# Strategic plan on evolving spectrum uses and spectrum management for growth and innovation

ANFR (*French spectrum management agency*) public consultation prior to finalisation of the strategic plan

15 December 2016

AGENCE NATIONALE DES FRÉQUENCES

## Practical details of the public consultation process

All interested parties are invited to voice their opinion on this document, which contains the “spectrum management issues” sections of the consultation.

Opinions may also be posted on the dedicated website, which includes a series of “spectrum usage sections” in addition to the “management issues sections”: http://planstrategique.anfr.fr/

Contributors’ attention is drawn particularly to the proposals set out at the close of each of the “management issues” sections.

This public consultation remains open until 6 pm on 28 February. Only contributions received prior to this deadline will be taken into consideration.

Contributions should be addressed to ANFR, preferably by email to the following address: planstrategique@anfr.fr

Failing which, contributions may be submitted by post to the following address:

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In the interests of transparency, ANFR will publish in full all contributions received, with the exception of any elements subject to commercial confidentiality. Should their reply contain any such elements, contributors are invited to submit two versions:

- a confidential version, in which the passages subject to commercial confidentiality are identified within square brackets and highlighted in grey, for example: “a market share of [25]%”;
- a public version, in which the passages subject to commercial confidentiality are replaced by “…”, for example: “a market share of “…”%”.

Contributors are invited to limit, as far as possible, the passages covered by commercial confidentiality. ANFR reserves the right unilaterally to declassify items of information that, by their nature, do not fall within the domain of commercial confidentiality.

# Strategic Plan

# Spectrum Usages

**Mobile communications**

Digital connectivity is one of the pillars of France's economic growth. It relies on fixed networks but also on a number of spectrum-dependent media including mobile networks (2G, 3G, 4G and, in the near future, 5G). Forecasts suggest that access to data by physical individuals will gradually be supplemented by massive communication between connected objects, making up the Internet of Things (IoT), which may rely in part on 5G.

The ubiquity of portable terminals (telephones, smartphones, tablets) in everyday life in France, the growth in data traffic on mobile networks and the increasing proportion of video content in these flows all bear witness to changing usage. On 30 September 2016, the number of SIM cards (excluding M2M) in France stood at 72.5 million, representing a penetration rate of 109.1% of the population. At the end of 2015, the number of subscribers to LTE, the standard on which 4G is based, passed the symbolic threshold of 1 billion worldwide, accounting for 15% of mobile subscriptions. This figure could rise to 3.3 billion subscribers by 2019, or 40% of all SIM cards worldwide (State of LTE & MBB spectrum worldwide, IDATE, December 2015.). Mobile device ownership in France is also on the increase: in 2016, 65% of the population aged 12 or over owned a smartphone, compared to 58% in 2015. 40% of that population also owned a tablet, up from 35% in 2015.

Traffic on mobile networks is growing rapidly. According to Cisco estimates, worldwide mobile network data in 2015 rose by 74% over 2014. Cisco also reported that traffic carried on cellular networks in 2015 was, for the first time ever, lower than the traffic offloaded from these networks via Wi-Fi access or femtocells. Moreover, in 2015 video content accounted for 55% of traffic on mobile networks.

Being mobile, such connectivity relies solely on radio frequencies. Despite technological advances, higher speeds carry with them a requirement for broader bandwidths. These developments call for new resources to be made available without compromising other previously authorised uses.

Mobile networks currently rely on the 700 MHz, 800 MHz and 2.6 GHz spectrum bands (for 4G), 900 MHz and 1800 MHz bands (2G and 4G) and 2.1 GHz band (used by 3G networks). Coming soon, however, is 5G, which will require frequencies both in these low bands already allocated and, in a new departure for the mobile communications sector, in higher frequency bands, above 24 GHz in particular.

5G is a foretaste of things to come for mobile networks. The new standard is set to provide significantly more powerful mobile communications, irrespective of geographic location and even when travelling at high speeds (by train, for example). 5G is also expected to support the massive connection of connected objects whilst at the same time providing greater reliability and very low latency for critical applications such as driverless vehicles, industrial applications (robots) or telemedicine (surgery). Certain sectors of the economy known as “vertical players” are currently examining the use of 5G networks for at least part of their connectivity needs (the rail sector, for example), or of 5G technology in dedicated frequency bands (driverless vehicles, for example).

If all these challenges are to be met, more efficient use than ever will have to be made of the limited resource that is frequency spectrum. Aside from making new resources available for 5G, another challenge will be to encourage the introduction of new broadcasting architecture across the territory, including allowing the deployment of small cells. Frequency harmonisation is essential to allow for economies of scale in the production of equipment and terminals. Though the first phase of 5G, based on low frequencies, is expected to roll out in 2020, with the second phase following in 2025, decisions on spectrum are being made now.

Many devices and connected objects (payment terminals in restaurants, for example) will initially continue to rely on 2G and 3G networks, but ultimately even these networks will need to evolve.

Finally, more insight into the needs of  “vertical players” will be required in order to prepare the necessary resources, depending on whether these sectors opt to rely on 5G networks or require spectrum resources and dedicated networks.

## Energy and smart meters

Smart meters are being deployed all over the world to provide more regular monitoring of the distribution of fluids (water, electricity and energy sources). In France, the energy sector is the most active in developing smart meters, including Suez, Veolia and GRDF with the Gazpar smart gas meter and ENEDIS with the Linky smart electricity meter.

Smart meters dispense with the need for manual meter reading and improve distribution network maintenance. They transmit consumption data at regular intervals to a hub and are able to check in real time that the grid is operating correctly at the point of distribution. In the future, they will also help to economise on resources by interacting with domestic appliances as part of smart home networks.

Several different communication techniques are currently in use in France:

- radio communication based on the use of unlicensed or licence-exempt spectrum: this is largely the option of choice for standalone battery-powered meters;

- wired communication over power cables (Power Line Communication or PLC) in the case of Linky, the smart electricity meter connected to the grid;

- mobile operators' public networks, generally reserved for communication between hubs and corporate servers.

Smart meters have raised questions as regards their radioelectric emissions, whether intentional (in the case of meters using radio frequencies) or unintentional (PLC meters, which produce electromagnetic interference). Measurements show that exposure to such emissions is very low as compared to the regulatory limits. Battery-powered meters consume very little energy (projected battery life is over a decade), and so produce very low levels of radio frequency emissions. As for LPC signals, their indirect impact on the environment is very limited, on a par with that of many everyday electrical appliances.

