such as Article S22.1 which says that *"space systems shall be fitted with devices to ensure immediate cessation of their radio emission by telecommand, whenever such cessation is required under the provisions of these Regulations"* but in general the Radio Regulations do not go beyond stating that space systems shall not cause unacceptable interference to other systems, and contain tables with power flux density levels that must not be exceeded. Furthermore, the example of the TEX satellite shows that apparently an article such as S22.1 which is very relevant for handling of defective systems can be interpreted in such a way that the manufacturer of a space station does not consider himself bound by this regulation.

In the examples given above, the problems with the TEX satellite and the GLONASS system are managed in compliance with the ITU Radio Regulations but obviously the other mentioned systems can continue their operations although they violate these regulations when commercial interest is given priority.

14.3.3.1. Recommendations

In order to improve the handling of defective space systems, the following recommendations could be considered:

- articulation of the UN Liability Convention on issues related to defective space systems into subsequent regulation of the problem (United Nations Treaties and Principles on Outer Space, 1994(United Nations Treaties and Principles on Outer Space, 1994);
- improvement of the definition of "damage" in the UN Liability Convention;
- international regulation to handle defective space systems. In such regulation key elements should be that:

(a) public interest has a higher priority than the commercial interest of the private party responsible for the defective system;
(b) the ITU Radio Regulations clauses addressing necessary cessation of space system operations (such as Article S22.1) need improvement to strengthen the responsibility obligations for the space systems and to provide Administrations with adequate enforcement instruments;
(c) extension of the liability to victims of defective space systems to Administrations which gave a licence to the application of the defective space system on its territory;

- development of adequate satellite monitoring facilities to support Administrations in their handling of the issue of defective space systems;
- development of internationally accepted procedures to provide enforcement tools to Administrations on the issue of defective space systems. Issues which need improvement are licensing and legislation to support enforcement to manage defective space systems. Licensing should not be restricted to the country from whose territory a space system is launched, or the country that hosts the base office of the space system operator (United Nations Treaties and Principles on Outer Space, 1994);
- development of a regime in which the licensing of a space system is made, subject to the administrative approval of demonstrated mitigation techniques and measures embedded in the space station to safeguard spectrum purity and prevent harmful interference to other applications using the electromagnetic environment;
- regulations to assist victim services and bodies in the quantification of claims against defective space systems;
- improvement and adjustment of relevant regional and national legislation wherever necessary (Spoelstra, 2000).

15. Conclusions and recommendations

From the deliberations in this document we can draw the following conclusions and recommendations:

- Scientists should work closely together on the continuous improvement of their equipment and, with a concerted voice, make their case clearly heard at the relevant fora. The already existing bodies (IUCAF, CRAF and CORF) should be strengthened in their role and used as the bodies representing the interests of scientific users of radio frequencies.
- Cooperation with the Administrations (at local, regional or global level) by providing them with adequate information, enables them to integrate the case of scientific use of radio frequencies in their management policy.
- Wherever possible, scientists should cooperate with active users with the aim of keeping radio frequencies used for scientific research free from interference.
- Scientists should work actively on education and explanation of their case to active users in particular.
- In collaboration with Administrations scientists should work via IUCAF, CORF and CRAF on the improvement of the ITU Radio Regulations: improved definitions, criteria and allocation principles are needed to make the regulatory case of passive services properly clear.
- Consult Administrations to develop regulations to manage defective space systems.

