

# Abstracts

## 08 The legal frameworks and instruments related to radio-frequencies

Olivier JAPIOT & Eddie TADEJ

The radio-frequency spectrum is a limited natural resource that many public and private actors are putting to a more intense use to develop wireless technology. Since radio-frequencies leap over borders, tight international coordination is needed to avoid interference. These two characteristics account for the dominance of international law and the role of the International Telecommunication Union (ITU), in particular its Radio Regulations Board, which sets, at the planetary level, the principal rules for assigning bandwidths. European Union mainly seeks to harmonize systems for authorizing frequencies; and the French legal framework is founded on the principle that these frequencies belong to the public domain. The state thus regulates uses within the precise limits set by these international and European legal frameworks. The management of bandwidths lies in the hands of the Agence Nationale des Fréquences (ANFR), which coordinates uses by the parties who are assigned bandwidths.

## 13 The global framework for managing the radio-frequency spectrum: Regulation and standardization

François RANCY

The radio-frequency spectrum is a scarce resource essential to most of the applications on which our societies have come to depend within a few decades. It is managed through a system of international regulations and standards adopted by the International Telecommunication Union (ITU). This process, conducted by ITU member states, involves working closely with major stakeholders who use the spectrum (operators, industries, international and sectoral organizations). It seeks to reach a regional and worldwide consensus about the best way to manage the spectrum by modifying national and international laws and regulations so as to adapt them to the rapid evolution of technology and uses but without jeopardizing the investments already made. Thanks to this 113-year-old process for making regulations and standards with a universal scope, radiocommunications, as we know them, have developed.

## 19 The regional management of radio-frequencies in Europe, a high level of harmonization through cooperation between the EU, CEPT and ETSI

Eric FOURNIER

The regional management of radio-frequencies is part of the world organization of the International Telecommunication Union (ITU), which sets the rules for avoiding interference among the frequencies used in member states. It also fits in with the national, sovereign bodies that manage the radio-frequency spectrum within each country's borders and assigns bandwidths. This regional management allows for harmonizing bandwidths, which is indispensable for economies of scale, the operation of the European single market and the effective operation of bandwidths in border zones. Harmonization in the EU focuses on the uses of radio-frequencies and the marketing of equipment in this sector. This involves close cooperation with the European Conference of Postal and Telecommunications Administrations (CEPT), which studies the compatibility of uses

and harmonizes frequency assignments, the European Telecommunications Standards Institute (ETSI), which drafts standards for harmonization, and the European Union, which may impose rules for harmonization in the single market. Through regional cooperation, questions about fair access to radio-frequencies in border zones are handled and joint proposals drafted for ITU conferences.

## 25 **The national management of radio-frequencies**

Gilles BRÉGANT

The radio-frequency spectrum, a vulnerable resource, requires an attentive management, which, in France, is done through the Agence Nationale des Fréquences (ANFR) and its consultations with stakeholders. By taking account both of international negotiations on changes in the uses of bandwidths and of the needs of national actors, the ANFR grants bandwidths to eleven “assignees”. The table listing assigned bandwidths is regularly updated and approved by the prime minister. These “assignees” then collect projects from “emitters”, which the ANFR, after having authorized them following consultations, will record in a digital registry. Permits for emissions are subject to coordination near the borders. This system of control settles problems of interference and regularly assesses the compliance of equipment in terminals. This work is steadily becoming more technical with growing recourse to the sharing of the spectrum, as higher frequencies are put to use and the number of emitters increases. This requires continually updating ANFR’s skills, qualifications and tools.

## 30 **Controlling the radio-frequency spectrum**

Nicolas SPANJAARD-HUBER

Control, the last phase in the management of the radio-frequency spectrum, entails checking whether uses comply with regulations and eliminating any interference that might occur despite all precautionary measures. Control is the “after-sales” service that guarantees authorized users that their assigned bandwidths are actually available. This necessary task is harder to perform as the spectrum is put to a more intensive use — we can barely mention a human activity that does not have recourse to radio waves. Various facets of this control are described, whether preventive (compliance with regulations) or remedial (elimination of interference), along with its technical means and methods.