Smart meters will soon be some of the most widespread connected objects, given the current roll-out plans: 35 million electricity meters and 11 million gas meters are to be installed in homes between now and 2022.

The frequency issues posed by smart meters are as follows:

- ANFR must be in a position to respond to requests for information from elected officials, housing managers and individuals. The exposure created by smart meters has been measured and recorded. Despite the very low levels of exposure, information on these devices must continue to be provided given their extensive deployment in homes and the expected development of their functions as part of the increasing interconnection of smart home appliances;

- the use of licence-exempt spectrum must continue to be possible over the long term, in view of the growing number of devices likely to transmit in the same frequency bands and the widespread deployment of smart meters.

**Defence**

In order to carry out the great variety of missions on national territory with which it is tasked even in peacetime, the French Ministry of Defence uses a number of frequency bands. The defence authorities need access to almost all the services defined by ITU's Radio Regulations. The frequencies they use are spread over the spectrum, be they designated for fixed or mobile systems (terrestrial, aeronautical or maritime), for space (geostationary or otherwise, for observation or communications), for radiolocation and radionavigation. Furthermore, these spectrum requirements extend beyond national frontiers.

In both peacetime and wartime, the military operate systems on a continuing basis to ensure the defence of national territory, on land and in the air as well as at sea and over maritime approaches. There is also, at all times, a need for the operation of territorial protection schemes (*Vigipirate*, *Sentinelle*). Uninterrupted capacity to deploy nuclear weaponry is a further requirement. The military ensure the defence of national territory and the protection of the population against nuclear, radiological, biological and chemical threats. Defence forces must be trained so that full operational readiness can be maintained. Finally, the defence authorities must be able to deploy military personnel for exceptional events in peacetime and for operations in crisis or war situations. In the latter event, spectrum needs, necessarily greater than in peacetime, may require some re-allocation of civilian frequencies, an issue that will not be described in detail in this document.

Some defence missions occur in an international context. France participates in a number of multinational operations with allies, or in coalition, and regularly hosts foreign troops on national territory for exercises. Such operations may take place in different contexts:

- the North Atlantic Treaty Organization (NATO), an alliance for the safeguarding by political and military means of the freedom and security of the 28 member states on the North American continent and in Europe;

- the European Defence Agency (EDA) which assists member states and the European Council in their efforts to improve European defence capacities and also runs certain support operations;

- the United Nations;

- in the context of bilateral or multilateral agreements.

To a certain extent, such operations require the availability on national territory of frequencies to service the equipment in use by allies or coalition partners.

One of the specific characteristics of military systems is their long life cycle, from the design phase through to commissioning and, finally, withdrawal from service. This generally lasts several decades, in particular for complex systems such as ships, aircraft and other weapon systems. Although some of the onboard devices can be upgraded over these extensive periods of time, the physical properties of mission-critical frequencies in use must be respected (for example, very long distance radiocommunication is necessarily restricted to the HF band).

On the industrial side of the defence sector, spectrum availability is an important factor in the development and export of weapon systems. The defence sector is one of France's key industrial assets. Its output in part funds acquisitions by the Ministry of Defence and its successful export performance makes a valuable contribution to the French economy. A 2016 Report to Parliament on French armament exports noted that in the 2008-2013 period, they had helped to reduce the balance of trade deficit by 5 to 8 points, with yearly variations. The defence sector provides jobs for almost 165,000 employees, i.e. 4% of France's industrial work force. In 2015, defence exports were particularly outstanding with orders totalling €16.9 billion. Over the same period, orders placed by the armed forces and Defence Ministry departments amounted to €11 billion.

When military use of facilities is limited geographically (army camps or training areas) or for an occasional event, some degree of sharing with commercial systems can be considered although this is not applicable to all frequency bands.

Since the early 90s, resources compatible with military purposes have been considerably reduced between 700 MHz and 3 GHz in response to an upswing in network and mobile usage, but the trend has now reached a limit for this frequency range, the physical characteristics of which favour mobility and long range applications.

In a globalised world, concepts of security, conflict and defence are evolving, and thus require strategic reappraisal, and this includes RF spectrum. Defence requirements, as described in the White Paper, point to a need for increasing transmission capacity to serve developments in military planning (battlefield digitization) or in equipment (robotization, increased autonomy and interoperability) for an extensive array of intervention scenarios.

**Drones**

The drone market in France in 2015 was estimated at €60 million and could rise to €650 million by 2025. Although the French authorities took regulatory measures at a very early stage, the spectacular boom in recreational drones has not yet been followed by any similar development for professional devices: there is a significant potential here for industrial growth.

Although initially driven by military defence and security requirements, professional uses also extend to civilian security (monitoring borders and sensitive sites, maritime security, site inspection following aviation accidents) and new commercial uses are appearing on the horizon (inspection of infrastructure and engineering works, high-voltage power lines, precision agriculture, etc.) This is a promising market but further expansion of civilian professional uses will call for regulatory and technological enhancement before major network operators such as SNCF, EDF and ENGIE can develop linear surveillance applications based on the use of drones.

All drones use frequencies for remote control. The use of long-range drones (non-line of sight or over the horizon operation) will require either protected spectrum resources or the development of safe operational procedures (in particular control redundancy) to ensure safe shared use of airspace.

The Defence Ministry already has the capacity for piloting drones by satellite, but in “segregated airspace” to ensure the safety of other aircraft. Military drones have been progressing steadily for over a decade because they are of great advantage when observing an area of operations, or for both brief and lengthy missions (up to and including several dozens of hours); as a result, drones provide strong complementarity with satellite observation.

A regulatory system featuring a variety of constraints depending on the type of usage, has been developed by the French civilian aviation authorities for small drones with line of sight (LoS) control. The frequencies, generally in what are known as the general authorisation regime Wi-Fi bands, are not protected.

Larger drones need totally reliable command-control links and they use frequencies already recognised for this type of operation, in particular in the 5 GHz band identified by WRC-12 for AMS(R)S / AM(R)S service. For long-range drone control, there is no alternative to satellites. Nevertheless, while awaiting the emergence of satellites capable of this function in the 5 GHz band, ITU considered at WRC-15 whether it would be possible to fall back on satellite commercial offers in the Ku and Ka bands for FSS. Such use of non-specific frequencies to pilot drones moving in “non-segregated airspace” (together with other air traffic) could not be contemplated unless subject to a number of conditions, due for ICAO consideration by 2023. This organisation is therefore currently working on drafting recommendations and standards applicable to drones in non-segregated airspace in the 5 GHz band as well as SFS Ku and Ka bands.