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17. Abbreviations

AII	Asia-Pacific Information Infrastructure
APT	Asia-Pacific Telecommunity
ASTAP	Asia-Pacific Telecommunity Standardisation Program
ATM	Asynchronous transfer mode technology
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardisation
CEPT	Conference of European Posts and Telecommunications Administrations
CERP	European Committee on Postal Regulation (CEPT)
CITEL	Inter-American Telecommunication Commission
CORF	Committee on Radio Frequencies (USA)
COSPAR	Commission on Space Research
CPG	Conference Preparatory Group (CEPT)
CPM	Conference Preparatory Meeting (ITU)
CRAF	Committee on Radio Astronomy Frequencies (ESF)
DAB	Digital Audio Broadcasting
DSI	Detailed Spectrum Investigation (CEPT)
DVB	Digital Video Broadcasting
EC	European Commission
ECA	European Common Table of Allocations (CEPT)
ECC	Electronics Communications Committee (CEPT)
ECO	European Communications Office (CEPT) – (from February 2002)
ECTRA	European Committee on Telecommunication Regulatory Affairs (CEPT)
EEA	European Economic Area
EFTA	European Free Trade Association
EMC	Electromagnetic Compatibility
ERC	European Radiocommunications Committee (CEPT)
ERO	European Radiocommunications Office (CEPT) – (before February 2002)
ESA	European Space Agency
ESCAP	Economic and Social Commission for Asia and the Pacific
ESF	European Science Foundation
ETSI	European Telecommunications Standards Institute
EU	European Union
EUTELSAT	European Telecommunications Satellite Organisation
GLONASS	Global Navigation Satellite System
GMDS	Global Maritime Distress and Safety System
GPS	Global Positioning System
GSM	Global System for Mobile communication
GSO	Geostationary orbit
HAP	High Altitude Platform
IARU	International Union of Radio Amateurs
IAU	International Astronomical Union
ICAO	International Civil Aviation Organisation

IEC	International Electrotechnical Commission
IMT-2000	International Mobile Telecommunication system (ITU)
INTELSAT	International Telecommunications Satellite Organisation
ISO	International Organisation for Standardisation
ITU	International Telecommunication Union
ITU-D	ITU Development Sector
ITU-R	ITU Radiocommunication Sector
ITU-T	ITU Telecommunication Standardisation Sector
IUCAF	Scientific Committee on the Allocation of Frequencies for Radio Astronomy and Space Science (UNESCO)
MSS	Mobile-Satellite Service
NAIC	National Astronomy and Ionospheric Centre (USA)
NASA	National Aeronautic and Space Administration (USA)
NASDA	National Space Development Agency (Japan)
NII	National Information Infrastructures
NRAO	National Radio Astronomy Observatory (USA)
Non-GSO	non-Geostationary orbit
OAS	Organisation of American States
PCC	Permanent Consultative Committee (CITEL)
PT	Project team
PTC	Pacific Telecommunications Council
PTT	Post, Telephone and Telegraph
R&TTE	Radio and Telecommunications Terminal Equipment
RRB	Radio Regulations Board (ITU)
SG	Study Group
S-PCS	Satellite Personal Communication Services
TG	Task Group
TSAG	Technical Standardisation Advisory Group (ITU)
UMTS	Universal Mobile Telecommunication System
UNCTAD	United Nations Committee for Trade and Development (UNO)
UNESCO	United Nations Organisation for Education, Science and Culture (UNO)
UPU	Universal Postal Union
URSI	International Union of Radio Science
VLBI	Very Long Baseline Interferometry
WARC	World Administrative Radio Conference (ITU)
WMO	World Meteorological Organisation (UNO)
WP	Working Party
WRC	World Radiocommunication Conference (ITU)
WTO	World Trade Organisation (UNO)

18. Keyword index

19. Useful addresses

Asia-Pacific Telecommunity

APT Secretariat, 12/49, Soi 5, Chaengwattana Road, Bangkok 10210, Thailand
Tel: +66 2 573 0044, 573 6893 95, Fax: +66 2 573 7479, E-mail: aptmail@aptsec.org,
URL: http://www.aptsec.org

Inter-American Telecommunication Commission

CITEL, 1889 F Street, Washington DC 20006, USA
Tel: +1 202 458 3004, Fax: +1 202-458-6854, URL: http://www.citel.oas.org

Committee on Radio Frequencies

CORF, 2101 Constitution Avenue, Washington, DC 20318, USA
Tel: +1 202-334-3520, Fax: +1 202-334-2791, URL: http://www.nas.edu/bpa/corf

Committee on Radio Astronomy Frequencies

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CEPT – European Radiocommunication Office

