Spectrum Management
Part 1

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As preparations for the Year 2000 World Radiocommunication Conference continue in earnest, ITU News will bring you in-depth analyses of what is at stake in the complex radio world. Indeed, how the spectrum/orbit resources are used and managed has a profound impact on society, its prosperity, security, culture, and education. This article takes you back in history on the use, management and regulation of the radio frequency spectrum resources. It then discusses current trends.

What is the spectrum?

The answer to this question is not as simple as one may expect, as spectrum has more than one meaning in the context of wireless communications. Originally, spectrum was only an abstract mathematical idea introduced by Jean-Baptiste Fourier (1768-1830) to solve differential equations. At the beginning, the idea was strongly criticized and considered as a curiosity of doubtful value.

It was not until Peter Dirichlet (1805-1859) and Georg Riemann (1826-1866) resolved these doubts, that the spectrum concept was generally accepted and has now become a powerful tool used in signal processing, communications, computers and many other fields. In the meantime, experimental science and instrumentation were being developed and the spectrum soon became a measurable physical object. Then came radio engineering; and now the concept of radiofrequency spectrum is in everyday use.

The ability to carry energy and messages at a distance, at no cost and at the speed of light, made the spectrum of radio waves a valuable resource from which everybody could benefit. Free access to it, from any place and at any time, added much to its attractiveness. The radio spectrum has become a natural resource, with which another abstract concept has been associated: invisible lines in the space-satellite orbits. Three elements added new dimensions to the spectrum concept:

− the market demand and pressure of wireless service providers, users, and equipment manufacturers;

− the development of international wireless services;

− the threat of cross-border radio interference.

An international treaty, signed by all governments, confirms that "... radio frequencies and the geostationary-satellite orbit are limited natural resources […] that must be used […] so that countries or groups of countries may have equitable access to both ..."[1] Radio waves and satellite orbits are now treated as a common heritage of humanity. No one nation can operate it alone, ignoring the others. It is subject to misuse and pollution by manmade radio noise and interference that decreases its utility.

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[1] *ITU Constitution and Convention (Geneva, 1992), Article 44, No. 196.*

Sharing

Sharing common resources, such as radio frequencies and satellite orbits, has its intrinsic benefits and drawbacks. The evident benefits are that all shareholders can draw profits from the access to the resources; disadvantages are not so evident. The main disadvantage is often referred to as the "tragedy of commons", after Hardin published his paper under this title[2]. He considered a simplified model of common pasture exploited by a group of herdsmen. He made a few assumptions. First, he assumed that herdsmen are "rational". It means each herdsman seeks to maximize his gain from the sale of animals, and there are no other aims or rules regulating the use of the pasture. Second, the pasture is common and each herdsman pays nothing for feeding his herd there. Third, the pasture is limited.

Under these assumptions, the scenario develops following the inherent logic of the commons, says Hardin. As each animal offers a unit gain, each herdsman tends to maintain as many cattle as possible. At the beginning, when the total number of animals is small, such an arrangement works well. The herds grow fast and the wealth of the herdsmen follows.

However, a moment comes when the population of animals approaches the carrying capacity of the pasture. When this critical point is reached, adding more animals leads to the degradation of the pasture. Then, each herdsman asks himself about the utility of adding one more animal to his herd.

Two components are to be taken into account, one positive and the other negative. The positive component reaches + 1, since the herdsman receives all the proceeds from the sale of the additional animal. The negative component results from the increased overgrazing created by one more animal. However, the effects of overgrazing are shared by all, so that the negative utility for any particular decision-making herdsman is only a fraction of -1. Adding together these partial components, the herdsman concludes that the only reasonable course for him to pursue is to add another animal to his herd. And another, and another, and this is the conclusion reached by every rational herdsman sharing a common heritage.

The result is that what was once rich pasture is being transformed into a desert. Hardin concludes: "Therein is a tragedy. Each man is locked into a system that compels him to increase his herd without limit - in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons ... ".

Regulation

Hardin's model portrayed that the concept of a free, unregulated access to a limited resource does not work if the number of its users exceeds certain limits. With radio waves, that conclusion has been reached very early from practical experience. The first uses of radio were military, to communicate with warships at sea. Soon, however, military secrets were abandoned under the pressure of business rushing to exploit the "no man's land" of civilian radio.

Two opposite forces appeared, one diverging and the other converging. The diverging force was due to the competition among the equipment manufacturers and service providers. They wanted no sharing, no control, no regulations and no common standards imposed. They also did not want to cooperate as this would result in disclosing their know-how secrets. Such an attitude can often be seen also today. The converging force came from the market, from the customers. The users of radio wanted to communicate freely, one with another, independently of the service provider or equipment supplier. Moreover, in a liberal environment, without any regulation, mutual interference often paralysed the operation of wireless systems, whereas the users wanted interference-free communications.

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[2] *Hardin G.: The tragedy of commons, Science, December 1968, pages 1243-1248.*

Finally, all interested parties came to the conclusion that the regulation, coordination and management of the uses made of the spectrum are an unavoidable necessity. Such management started on a national scale. However, as radio waves do not recognize political borders, the global nature of the problem required international cooperation.

Only two years after the first transatlantic transmission astonished the world, and just a few years after Marconi received his patent on wireless telegraphy, the first international conference was held in Berlin in 1903 to regulate and manage the use of the spectrum.

That conference marked the end of the first period of uncontrolled rivalry and unregulated radiocommunications. The spectrum resources consisted at that time of only two frequency bands (one near 500 kHz and another about 1 MHz) and were used to help in marine disaster relief off the coast.