In 2016, Thalès Alenia Space (TAS) presented a new concept based on low-orbit satellites with 5 GHz command-control capacity.

Such ongoing research efforts raise hopes of safe solutions emerging within the next few years, to the accompaniment of reductions in the price of components and harmonisation of European regulations together with the development of a regulatory framework in the United States.

Building on expectations that regulatory hurdles can be negotiated and on gains in competitiveness relative to existing vectors (satellites, helicopters, small aircraft), projects involving satellite-controlled drones for civilian applications are expanding apace. Some emblematic projects are already in the offing, for example the 5G global solar-powered drone network Google is sponsoring or Amazon's delivery drones. An abundance of rather more accessible projects for personal monitoring and safety, on land or at sea, are also under scrutiny.

**Geolocation**

Many geolocation systems use radio frequencies to provide two essential items of information: the receiver's position and the exact time. A large number of applications using this data have been developed, ranging from creating itineraries on smart phones to precision agriculture, where detailed maps of fields are produced to improve crop management. Vehicle pools can be run more efficiently, using less fuel or reducing response times with the help of such data. Other means of transport also use geolocation: trains, ships and aircraft all need to know their positions to ensure the safety of passengers and freight, facilitate operations and optimise routes.

Time-stamping is an application often related to geolocation. Although the main objective of geolocation systems is to supply information on the receiver's position, transmission of a synchronised time scale, in particular through satellite systems, has led to the development of applications using this function alone. They serve for example for the time synchronisation of electrical distribution networks, for communications (mobile telephones, the Internet) and television broadcasting (digital terrestrial television). They can also provide the precisely time-labelled messages which are of such crucial importance for the reliability of financial transactions and therefore of the banking system as a whole.

Of the various technical solutions for geolocation, one that has progressed in a particularly spectacular fashion in recent years is GPS, an American constellation of satellites sending signals that provide positioning and navigational data. There are other equivalent systems, less familiar to the general public: the Russian GLONASS and the Chinese BeiDou. A European system, Galileo, is now being deployed. All these systems share three frequency bands: 1559-1610 MHz (historic core band), 1215-1300 MHz (extension band) and 1164-1215 MHz (additional extension band).

The Galileo system is being deployed under the aegis of the European Commission by the European Space Agency and the European Global Navigation Satellite Systems Agency. Unlike other systems, it was designed to be a global system operated by civilian authorities and intended for primarily civilian use (although it does include a dedicated governmental signal). This approach is a guarantee of European independence which is a crucial economic necessity in today's world: the European Commission estimated that some 6 or 7% of Europe's GDP — close to €600 billion — depends on the accuracy of data supplied by satellite navigation systems.

The Galileo system is in the final roll-out phase and initial services were declared operational on 15 December 2016. Full operational capacity will become available in 2020. The spectrum the system uses has had guaranteed international status since 2003 and is registered with ITU.

At some future time, satellite systems could replace the older terrestrial positioning systems such as DECCA, LORAN and Omega, widely used for ships and aircraft.  In contrast, the systems used specifically for aircraft (e.g. DME/TACAN) are likely to survive, mainly due to their resilience.

Some terrestrial positioning systems act as a complement to global satellite systems coverage, in particular to provide precise geolocation inside buildings (e.g. shopping centres or offices).  Several technical possibilities are on offer, for instance transmission within such buildings of signals similar to those carried by GPS/Galileo or Wi-Fi networks.

Other ground-based positioning systems aim to reinforce the accuracy of GPS and Galileo signals by supplying corrective “Differential GPS” data, or to improve their reliability with higher reception levels making them less vulnerable to possible interference (pseudo-satellites or “pseudolites”).

**Meteorology**

In order to acquire the data for the development of climatological models and forecasts, meteorology needs to access RF spectrum. In France, *Météo France* is the entity using radio frequencies for these purposes.

A number of satellite sensors currently collect meteorological and climatological data, for which sustainable spectrum availability must be provided. This applies to frequency ranges suited to the observation of natural phenomena as well as to frequency bands carrying the collected data back to Earth. For space applications, current usage and developments depend on projects led by EUMETSAT for Europe and by other meteorological satellite operators at global level (e.g. NOAA in the United States or CMA in China). Projects managed by other space agencies present on the international scene (CNES, ESA, NASA, JAXA) are also vital for subjects more specifically related to Earth observation.

Apart from satellite systems, acquisition of meteorological data uses three other types of RF devices:

- drifting balloon-borne radiosondes collecting data using frequencies in the 403 MHz range to transmit the data back to ground;

- 2.8 GHz, 5.6 GHz and 9.4 GHz meteorological radars, used to detect the movement of weather disturbances; in future, higher frequency bands — 24 GHz, 35 GHz, 95 GHz — will enable radars to be deployed for measurements related to hydrometeors or clouds;

- 45 MHz and 1280 MHz wind profiler radars. Among the developments in radio applications servicing meteorology are land-based passive radiometers for the measurement of certain characteristics connected to the gaseous composition of Earth's atmosphere (for example in the 20/30 GHz, 50/60 GHz, 90 GHz, 150 GHz and 183 GHz frequency ranges).

**Connected things**

The "Internet of Things" (IoT) is extending Internet usage — hitherto limited to communications between physical persons using computers or, more recently, mobile telephones — to objects communicating with each other or with servers. As a result, by 2020 according to some forecasts, as many as 50 (Cisco, Ericsson) to 80 (IDATE) billion objects could be interconnected. While figures and corresponding perimeters vary considerably, all the estimates indicate that connected objects will impact data transmissions.

The IoT will no doubt affect significantly such diverse sectors as health, transport and agriculture and will be making a contribution to the future configuration of industry, networked homes and smart cities. Such developments will benefit the economy and society as a whole but may also raise challenging issues, in particular as regards security and protection of privacy.

Irrespective of the type of connection chosen — local, dedicated, cellular or satellite networks for example — the IoT will be largely dependent on access to spectrum. While wireline networks serve to connect some objects, wireless technology will likely be the main vehicle for the growth of IoT, as ARCEP noted in their 2016 White Paper. For short range applications, such as those connecting smart home devices, Wi-Fi or Bluetooth technology will likely be adequate. Cellular networks, LPWA networks dedicated to the IoT or again satellite networks could likely be preferred for the development of device connection over long distances. For players involved in managing spectrum, the challenge of the IoT could be both the vast number of objects to be connected and the diversity of connectivity solutions.