(from February 2002 onwards: **European Communications Office**)

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European Science Foundation

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Appendix 1

Public Consultation on EC Green Paper on radio spectrum policy

Dwingeloo, 1 April 1999

1. Introductory remarks

The Committee on Radio Astronomy Frequencies of the European Science Foundation, CRAF, coordinates activities to keep the frequency bands used by radio astronomers free from interference. CRAF represents the radio astronomy communities in 17 European countries. The European Incoherent Scatter Facility, EISCAT, the European Space Agency, ESA, and the Institute for mm-Wave Radio Astronomy, IRAM, are also members of CRAF.

In Europe, scientific research is generally funded by public money. Furthermore, scientific facilities may extend over Europe as a whole and even beyond this region (such as in Very Long Baseline Interferometry). Therefore, CRAF appreciates that the Green Paper pays attention to the science services; one of which is the radio astronomy service.

CRAF welcomes the Green Paper of the European Commission as a discussion document and recognizes the relevance of a debate on the current European spectrum policy. However, CRAF observes that in the Green Paper an analysis of strong versus weak aspects of the current practice is lacking. CRAF regrets this. In Resolution 92/C318/01 of November 19th, 1992, the Council of Europe invited the Commission «to give full consideration in future to the mechanism of ERC Decisions as the primary method of ensuring the provisions of the necessary frequencies for Europe-wide radio services». The mentioned analysis could have contributed to this aim.

CRAF considers that the working method and results of CEPT-ERC in general satisfactory. In a satisfactory manner, measures have been taken towards an open, transparent decision making process. This process is also open for contributions from interested parties. Nevertheless, CRAF appreciates proposals to improve mutual co-existence in the radio frequency domain of the various radiocommunication services.

2. General comments

2.1. Active and passive services

CRAF observes that the spectrum policy presented in the Green Paper is discussed primarily in terms of interests and requirements for the active radiocommunication services. A strategic view on the specific interests and requirements of the passive (i.e. receive-only) services and applications compared with those of the active services is, however, lacking. CRAF regrets this, because it reduces the balance of the spectrum policy, since the requirements and characteristics of active and passive services are significantly different.

2.2. Spectrum impurity – cooperation between active and passive users of radio needed

The Green Paper is clear in its statements on spectrum availability for each of the radiocommunication services, i.e. on telecommunications, broadcasting, transport and also on

R&D. However, availability in a regulatory sense is different from availability at a quality level which is sufficient for the radiocommunication's requirements. Spectrum impurity degrades spectrum efficiency and reduces spectrum availability dramatically, especially when inadequate spread-spectrum modulation techniques are used. Technological cooperation between the users in these different radiocommunication services may well lead to a significant alleviation of the problem. The results of such a cooperation can be considered as beneficial for all users of the radio spectrum. The cooperation between active and passive users of the radio spectrum needs special attention because of the different requirements for the active and passive services.

For the benefit of the active and passive services, industry, operators and users of the provided facilities, cooperation between active and passive services could be improved and the European Commission could play an important and stimulating role in this respect.

CRAF considers, therefore, that the need for such a cooperation could be more clearly articulated as a strategic goal in the Green Paper.

2.3. Space systems – defective space system

CRAF observes that the spectrum policy outlined in the Green Paper is primarily written from the perspective of terrestrial use of radio. Coordination and regulatory procedures for terrestrial radiocommunication applications exist already to a great extent. This holds also for defective systems which have harmful impact on other radiocommunication services.

A great concern of CRAF is the existence of defective space systems of which at the present day about half a dozen can already be identified. In many respects the ITU Radio Regulations are not adequate to give guidance to the Administrations to manage such situations. These system defects may originate from (1) malfunction of a system; from (2) ignorance in the design and construction phase of the system; or from (3) plain bad system design. These defects are known because they generate harmful interference or produce some other negative impact on other systems. But nonetheless, at present, operators of such systems meet no constraints.