## 35 **Spectrum economics: Serving public policies**

Gérard POGOREL

Since the 1990s, economic approaches and assessments have played an increasing role in policies for managing the radio-frequency spectrum. Along with stiffer competition in telecommunications, they have generated considerable benefits for citizens, consumers, industry and governments in Europe and the world. More recently, as concerns have grown about the relatively slow speed of the deployment of 4G networks and fears arisen about a repetition of these delays during the deployment of 5G, the ability of these economic and financial approaches to provide the guiding principles for a spectrum policy has come under question. This “spectrum economics” is examined, specifically the policies for assigning bandwidths. Examples of policy decisions with an impact on market developments along with evidence drawn from recent in-depth studies lead us to reconsider the principle that auctions are the most effective means for promoting competition and driving investment. We are also led to question another principle, namely: that the amount

of revenue raised through an auction of bandwidths is overriding proof of the auction's success. After reviewing analyses of the causal relations and trade-offs between various methods for assigning bandwidths and setting fee structures, guidelines are suggested for a more effective, balanced approach to bandwidth assignments that would better align the award process with broader, economic and societal, objectives.

#### 41 **The radio-frequency spectrum as an asset**

Olivier COROLLEUR

The many aspects of assigning a “value” to the radio-frequency spectrum are discussed along with the studies that calculate this value. Like other environmental assets, the spectrum serves not just one but many, simultaneous needs. The competition between commercial and noncommercial uses, the scope (sometimes worldwide) of the decisions made about how to manage this asset, the necessity to reckon with not just the spectrum's current use value but also its “conservation value” (which would make allowance for future uses or for the demand to limit the exposure to electromagnetic waves as much as possible)... so many challenges for the organizations that regulate this commons.

#### 47 **Radio-frequencies and health**

Olivier MERCKEL

Research on the potential health effects of an exposure to radio-frequencies has apparently followed in the footsteps of advances in technology, with more or less of a lag and in a more or less organized manner. When mobile networks were being deployed during the first decade of this century, major questions were raised (chief among them: the risk that using mobile phones would cause brain tumors) and apparently settled — for a while. Findings from recent research along with the change of scale in “connectivity” (and thus of our exposure to electromagnetic waves) have made it necessary, once again, to assess risks. In particular, research on the relation between this exposure and the functioning of the brain, though not having detected any pathological effects, seems to open new approaches to understanding the interactions between electromagnetic fields and life.

#### 55 **Radio-frequencies for the Internet of Things: A new paradigm for engineers**

Benoît PONSARD

The Internet of Things (IoT) is going to generalize the use of radio waves to connect devices of varied sorts: new uses but also new constraints. Short, infrequent messages emitted by millions of devices cannot be managed like downloads of videos or online gaming. The IoT forces us to rethink the assignment of bandwidths and adapt communication protocols. Sigfox network invented such an approach with its ultra narrowband technology, a paradigm that the cellular and satellite IoTs have taken into account. Since the radio-frequency spectrum necessary for the IoT is small in comparison with other uses, we can imagine that a bandwidth would be devoted to the IoT. Such a bandwidth, if harmonized worldwide, would be conducive to the emergence of global solutions for the Internet of Things.

## 60 5G Connectivity

Roberto VIOLA

The importance of 5G connectivity is placed in the policy context of the 5G Action Plan approved by European Commission (EC). There will be no digital single market without first-class communication networks. The Commission was already sponsoring visionary EU-funded research activities in 2012, which led to the European 5G Public Private Partnership (5G PPP). An important policy objective for the Commission is to pursue its 5G spectrum roadmap, which takes account of the views of member states and serves the EU's Gigabit connectivity targets. To make 5G deployment a success, the conditions have to be set for ensuring timely access to the appropriate part of the spectrum and mustering the investment necessary for high-capacity networks. The European Electronic Communications Code advocates a more flexible and dynamic access to the radio-frequency spectrum through trading and leasing; and it backs sharing solutions for spectrum-licensing. The available spectrum for 5G in all bands (low, mid and high) is still at issue. Whereas the EU has already harmonized the 700 MHz band, legal requirements call for assigning upper bands in all member states by the end of 2020. Insisting on this deadline, the EC considers exemptions only for very exceptional, fully justified cases. The short-sighted objective of maximizing auction revenues should not lead us to compromise the deployment of 5G. Although health remains a matter of national jurisdiction, discussions must be undertaken with all competent authorities to ensure that any decision regarding the exposure limit to radio-frequencies that goes beyond the precautionary European and international levels will be made in full knowledge of both the evidence and likely effects. The EC is following up on developments, attentive: to major horizontal topics having to do with an efficient and sustainable spectrum management; to molding an opinion among regulators and industries in favor of spectrum-sharing; and to the "greening" of other economic sectors. These topics should underlie a longer-term European spectrum strategy.