Many French players (Sigfox, Qowisio, Actility, Adeunis RF and Kerlink) are as of now staking out a claim to the IoT, in France and abroad. The sector also offers a large number of opportunities for improving the production process and also for cost saving, in particular thanks to predictive maintenance, remotely controlled equipment and sensor data processing. Sensors, which could be integrated into machines, will measure temperature, vibration, humidity, pressure or the object's position, for example.

In the production sector, a PWC report, *Industry 4.0 - Opportunities and Challenges of the Industrial Internet*, predicts that the industrial internet (the digitization of value chains and connectivity of objects) could lead to an increase of 18% in productivity and efficiency in the use of resources within five years, thus making a contribution to sustainable development. The report, which was based on a questionnaire sent to companies in the German industrial sector, the results of which were extrapolated to Europe, also came to the conclusion that the digitization of products and services could generate as much as €110 billion per annum in additional revenue accruing to the European industrial sector. Concerning the IoT, IDATE predicts a compound annual growth rate (CAGR) of 14% in the 2015 to 2025 period, arriving at a global figure of 155 billion objects by 2025. This same report notes that in 2013, North America was the leading geographical IoT market with a 12% CAGR. Europe came second but would drop down to third on the list in 2025 because of its lower CAGR (14%) compared to Asia-Pacific's 16%.

The proliferation of connected objects, the nature of these devices, their environment (domestic or industrial, for example), the rate at which their use expands, the role of their operators, the kind of network involved, the kind of authorisation procedure governing them, as well as quality of service, are all factors which must be integrated into spectrum management for connected objects. Spectrum control and public exposure also enter into the equation.

A vast palette of resources is already available for connected objects, including:

• mobile operator networks (currently GPRS technology; new broadband or narrowband technologies developed by 3GPP in the near future);

• licence-exempt bands, including 169 MHz, 433 MHz, 868 MHz, 2.4 GHz, 5 GHz;

• private networks for certain sectors (energy, transport);

• satellite frequencies.

A number of IoT stakeholders have nevertheless underlined the urgent need for new resources to be provided in the 800 and 900 MHz bands under a general authorisation regime. This view echoes the work the Agency has been doing since 2015 in cooperation with ARCEP and the Ministry of Defence. ARCEP's White Paper on IoT also highlights this point.

While a large number of objects could be connected using low-speed services, such objects might be in everyday use and therefore present in large numbers, which would raise issues of spectrum occupancy. Other objects might require broadband connectivity, for example to send video content. The degree of pressure that connected objects will exert on spectrum will still depend on how they are connected to their servers. Connection may be either direct, requiring kilometric frequencies and therefore the obligation at some point to find specific frequency bands for such uses, or indirect, using licence-exempt bands to access smartphones or nearby access sites relaying communications to servers. This second type of configuration, which is currently predominant, helps to moderate the demands these new applications make on spectrum.

There is ongoing work on the following:

• the possible usefulness of opening other frequency bands for IoT, the 1900-1920 MHz band for example, under a general authorisation regime.

• the measures to be taken to facilitate spectrum use for private networks in the case of IoT applications needing protection from interference. Preferences as regards PMR and IoT frequency ranges and technologies will have an impact on future decisions regarding the 400 MHz band or the PMR bands above 1GHz (see the section on future PPDR and PMR networks);

• the technological choices that mobile operators will be making as regards new radio interfaces dedicated to IoT connections.

**Earth observation**

Observations made from space divide into two main categories. In the first, some of Earth's natural phenomena produce infinitely small variations in the radio emissions of molecules that exist on our planet, emissions that can be measured by sensitive satellite-mounted sensors. In the second, space offers an ideal location from which to carry out global imaging of the planet.

When it comes to observing natural phenomena on Earth, satellites equipped with radio instruments (radars, altimeters or passive sensors) designed to measure geophysical parameters can now be used for different types of observation:

- climatology, understanding the atmosphere, or meteorology: measurements can be used to study a range of different geophysical phenomena (salinity, humidity or temperature profiles) affecting the oceans or land masses, helping to identify, for example, areas of drought susceptible to outbreaks of forest fires, or to add to our knowledge of cyclones;

- altimetry: sensors record the altitude of the oceans and inland waters, and even of the ground, revealing information such as the impact of earthquakes on ground topography or on tectonic plates;

- detection of electric and magnetic disturbances of the Earth, often linked to earthquakes.

The spectrum required for these observations is dictated by the physical characteristics of the phenomena to be observed. Because these phenomena are natural in origin, the required frequency bands are unique, and cannot be open to reorganisation.

In the field of imaging, satellites are ideal platforms for acquiring images of the Earth. There are many optical imaging satellites currently in orbit and they are naturally not dependent on radio frequencies to gather their images, since they rely on visible light or infrared. These satellites are inoperative, however, in cloudy conditions or at night. Equipping them with synthetic aperture radar, however, enables them to carry out imaging irrespective of meteorological conditions.

Imaging applications, both optical and radar, also contribute to Earth observation, for example by monitoring changes in sea and lake ice, or possible marine pollution incidents, whether accidental or deliberate. They can also encourage better use of agricultural resources by observing agricultural fragmentation or deforestation.

Downloading the data gathered, while not a scientific application as such (simply a data transfer) is essential for the data to be used and is thus a major issue in the operation of Earth observation systems. These applications can be divided into three types:

- data collection platforms (beacons in systems such as ARGOS), which are used to gather scientific information such as readings of temperature, pressure, humidity or water levels, as measured by instruments deployed across the Earth's surface, transmitted directly to satellites, which then retransmit the data to ground stations for processing;

- direct links between satellites and ground stations, so that data collected on board the satellites can be downloaded to laboratories for interpretation;

- data relay systems: geostationary satellites communicate with non-geostationary Earth observation satellites, which transmit their observations to the geostationary satellites by radio or laser; the geostationary satellites then download the data to Earth. These systems offer the advantage of more frequent downloads of the data collected, without having to wait for the non-geostationary satellite's next pass over the data collection station. The United States of America and the Russian Federation have deployed such systems since the 1990s. Thanks to a public-private partnership between ESA and Airbus Defence and Space, a comparable European infrastructure, known as the European Data Relay System or EDRS, is in the process of deployment.

Unlike the spectrum used for observation of natural phenomena or for imaging, frequency bands used for the transmission of scientific data have no particular specific physical characteristics and are much more coveted by other applications.