CRAF considers that a strategic position of the European Commission on this issue is urgent and needs to be developed in close cooperation with the CEPT. Such a strategy would be of great help to Administrations, especially when it is notified that there are reasons to expect that the extent and impact of this problem on other applications of radio (space based or terrestrial) is rapidly increasing.

A strategy on defective space systems has as a complicating aspect that some operators of space applications do not pay adequate attention to system quality if, in their view, this is not commercially justified.

3. Specific Comment

The Green Paper formulates **Issue 4** as:

The European Commission would welcome views on the link between Community policy on radio equipment, standards, and radio spectrum, with particular regard to the cooperation between bodies responsible for standards and radio spectrum and the measures needed at the operational level of radio spectrum management.

And asks:

Is there a need to improve the link between the elaboration of standards and the harmonisation of radio spectrum allocation for pan-European services in the areas of telecommunications, broadcasting, transport, and R&D?

In reaction to this question, CRAF observes that it is not yet common practice, that in the process of the development of standards spectrum issues are adequately taken into account. The industrial view on standards appears to be directed to issues of interconnectivity rather than those of spectrum purity and efficiency. CRAF considers that in standards development the issue of spectrum pollution should be addressed adequately. It is also important that in the development of standards, active users of the radio spectrum take the requirements of passive radiocommunication services into account.

CRAF, therefore, recommends that especially in this process of standards development, the cooperation between active and passive users of the radio spectrum should become more manifest to avoid complicated corrective work at a later phase. The European Commission could play a stimulating role to achieve this.

Appendix 2

ITU Radio Regulations Article S29

Radio astronomy service

Section I – General Provisions

S29.1 *§1 Administrations shall cooperate in protecting the radio astronomy service from interference, bearing in mind:*

S29.2 *a) the exceptionally high sensitivity of radio astronomy stations;*

S29.3 *b) the frequent need for long periods of observation without harmful interference; and*

S29.4 *c) that the small number of radio astronomy stations in each country and their known location often make it practicable to give special consideration to the avoidance of interference;*

S29.5 *§2 The location of the radio astronomy stations to be protected and their frequencies of observation shall be notified to the Bureau in accordance with No.* ***S11.12*** *and published in accordance with No.* ***S20.16*** *for communication to Member States.*

Section II – Measures to be taken in the radio astronomy service

S29.6 *§3 The locations of radio astronomy stations shall be selected with due regard to the possibility of harmful interference to these stations.*

S29.7 *§4 All practicable technical means shall be adopted at radio astronomy stations to reduce their susceptibility to interference. The development of improved techniques for reducing susceptibility to interference shall be pursued, including participation in cooperative studies through the Radiocommunication Sector.*

Section III – Protection of the radio astronomy service

S29.8 *§5 The status of the radio astronomy service in the various frequency bands is specified in the Table of Frequency Allocations, Article S5. Administrations shall provide protection from interference to stations in the radio astronomy service in accordance with the status of this service in those bands (see also Nos. S4.6, S22.22 to S22.24 and S22.25).*

S29.9 *§6 In providing protection from interference to the radio astronomy service on a permanent or temporary basis, administrations shall use appropriate means such as geographical separation, site* *shielding, antenna directivity and the use of time-sharing and the minimum practicable transmitting power.*

S29.10 §7 *In bands adjacent to those in which observations are carried out in the radio astronomy service, operating in accordance with these Regulations, administrations are urged, when assigning frequencies to stations of other services, to take all practicable steps to protect the radio astronomy service from harmful interference in accordance with No. S4.5. In addition to the measures referred to in No. S29.9, technical means for minimising the power radiated at frequencies within the band used for radio astronomy should be given special consideration (see also No. S4.6).*

S29.11 §8 *When assigning frequencies to stations in other bands, administrations are urged, as far as practicable, to take into consideration the need to avoid spurious emissions which could cause harmful interference to the radio astronomy service operating in accordance with these Regulations (see also No. S4.6).*

S29.12 §9 *In applying the measures outlined in this Section, administrations are urged to bear in mind that the radio astronomy service is extremely susceptible to interference from space and airborne transmitters (for further information, see Recommendation ITU-R RA.769).*

S29.13 §10 *Administrations shall take note of the relevant ITU-R Recommendations with the aim of limiting interference to the radio astronomy service from other services.*

Appendix 3

Relevant ITU-R Recommendations

The ITU-R Recommendations identified in Table A3 are relevant to spectrum management issues and the protection of scientific applications of radio frequencies as of the time of writing this document. Some recommendations include references to others which may not be mentioned in Table A3.