## 64 High-altitude platforms

Christine MENGELLE

Mainly used at the start for scientific purposes, high-altitude platforms have increasingly attracted interest since the 1990s as a complement to land and satellite networks. At a position above the altitude of commercial air traffic and the jet stream, such platforms — which are easy to deploy and necessitate a minimal infrastructure (networks and maintenance) on the ground — offer, in addition, a wide zone of coverage with very low latency. They are, therefore, of special interest for civil or military surveillance operations and for telecommunications in areas isolated by geography or a disaster. Technological progress and a propitious regulatory framework — established since 1997 by successive World Radiocommunication Conferences (WRCs) — open the possibility of rolling out plans for high-altitude stations in the near future.

## 67 Satellite constellations

François RANCY

Since the start of the space era, geostationary satellites (GSOs) have been used to provide commercial telecommunication services. International regulations soon caught up thanks to Radio Regulation 22.2 of the ITU. At the start of the 1990s, plans for constellations

with dozens of nongeostationary satellites (NGSOs) were made to provide the equivalent of a cellular mobile service for portable telephones. As a consequence, the ITU's World Radiocommunication Conferences (WRC), successively from 1992 to 1997, set up a regulatory framework adapted to this demand, assigned a few hundred megahertz and defined procedures for access to the radio-frequency spectrum based on the "first come, first served" principle. By 1995, plans for hundreds of NGSOs were being made to offer all countries on the planet access to the Internet. The WRCs in 1997 and 2000 could satisfy the subsequent requests for a spectrum of several gigahertz only by adopting (after surmounting major difficulties) a global approach that replaced Regulation 22.2 with a system that had verifiable, mandatory limits in order to protect the full spectrum shared with GSO systems. In the first years of the 21st. century, these plans lay dormant owing to the dot-com bubble. Nowadays, technological progress and the ITU's decisions from twenty years ago have set the conditions for launching constellations with thousands of NGSOs — a rare example of global regulations preceding technology.

## 72 Using radio-frequencies to observe the Earth

Dominique MARBOUTY

Radio-frequencies are heavily used to observe the Earth, in particular from satellites. This Earth watch, the measurements made and their impact are described with regard to weather predictions. The decision to assign 5G a bandwidth close to that of the absorption of water vapor (crucial for measurements) could endanger observations of the Earth

## 78 The armed forces' current and future needs of radio-frequencies: A strategic issue for France

Jérôme BORDELLÈS & Mickael ULVOA

To remain competitive in dealing with an enemy that taps digital technology's potential, armies are modernizing and acquiring innovative equipment to implement the concept of "collaborative combat" based on more connectivity and a broader use of the radio-frequency spectrum. Such is the case of major programs in France (*e.g.*, SCORPION for the army or SCAF for the air force). Characterized by a quest for high speeds and very low latency (required for air/naval combat), this trend relies on all types of radio support and on satellite constellations. Obtaining a real-time view of a tactical situation, thanks to this connectivity, depends on sensors for collecting information, satellites for observations, drones, interplatform connections for handling data, and better means of detection (like the radar systems to be installed on ships under the FDI, a completely digital program capable of guiding missiles in a hostile environment). Decision-making will thus be shortened when dealing with threats, including the menace of high-speed missiles. Dependent on using an ever more limited radio-frequency spectrum, the armed forces must foster resilience to cope with interferences and jamming, a sensitive but highly strategic maneuver.

## 89 The physical layer, a key layer for wireless networks

Philippe CIBLAT & Alain SIBILLE

The success of wireless networks since the 1990s stems from digital technology and the conception of a cellular network. These have made it possible to efficiently use the radio-frequency spectrum while observing the fundamental laws of electromagnetism. Since forty years ago, enormous progress has been made in using the spectrum, as the latter's

high end has been increasingly put to more diversified uses. The physical layer of the Open Systems Interconnection (OSI) model [ROLI2016], which underlays the architecture of networks since the 1970s, handles both the transmission and emission of signals from the physical world via antennas and the reverse operations for receiving signals. This layer's characteristics are decisive for the performance of wireless networks, for their coverage of geographical zones and their capacity to provide reliable services.