At the European level, Earth observation applications are grouped under a structural programme known as COPERNICUS (for further details, please visit the project's official website or the ESA website).

Radio astronomy can also be used to study the physical and chemical properties of the Earth's atmosphere; when used for this purpose, it is referred to as aeronomy, the study of those planetary atmospheric regions in which the phenomena of ionisation and dissociation, mostly triggered by solar radiation, take place. Aeronomy is particularly useful to our understanding of holes in the ozone layer, the greenhouse effect or the magnetic storms that can disrupt telecommunications systems. Whereas meteorology focuses its attention primarily on atmospheric dynamics, aeronomy pays more attention to the physical and chemical structure of the atmosphere, using the measurement techniques of radio astronomy in dedicated frequency bands. The 22.21-22 GHz band is currently the one most commonly used, due to the presence of one of the spectral lines of water vapour at 22.235 GHz. Radio astronomers mainly use radiometers for these measurements, because their cooled receivers are highly sensitive. Unlike radio telescopes, radiometers offer much lower antenna gains and are much smaller (in size and weight), making them movable.

**Observing the cosmos**

Radio astronomy is the observation of astronomical phenomena via the reception of radio waves originating in the cosmos. ITU has identified the frequency bands necessary for these observations based on the physical characteristics of the chemical molecules under observation: hydrogen, water vapour, methanol or carbon monoxide, for example. Radio astronomical measurements are often carried out as part of an international framework involving research laboratories in several countries.

Because they measure radio emissions from celestial objects at cosmic distances from the Earth, radio astronomy receivers are designed to detect extremely weak signals, without comparison with those used in terrestrial applications. There are two types of radio astronomy observations:

- observation of spectral lines, where the radiation detected by the radio telescope is the result of spontaneous emissions (associated with changes of quantum state) by certain atoms or molecules (hydrogen or hydroxyl radical, for example). These lines are characterized by precise central frequencies, determined by the characteristics of and physical changes to the molecules under observation;

- observation of continuum emissions, whether thermal or non-thermal in origin (planetary magnetosphere, for example, or solar flares), for which radio spectrum is wide-band.

To observe these cosmic sources, radio astronomers use either an extremely large antenna providing sufficient spatial resolution to distinguish the various celestial objects under observation, or interferometry systems combining simultaneous measurements by a number of radio telescopes thousands of kilometres apart. These systems achieve resolutions so fine that they are able to study the detailed structure of distant radio sources. Observations made by high spatial resolution interferometry therefore rely on simultaneous reception of the same radio frequency by widely dispersed reception systems, further emphasizing the international scope of the protection afforded to radio astronomy: if just one of the observation systems is affected by interference, all the other international measurements are compromised.

There are four radio astronomy observatories in France: Nançay, the plateau de Bure, Maïdo on the island of Réunion and Floirac.

While radio astronomy studies the cosmos from Earth, satellites, too, can be used to observe celestial objects. Scientific space research is set firmly in a dynamic of international cooperation: costly programmes (astronomical missions such as the Herschel infrared space telescope or the Planck cosmic microwave background mapping mission) are conducted by the European Space Agency (ESA) and financed by a budget to which member states contribute. Onboard instruments are supplied by member states following requests for proposals. France’s participation in ESA is coordinated by the French space research agency, CNES.

In addition to its European initiatives, CNES conducts national programmes (such as the MICROSCOPE project launched in April 2016, designed to verify the principle of equality of gravitational and inertial mass, one of the foundations of the theory of general relativity) and engages in multilateral cooperation (such as the CoRoT satellite carrying a space telescope designed to study the internal structure of stars and search for exoplanets). These programmes are generally based on micro or mini-satellites. For projects such as these, CNES brings in scientific and industrial partners to carry out the space programmes it designs.

Because they are so intrinsically international in nature, space research systems rely solely on frequencies that have been globally harmonised under the ITU Radio Regulations. In France, CNES operates a space research station, based on the Kourou site, in the 8400-8500 MHz band, for the needs of projects such as Mars-Express, Rosetta, Herschel or Planck.

**Production of audiovisual content**

A wide variety of wireless devices, microphones and video cameras for instance, are needed to produce audiovisual programmes. They are often referred to collectively as PMSE (Programme Making and Special Events) systems and divided into two major subsets which are wireless audio (audio PMSE) and video (video PMSE) devices used by professionals, in particular for film shoots, TV programme production, live entertainment or major events.

Audio PMSE refers to various devices such as various types of wireless microphones and onstage monitor systems) for the production of TV, theatrical and operatic content as well as for covering media and sports events. In France, such equipment is used under a general authorisation framework ensuring the possibility to access a number of specific frequencies in compliance with technical conditions set out by ARCEP. With the exception of two bands, harmonised by the EU in 2014, PMSE spectrum available across Europe and licensing systems vary from one country to another. Currently, audio PMSE operates mainly in the TV UHF band. Analog wireless microphones are still in use today as they offer low latency which is essential for sound feedback and synchronisation with actors' gestures.

Audio PMSE, operating in the white spaces left by TV broadcasting, has come up against successive reconfigurations of the UHF band intended to clear the 800 MHz and later 700 MHz bands for use in mobile communications. Before 2010, the 470-862 MHz band was accessible, but now only the 470-694 MHz range is available, meaning that 168 MHz worth of spectrum was lost. And yet PMSE needs are growing because of increasingly complex productions. Between 2003 and 2012, TV production needs increased more than six fold and there was a further increase of 88% between 2009 and 2012.

There is also a significant increase in demand when major media events take place, such as the *Tour de France*, the *24 Heures du Mans* and *Roland-Garros*, the international tennis tournament. Over the past ten years, the *Tour de France* has seen a continuous increase in the number of audio PMSE frequency requests, rising from 365 frequencies in 2007 to 687 in 2016 (+88%). There was a similar increase for *Roland-Garros*, which grew from 187 audio PMSE frequencies in 2007 to 416 in 2016 (+122%). ANFR, acting under delegation of powers from ARCEP, plays a key role in the coordination of these frequencies and allocating temporary frequency authorisations for the duration of the event concerned.

Frequencies above 1 GHz are still available for specific applications, for instance for use in conference rooms where the environment is predictable and latency due to digitising (and therefore signal encoding) is acceptable.

Video PMSE refers to the equipment used for transporting video signals from portable wireless cameras, either ground-based or aboard land or airborne vehicles. Unlike audio PMSE devices, the use of frequencies for this type of equipment is granted through individual temporary or permanent authorisations.