Table A3

ITU-R Recommendations relevant to spectrum management for scientific applications of radio frequencies.

Number[1]	Title
M.1316	Principles and a methodology for frequency sharing in the 1610.6-1613.8 MHz and 1660-1660.5 MHz bands between the mobile-satellite service (Earth-to-space) and the radio astronomy service.
M.1225	Technical and operational characteristics of wind profiler radars in bands in the vicinity of 50 MHz.
M.1226	Technical and operational characteristics of wind profiler radars in bands in the vicinity of 1000 MHz.
M.1460	Technical and operational characteristics and protection criteria of radiodetermination and meteorological radars in the 2900-3100 MHz band.
M.1464	Characteristics of and protection criteria for radionavigation and meteorological radars operating in the frequency band 2700-2900 MHz.
P.310	Definition of terms relating to propagation in non-ionized media
P.452	Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above 0.7 GHz.
P.525	Calculation of free space attenuation.
P.526	Propagation by diffraction.
P.620	Propagation data required for the evaluation of coordination distances in the frequency range 100 MHz to 105 GHz.
P.676	Attenuation by atmospheric gases.
P.1407	Multipath propagation and parametrization of its characteristics.
RA.314	Preferred frequency bands for radio astronomical measurements.
RA.479	Protection of frequencies for radio astronomical measurements in the shielded zone of the Moon.
RA.517	Protection of the radio astronomy service from spurious emissions.
RA611	Protection of the radio astronomy service from transmitters in adjacent bands
RA.769	Protection criteria used for radio astronomical measurements.

[1] The numbers are given without revision number which means that the latest version of the document is always meant.

Number[1]	Title
RA.1031	Protection of the radio astronomy service in frequency bands shared with other services.
RA.1237	Protection of the radio astronomy service from unwanted emissions resulting from applications of wideband digital modulation.
RA.1272	Protection of radio astronomy measurements above 60 GHz from ground based interference.
RA.1417	A radio-quiet zone in the vicinity of the L2 Sun-Earth Lagrange point.
RA.1513	Levels of data loss to radio astronomy observations and percentage-of-time criteria resulting from degradation by interference for frequency bands allocated to the radio astronomy on a primary basis.
S.1069	Compatibility between the fixed-satellite service and the space science services in the band 13.75-14 GHz.
S.1339	Sharing between spaceborne passive sensors of the Earth exploration-satellite service and inter-satellite links of geostationary-satellite networks in the range 54.25-59.3 GHz.
S.1341	Sharing between feeder links for the mobile-satellite service and the aeronautical radionavigation service in the space-to-Earth direction in the band 15.4-15.7 GHz and the protection of the radio astronomy service in the band 15.35-15.4 GHz.
S.1433	Equivalent power flux-density $epfd_{up}$ and $epfd_{is}$.
SA.509	Generalised space research Earth station and radio astronomy radiation pattern for use in interference calculations, including coordination procedures.
SA.510	Feasibility of frequency sharing between the space research and other services in bands near 14 and 15 GHz – Potential interference from data relay satellite systems.
SA.514	Interference criteria for command and data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services.
SA.515	Frequency bands and bandwidths used for satellite passive sensing.
SA.516	Feasibility of sharing between active sensors used on Earth exploration and meteorological satellites and the radiolocation service.
SA.577	Preferred frequencies and necessary bandwidths for spaceborne active remote sensors.
SA.1012	Preferred frequency bands for deep-space research in the 1-40 GHz range.
SA.1012	Preferred frequency bands for deep-space research in the 40-120 GHz range.
SA.1015	Bandwidth requirements for deep-space research.
SA.1016	Sharing considerations relating to deep-space research.
SA.1022	Methodology for determining interference criteria for systems in the Earth exploration-satellite and meteorological-satellite service.
SA.1023	Methodology for determining sharing and coordination criteria for systems in the Earth exploration-satellite and meteorological-satellite service.