The use of the spectrum has been regulated by necessity to prevent mutual interference, and to allow for intercommunication. In the early days of radio, with few radio stations operating, the probability of interference was low and the inter-communication issues were more important.

In 1902, Prince Henry of Prussia attempted to send President Theodore Roosevelt of the United States a courtesy message while crossing the ocean after his visit to that country. He was refused the service because the shore station, operated by the Marconi Company, would not deal with a ship station of its German competitor.

Not without the influence of that incident, the Berlin Conference ruled that a communication service with ships must be provided regardless of the system used. However, international treaties are all part of a worldwide game which nations agree to play following certain rules - consensus is an inevitable ingredient here. Great Britain and Italy, where Marconi was exploiting his system, did not agree and made reservations. Such reservations were removed, and the first operational standards on radiocommunications were agreed, only nine years later, at the London Conference in 1912. To a large degree, it was under the pressure of public opinion, shocked by the *Titanic*[a] disaster.

The "Titanic" was the most luxurious and largest ship at that time, claimed as being unsinkable. During its maiden voyage, it hit an iceberg and sank on the night of 14-15 April 1912. About 1500 passengers lost their lives and the recent film, "Titanic", revived the event. Inquiries alleged that another liner was nearby and could have helped had its radio operator been on duty to receive the distress signals of the "Titanic".

Today, the uses made of the spectrum are internationally coordinated through the International Telecommunication Union (ITU). This specialized agency of the United Nations has, among its major purposes, to ensure that radio interference is avoided and that the spectrum/orbit resources are used in a rational manner, taking into account the special needs of developing countries.

The Radio Regulations, appended to the ITU Convention and Constitution, have the status of an international treaty. Each government warrants that the Radio Regulations are respected by everybody under its jurisdiction.

To keep pace with technological, political, and economic changes, the Regulations are periodically reviewed at competent world radiocommunication conferences. However, experience has shown that only minimum modifications are agreed at each conference, leaving fundamental principles essentially untouched. One reason is that the process of intergovernmental conferences is often more about the art of politics and public relations than an exercise in economics and engineering.

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[a] *Od Redakcji TiTI: Dwa zdjęcia z filmu „Titanic" w reż. Jamesa Camerona zostały w tej edycji pominięte.*

Evolution

It is interesting to note that, in dealing with the spectrum/orbit resources, we are following the same approach as with other common resources. Our past confirms that the approach to such resources changes, as does our understanding of their value and social role. In our uncontrolled growth, we have discovered with surprise that many resources, considered for a long time as inexhaustible, have become scarce.

After a period in the past when there was an abundance of "no man's land", there is no free farmland now. Open pastures and free hunting and fishing areas have been restricted. Regulations have been imposed on the disposal of sewage and are now widely accepted throughout the world. The concept of the environment and its protection has been developed and restrictions have been imposed on the pollution of land, water, and air.

Radio frequencies and satellite orbits are therefore no exception. The issue of rational use, sharing, and protection of the limited common resources has become a serious problem on the national and international scale. We believe all these regulations to be necessary for the common benefit of humanity. Several approaches to scarce resources are possible.

"We might sell them off as private property. We might keep them as public property, but allocate the right to enter them. The allocation might be on the basis of wealth, by the use of an auction system. It might be on the basis of merit, as defined by some agreed-upon standards. It might be by lottery. Or it might be on a first come, first served basis ...".[3]

For the time being, the spectrum/orbit resources are still treated as public on the international scene. No access fee mechanism has been envisaged till now, but the access is controlled following the Radio Regulations negotiated by all ITU Member States at the competent conferences. However, on the national scene, most countries have introduced a system of access fees.

A few countries even created a spectrum market, but the market approach has not been universally accepted. There is a continuing debate over whether spectrum is to be treated as a free common heritage of humankind, a scarce natural resource, a renewable and reusable commodity, or a saleable, auctionable, rentable piece of real estate. J. D. Bedin, a French jurist, defined it in a few words: "the frequency spectrum is technology, industry, money, culture, and power".

A matter of preference

Which of the possible approaches is the best? It all depends on the criteria applied. The final answer lies with human preferences of goals and hierarchies of values. In practice, it is often impossible to separate technical aspects of resource sharing from their economical, social and political contexts, and from the interests affected by them.

The problem of sharing scarce resources cannot be solved by technical means, without involving systems of human values, convictions and ideas. Tradition, experience, and investments may play a significant role here. Of all the possible ways in which the resource can be used or shared, the one to be adopted will be that which is valued most by a given population in terms of that population's own system of values and beliefs.

"Where a resource process involves beliefs and techniques that are incongruous with a people's system of activities, it will not be adopted by that population, however superior it may be by other criteria. "[4]

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[3] *Op. cit.*

[4] *Firey W.: Man, mind and land, a theory of resource use, Greenwood Press (1977).*

However, in a pluralistic society the goals and hierarchies of values are often inconsistent and conflicting. First, the hierarchies of values and preferences of each individual or group may be inconsistent. It means that progress towards realization of one value or goal is destructive to another value or goal held by the same individual or group, and the lack of consistency may not be obvious to the individual or group concerned. Second, different individuals and groups may have different hierarchies of values and preferences. And these values and preferences may be partially in conflict with those of other groups and individuals. Conflicting goals or values cannot be served by the same policies: what enhances one will degrade the other. Finally, the capacities of different groups to implement their preferences may be different.

Our experience shows that the way in which the spectrum/orbit resources are used and managed follows the technological, economic, political and social changes in the world. These changes usually begin in one leading or dominating nation or region. Sooner or later, however, the rest follow that example and accept, more or less voluntarily, the approach, "mode of life" and hierarchy of values of the leader.

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