In France, demand may on occasion exceed capacity as identified in the TNRBF (*Tableau national de répartition des bandes de fréquences*/National table of frequency allocations) for that purpose. Negotiation between ANFR and assignees is then required to access the bands involved and thus satisfy demand on a local and temporary basis.

**Radio**

Today's radio programmes are broadcast via a number of carriers. Historically, radio was broadcast using several frequency bands, such as long wave (148.5-283.5 kHz), medium wave (526.5-1606.5 kHz), short wave (3200-26100 kHz), FM (87.5-108 MHz), band III (174-230 MHz) or even the L band (1457-1492 MHz). Satellite and cable networks also broadcast radio content. Many radio programmes can be heard through the Internet, fixed or mobile.

Frequency bands below 30 MHz are mainly used with analog technology. They may, however, be used for digital broadcasting based on the Digital Radio Mondiale standard (DRM/DRM+). These bands are used for broadcasting internationally and their coverage can be as far-reaching as thousands of kilometres. But this long range, combined with a small number of available channels, limits the number of such radio stations worldwide. At this point, several radio stations have already ceased analog long wave broadcasting and, in France, *France Inter* is due to close down by the end of 2016. So far, there are no analog or digital plans for replacing them.

Most of today's radio broadcasting uses the FM band. According to a report from the French observatory for home audiovisual equipment in 2015, 99.4% of people have access to radio, of which 96% is via FM, as compared to 95% in 2014. The FM band is very popular in France so that the 87.5-107.9 MHz frequency band is used intensively. Despite repeated and highly sophisticated efforts by the French Audiovisual Council (*Conseil supérieur de l'audiovisuel, CSA*) to reorganise it, the FM band is now saturated. It seems unlikely that any substantial quantity of new frequencies can be released in future.

As regards Band III, 174-230 MHz, several European countries — the United Kingdom, Germany and Switzerland among them — have already made considerable progress in broadcasting digital radio services, thanks to digital audio broadcasting technology (DAB/DAB+). In France, digital terrestrial radio (DTR, *RNT* in French) uses mainly the 174-225 MHz band while the 225-230 MHz band is assigned to the Ministry of Defence. After DTR broadcasting began in Paris, Nice and Marseilles on 20 June 2014, the CSA published a timetable for forthcoming calls for tenders in mainland France covering 2016 to 2023, so as to enable continued deployment in France using two, or even three, multiplexing channels in major cities. Such a call for tenders was launched on 7 June 2016 for Lyon, Lille and Strasbourg. The list of stations accepted for DTR broadcasting in these three cities was published on 3 December 2016.

This phase should significantly extend DTR coverage which will be approaching the 20% threshold coverage of mainland territory that triggers the rule that any new radio set sold in France must integrate the DAB+ standard enabling DTR reception. This same frequency band is also used for

PMSE during major events, such as the *Tour de France*, for example, or in other countries for digital terrestrial television (DTT, *TNT* in French).

The L band, up to now allocated to a radio network able to broadcast via terrestrial and satellite channels after having relinquished the benefit of its convention, is now being reassigned to mobile communications.

Another possibility of broadcasting radio content is the Internet, fixed or mobile. The vast majority of radio programmes can be heard in real time via their Internet site for fixed access or with a specific application for tablets and smartphones.

4G+ has a distribution mode suitable for radio (broadcasting instead of unicasting) and 5G will also provide radio programme broadcasting possibilities. It will, however, be necessary to be mindful of the pluralism of schools of thought and opinion expressed through this new medium.

Turning to satellites, the vast areas covered by geostationary satellites qualify them as excellent broadcasting platforms. Thousands of television channels and radio stations use satellites to broadcast programme content in Europe and their numbers are constantly growing. In France, all of the DTT channels are broadcast in HD via two satellite platforms. Satellite technology pioneered improvements to TV broadcasting formats: digital broadcasting was introduced in the 1990s, then high definition arrived in 2005 (and it is expected that by 2020, HD channels will be generating 20% of the satellite broadcasting market) and finally, today, UHD has just arrived on the scene. As with the terrestrial platform, this new format will be facilitated by the HEVC video compression standard. One of the advantages of the satellite platform for UHD broadcasting is its immediate availability: satellites already in orbit are technically capable of broadcasting a large number of extra UHD channels without delay.

Although, strictly speaking, it cannot be classified as a broadcasting application, satellite broadcasting also plays a crucial role in the distribution of DTT channels by feeding content to terrestrial transmitters. Most of these transmitters are not fed by cable or fibre, but by radio relay either from a nearby terrestrial relay or by satellite. In France, therefore, satellite broadcasting contributes indirectly to the transmission of DTT throughout the country.

As for the frequency bands in use for satellite broadcasting, almost all the satellites currently transmitting to Europe do so via the 13-14 GHz/10-11-12 GHz frequency range. This being the core range for satellite broadcasting in Europe, it seems clearly earmarked for hosting today's channels well into the future and providing room for expansion to house the new channels constantly being created.

**Radio amateurs**

Radio amateurs are devotees of a technically-inclined hobby that enables them to experiment with and acquire the techniques of radio transmission and to make radio contact with other radio amateurs around the world. Their transmissions use spectrum allocated by ITU to the Amateur and Amateur-Satellite services. These bands are harmonised internationally and reserved for this specific purpose.

ITU also recommends that administrations take the necessary steps to verify the technical and operational qualifications of any person wishing to operate an amateur station, and that anyone applying for a licence to operate an amateur station should be required to demonstrate their theoretical knowledge. These rules and recommendations are applied by most countries on the same terms and determine the issuance of an amateur radio operator certificate and a call sign by the regulatory body. France is currently home to close on 14,000 radio amateurs.

French regulations do not, at present, cover interconnections to Internet by radio amateur stations. Voice over IP (Voice over Internet Protocol, more commonly known as VoIP) extends beyond national frontiers and has captured the attention of the radio amateur world. How could anyone not be interested in these new means of communication via public networks that can be used, thanks to IT, to transmit data instantly at high speeds and over long distances?

Digital transmission improves the quality of voice communication and offers the possibility of simultaneous data transmission.  The move towards IT-based use, with computers linked to a network, is seen as desirable by the majority of radio amateur organisations, in that it offers a number of advantages: easier localisation, archiving of contacts and data transmitted, or wider sharing of information by reaching more radio amateurs all over the world.