Number[1]	Title
SA.1024	Necessary bandwidths and preferred frequency bands for data transmission from Earth exploration-satellites (not including meteorological satellites).
SA.1026	Interference criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit.
SA.1027	Sharing and coordination criteria for space-to-Earth data transmission systems operating in the Earth exploration-satellite and meteorological-satellite services using satellites in low-Earth orbit.
SA.1028	Performance criteria for satellite passive remote sensing.
SA.1029	Interference criteria for satellite passive remote sensing.
SA.1154	Provisions to protect the space research (SR), space operations (SO) and Earth exploration-satellite services (EESS) and to facilitate sharing with the mobile service in the 2025-2110 and 2200-2290 MHz bands.
SA.1157	Protection criteria for deep-space research.
SA.1158	Sharing of the 1675-1710 MHz band between the meteorological-satellite service (space-to-Earth) and the mobile-satellite service (Earth-to-space).
SA.1160	Interference criteria for data dissemination and direct data readout system in the Earth exploration-satellite and meteorological-satellite services using satellites in geostationary orbit.
SA.1161	Sharing and coordination criteria for data dissemination and direct data readout system in the Earth exploration-satellite and meteorological-satellite services using satellites in geostationary orbit.
SA.1163	Interference criteria for service links in data collection systems in the Earth exploration-satellite and meteorological-satellite services.
SA.1164	Sharing and coordination criteria for service links in data collection systems in the Earth exploration-satellite and meteorological-satellite services.
SA.1166	Performance and interference criteria for active spaceborne sensors.
SA.1258	Sharing of the frequency band 401-403 MHz between the meteorological-satellite service, Earth exploration-satellite service and meteorological Aids service.
SA.1259	Feasibility of sharing between spaceborne passive sensors and the fixed service from 50 to 60 GHz.
SA.1260	Feasibility of sharing between active spaceborne sensors and other services in the vicinity of 410-470 MHz.
SA.1261	Feasibility of sharing between spaceborne cloud radars and other services in the range 92-95 GHz.
SA.1262	Sharing and coordination criteria for meteorological aids in the 400.15-406 MHz and 1668.4-1700 MHz bands.
SA.1263	Interference criteria for meteorological aids operated in the 400.15-406 MHz and 1668.4-1700 MHz bands.

Number[1]	Title
SA.1264	Frequency sharing between the meteorological aids service and the mobile-satellite service (Earth-to-space) in the 1675-1700 MHz band.
SA.1277	Sharing in the 8025-8400 MHz frequency band between the Earth exploration-satellite service and the fixed, fixed-satellite, meteorological-satellite and mobile services in Regions 1, 2 and 3.
SA.1278	Feasibility of sharing between the Earth exploration-satellite service (space-to-Earth) and the fixed, inter-satellite, and mobile services in the band 25.5-27.0 GHz.
SA.1279	Spectrum sharing between spaceborne passive sensors and inter-satellite links in the range 50.2-59.3 GHz.
SA.1282	Feasibility of sharing between wind profiler radars and active spaceborne sensors in the vicinity of 1260 MHz.
SA.1344	Preferred frequency bands and bandwidths for the transmission for space VLBI.
SA.1345	Methods for predicting radiation patterns of large antennas used for space research and radio astronomy.
SA.1396	Protection criteria for the space research service in the 37-38 and 40.40.5 GHz bands.
SA.1416	Sharing between spaceborne passive sensors and the inter-satellite service operating near 118 and 183 GHz.
SA.1449	Feasibility of sharing between the fixed-satellite service (space-to-Earth) and the Earth exploration-satellite (passive) and space research (passive) services in the band 18.6-18.8 GHz.
SM.329	Spurious emissions.

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