## 94 Techniques for managing radio-frequencies

Yann MAIGRON

The radio-frequency spectrum, now at the core of economic activities in modern digital societies, is related to major social, cultural and political issues. However this limited resource has to be shared out among all countries on the planet and for a wide range of uses and services. Managing the spectrum soon became indispensable at the supranational and national levels in order to guarantee the quality of radio-frequencies assignments and to prevent interference. Procedures for backing up this guarantee are designed by the International Telecommunication Union (ITU) and adjusted at the national level. Implementing them means tapping capacities for processing and sharing data and adopting analytical methods, techniques and tools — which will have to evolve to cope with the problems that the proliferation of new services and forms of technology will force upon the management of the radio-frequency spectrum.

## 98 Television and the radio-frequency spectrum

Walid SAMI

Television has changed along with technology, especially during the past two decades. Watching television used to be a group activity but has now become, especially for young adults, an individual form of consumption via personal, connected devices. Diverse contents are now offered, and viewers can select what they want to watch, and where and when they do so. They have at their fingertips a slue of channels of transmission and business models that have benefitted from the growth of the Internet via landline or wireless connections. Under pressure, landline transmission has already lost much of the radio-frequency spectrum reserved for it. Nevertheless, the consumption of linear contents on a television set that receives for free Hertzian signals has apparently not declined. This is an argument for maintaining and even improving a platform based on land lines in order to adapt to new uses.

## 104 Managing radio-frequencies in a crisis situation

Claire LANDAIS

Feedback from major crises during the past twenty years reveals that disorganized communications are a key factor that makes a crisis worse for governments to handle and for people who are trying to contact rescue services, authorities or persons close to them. Radio-frequencies are being more intensively used for mobile telephones (GSM) and radio receiver-transmitters (PR4G for the French armed forces, ACROPOL for the police and ANTARES for rescue services). Since these frequencies are a scarce resource, it is necessary to be able to reassign them fast, for example during a terrorist attack. For this reason; the prime minister has issued an edict for exceptionally assigning additional frequencies to the ministries of the Interior and of the Armed Forces in case of menaces.

## 108 Policing the radio-frequency spectrum: Unintentional interferences and jamming — Are the security of the spectrum, cybersecurity and electronic warfare a single combat?

Catherine GABAY

Unintentional interference on radio-frequencies and deliberate jamming are dangers for the economy and state on par with the menaces stemming from cyberattacks. The frequencies undergoing interference can hardly, or not at all, be used in the zone affected, and this jeopardizes all sorts of applications. The security of the radio-frequency spectrum is a matter of sovereignty. To prevent and handle cases of interference, a police is needed. The Agence Nationale des Fréquences (ANFR) has this role among its assignments for overseeing the spectrum: more than 1400 cases of prejudicial interference are reported to it each year. To cope with trends in technology and uses, the ANFR is continually bolstering its means and methods of control; and it advocates making all users aware of issues related to the security of the spectrum.

## 114 Frequencies for radio astronomy

Ivan THOMAS & Karl-ludwig KLEIN

Thanks to the transparency of the earth's atmosphere, radio astronomy observes the sky in a given bandwidth (from a dozen MHz to a few THz). As the means of observation become more sensitive, the universe can be sounded ever farther, closer to its creation. We thus discover how the universe has evolved over time. Radio astronomy supplies astrophysics with data, but the intensive use of the radio-frequency spectrum is restricting (even threatening) this activity. A brief description of the contributions made by radio astronomy to research in astrophysics and to technology and of its need for a protection of radio-frequencies...

## Miscellany

### 119 The 2019 digital barometer survey

Gérard LALLEMENT, Matthias DE JOUVENEL & Michel SCHMITT

Since 2000, the Conseil Général de l'Économie (CGE) has conducted a yearly survey on the diffusion of information and communications technology in French society. This survey follows up on electronic devices and their major uses and tries to detect new trends. The reliability of its findings comes from the face-to-face interviews conducted with a large sample of persons (2259 in 2019, including 207 under the age of 18). Since this survey has been repeatedly conducted for more than a decade, it has become a reference source, a genuine barometer of digital technology, now a full-fledged part of modern societies. The 2018 survey drew attention to the population's concerns about the protection of personal data. In 2019, respondents were asked about how digital technology has affected their lives, personal and occupational, and society in general. Trends related to mobility, uses and user's needs (*e.g.*, the portability of mobile applications and of user data) have been analyzed as well as people's confidence in the media, the effects of this technology on the environment and its role in changing our relations with public administrations.