Transmission protocols have been developed, such as packet radio (text and data), APRS (text and data), D-Star (voice and data), DMR (voice and data) or Tetra (voice and data). Software designed specifically for radio amateur use (Echolink, D-RATS, Hamsphere) offers still more possibilities for network connection. The authentication procedures for connecting to a network still need to be standardised in order to guarantee user confidentiality for those who request it, including an option for online monitoring via connection to the official directory of licensed radio amateurs managed by ANFR.

In the French Overseas Communities (COM) and French Antarctic and Austral Territories (TAAF), the decree of 30 January 2009 defining the use of radio amateur stations (in terms of frequency bands and classes of emission according to the three levels of radio amateur certificates that existed in the past) currently does not take into account the use of digital modes (see ARCEP decisions 2012-1241 and 2013-1515). Nor does it incorporate the changes to radio amateur certificates, with only one level now available (decree of 23 April 2012).

**Augmented reality and virtual reality**

Increases in computing power, miniaturisation of hardware and the speeds envisaged for radiocommunication are paving the way for large-scale development of virtual reality (VR) and augmented reality (AR). VR involves immersing the user in a digitally reconstituted environment in which the user may be a spectator or even interact with virtual objects or persons known as “agents”. AR retains the real world environment but overlays it with information or images. The frontier between the two concepts remains subjective and varies according to the proportion of the real/virtual in the environment presented to the user.

One way in which the technology can be used involves a specially adapted room (CAVE, a recursive acronym for Cave Automatic Virtual Environment) in which 3D images are projected onto the floor and white-screen walls surrounding the user, who wears 3D glasses and carries sensors to detect their location and movements. This requires dedicated infrastructure and is therefore generally reserved for corporate use.

A second and more recent option relies on the small, high-resolution screens that have now become more widely available, mounted in specially designed headsets. The computing power still resides in an independent PC, however, meaning that cabling is required. These are mass market electronic devices, mainly used at the moment for immersive video games.

A third possibility involves using a smartphone to scan in all directions for virtual objects, but the applications and image quality remain limited by the computing power of the device itself. Unlike the first two uses, this approach does away with the need for wired networks and relies, out of doors, on mobile network frequencies. At present, it is particularly well suited to augmented reality thanks to its ability to display a variety of information or images, as illustrated by the Pokémon Go game.

The expected growth in VR and AR requires access to speeds sufficient to dispense with wired devices whilst supporting mobile display, at very high resolution, of complex, dynamic environments, and limiting latency. This relies on spectrum resources, which may be implemented from 2019 onwards in the form of local networks on licence-exempt spectrum (WiGig) or via 5G.

**Private networks**

ANFR receives and processes applications for private mobile radio (PMR) networks on behalf of ARCEP, under the terms of an agreement between the two agencies. On 30 November 2016, there were 25,475 PMR networks under ANFR management. In 2015, ANFR processed 5,331 frequency applications for low-speed PMR networks (2,546 for permanent networks and 2,785 for temporary networks), to serve the needs of a wide variety of sectors of activity.

These frequency applications come from several different categories of user, to meet ongoing or more occasional needs:

- Business users, from self-employed professionals to major groups, in sectors ranging from transport (road haulage companies, bus companies, taxi firms, airport services, motorway concession operators or ambulance companies), security, building and public works, industry and energy;

- Cultural, sports or leisure groups;

- State services, including hospitals, local authorities or public establishments;

- Companies, media or organisations using frequencies for very short periods to cover one-off events (Roland-Garros tennis tournament, Le Mans 24-hour race, exhibitions or news events).

PMR relies on narrow-band analog and digital technologies (from 6.25 kHz to 25 KHz) in frequency bands below 470 MHz. 70% of networks are currently authorised in the 400 MHz band. The shift from analog to digital seem to be gaining ground as new needs are identified or when obsolete equipment is due for replacement. At present, 12% of the installed base uses digital technology (of which 10% in the 6.25 KHz, 58% in the 12.5 KHz and 32% in the 25 KHz bands).

Changes to the LTE standard now make it possible to provide standard PMR features (group call or direct call between terminals) on high-speed systems. The 400 MHz band is preferred to the 170 MHz or 80 MHz bands, since it means antennas and terminals can be kept to a reasonable size. A number of experiments have been carried out in the 400 MHz band (Airbus, Nokia), the 700 MHz band (Hub One) and in the 2.6 GHz band (members of AGURRE, the organisation of professional PMR radio network users).

While broadband constitutes a solution for certain major users, most PMR users or professionals seem willing to settle for low-speed solutions on a long-term basis, given their specific requirements. ARCEP is planning public consultation on the subject. This situation means, therefore, that frequency spectrum must be set aside to meet the ongoing needs of these users, who see no immediate need for a change of system.

**Satellite Communications**

Starting in the 1980s, VSAT (Very Small Aperture Terminal) technology using private networks has been key to the development of satellite data transmission. Currently, however, audiovisual broadcasting and distribution are the main sources of income for satellite operators and will remain so for many years to come.

Recent technological developments in satellite design are providing an opening for satellites to penetrate two new digital connectivity market segments:

• high-speed fixed Internet access (very high-speed by around 2020), as a complement to coverage provided by terrestrial infrastructure;

• connectivity offers for travellers, in particular at present for ship or aircraft passengers.

Commercial in-flight communication capability (as distinct from communications concerning flight security and the regularity of flights) has recently emerged due to improvements in antenna design: repointable satellite antennas can be mounted on board today's commercial aircraft. Two technical possibilities co-exist currently, one in the 13-14/10-11-12 GHz range, and the other in the 30/20 GHz range. For medium-haul flights, a system based on a hybrid network made up of both a terrestrial and a satellite component in the 2/2.2 GHz range is in the process of development in Europe. It will probably be launched in 2017.

Other means of transport will be following suit, such as railways: on certain lines (Thalys for instance) commercial services have already been available for several years although this is not the general case as yet. In the 2/2.2 GHz range, where ground antenna pointing is not as critical as for other frequency bands, the entry into service of two satellites covering Europe towards the end of 2016 or early in 2017 could mean new offers for trains and also, probably, for road vehicles.

Fixed broadband Internet access, such as the connectivity on offer for users of public transport, will benefit from ANFR's European and global work on earth stations in motion during WRC-19 and the securing of required frequencies in the 30/20 GHz range.

**Internal security and emergency assistance to the public**

The French Ministry of Internal Affairs needs spectrum resources to carry out its functions, including those relating to the fire and emergency services (Law n° 2004-811 on the modernisation of civil security, dated 13 August 2004). Like the Defence Ministry, a special feature is that its use of spectrum includes many services defined by the ITU Radio Regulations. The Ministry of Internal Affairs has listed several categories of applications for which it exercises direct control over authorisations for spectrum use:

- mobile radio networks for security and emergency purposes;
- fixed communications infrastructure;
- drones;
- video surveillance (CCTV) and video reporting.

A PMR type of network (the *infrastructure nationale partageable des transmissions/*INPT - national shared-use transmissions infrastructure) makes the ACROPOL service available for use by police and mobile *gendarmerie* units as well as the ANTARES service *(Adaptation nationale des transmissions aux risques et aux secours* - National plan for adapting transmission systems for security and emergency purposes*)* for use by emergency and civil security organisms (UISC, BSPP, BMPM and SDIS). This national network uses TETRAPOL technology and is situated in the lower part of the 400 MHz band. The Ministry of Internal Affairs' mobile radio system uses a small portion of the 400 MHz band. This narrow band system cannot cope with current communications requirements in areas with high population density. However, an agreement with the Defence Ministry authorises the Ministry of Internal Affairs to use extra spectrum when required.

Fire and emergency services (SDIS, BSPP, BMPM) use some frequencies in the VHF bands (80 MHz and 170 MHz) to implement early warning systems such as Alphapage.

The *Gendarmerie's* RUBIS network is not included within INPT; it mainly uses spectrum in the Defence Ministry's 70 to 80 MHz band.

Some communities as well as public transport operators have set up video surveillance networks. ARCEP authorises such networks if they rely on radio links. Some imagery feedback goes to police and *gendarmerie* command posts.

Services such as the SAMU (urgent medical assistance), run by the Ministry of Health, coordinate their activities with fire and emergency services, sometimes also with the police and the *gendarmerie.* They use networks authorised by ARCEP. For these missions, the SAMU networks are hosted by INPT.

It is already agreed that future PPDR radio networks, developed for 4G LTE technology, will subsequently follow the mobile networks' migration to 5G. Similarly, the "business" applications for homeland security and disaster relief are already using connected objects for monitoring and protecting response teams as well as for direct machine-to-machine (M2M) communication. The use of these technologies for the specific needs of government missions will no doubt expand at the same rate as does their development on the consumer market. However, in order to ensure the high level of resilience and availability for such missions, they will need secure spectrum resources, which does not seem compatible with an assignment of the licence-exempt bands in use for mass-market applications.

Infrastructure links

The Ministry of Internal Affairs furthermore uses the 8 GHz, 13 GHz, 22-23 GHZ and 37-39 GHz frequency bands (the long-distance links in the 1.5 GHz and 3.5 GHz bands will be migrating to other bands in the medium term) for the infrastructure networks supporting the INPT networks (40%, the remaining being leased lines) and RUBIS. However, the lessons learned from emergency relief operations (Klaus and Xinthya storms) have demonstrated the need for revising strategies as regards radio relay infrastructure networks (redundancy and availability). Efforts to pool radio relay infrastructures within the ministry (with the *gendarmerie* in particular) and increases in throughput achieved with IP (Internet Protocol) technologies have already made an impact on requirements across the spectrum.

Finally, radio relay links are in use for data transmission from regional fire and emergency services not included in ANTARES, as well as for a few infrastructure connections for the benefit of regional authorities (*préfectures).*

<u>Drones</u>

The Ministry Internal Affairs has entered into a bilateral agreement with the Defence Ministry for the development of small drones. Constantly evolving needs for surveillance and maintenance of infrastructure on the one hand, and awareness of the extremely tense situation created by the

2015/2016 terrorist attacks on the other, have led the Ministry to give more weight to secure spectrum resources and to engage in a more comprehensive consultation with operational entities to decide whether such activities will require the same level of protection as is provided for law enforcement drones (GIGN and FIPN).

Video surveillance and reporting applications

The Ministry Internal Affairs uses CCTV video systems to meet surveillance and protection requirements.  Links are divided into the following categories:

- point-to-point to connect remote collection points to centres of operation (video protection);
- point-to-point infrastructure (video protection in the absence of wired systems);
- point-to-multipoint to transmit information from mobiles to a central operating unit or from a mobile to a fixed point of capture (video protection).

The Ministry is implementing video-reporting systems to cover pursuit or terrain visualisation needs during various operations, i.e.:

- airborne, to transmit imagery from police, civilian security and fire service helicopters in the 1350-1375 MHz bands (DEF derogation) and gendarmerie in the Defence Ministry's 4.4-5 GHz band;
- terrestrial, to transmit ground imagery in the greater Paris area and in other cities in the 1375-1400 MHz band (coordinated by ARCEP);
- tactical, for video reporting enabling real-time crisis management, which will be a section of future needs as part of the move towards higher speed networks (Broadband PPDR).

Other applications

The Ministry of Internal Affairs uses various spectrum resources for:

- "Business" aeronautical communications between:

  - aircraft and ground-based law enforcement teams;

  - aircraft and local or remote centres of operation.

- specific applications (e.g. long-distance communications networks in tropical forests) in French overseas territories for civilian security communications;

- last-resort civilian rescue measures in certain *préfectures* (regional civilian authorities) such as fixed and mobile radio sets in SSB mode, for instance during the KLAUS storm;

- specific applications for one-off long-distance links assisting law enforcement units (GIGN and FIPN) as well as for the specific requirements of the *direction générale de la sécurité intérieure* (DGSI) - internal security directorate;

- emergency networks, in particular for mountain rescue operations and forest monitoring; users of these networks are employees of the Ministry of Internal Affairs; rescue associations (reserve manpower for forest fires and mountain rescue) may need to connect to these networks for one-off operations or major events;

- overseas security and rescue forces' networks (analog); they are currently migrating to digital;

- finally, many systems are implemented for the benefit of fire services. Each of the departmental fire and rescue services/*Service Départemental d'Incendie et de Secours* (SDIS) implements analog or digital alert networks for agents (volunteers, forest fire reservists, etc.) as well as departmental alert networks for emergency and rescue centres. They respond to SDIS needs for purposes not supported by ANTARES, the digital network reserved for public services participating in civilian security missions.

**Television**

Television plays an important role in society and is still a key tool to access information for French audiences: in 2015 they devoted an average of 3 hours and 44 minutes per day to watching it and 92% of the population had at least one weekly contact with TV (see *Enquête Médiamétrie 2015*).

Originally, television was exclusively broadcast via terrestrial technology, but its means of access have diversified over the past thirty years. Some are now based on wired infrastructure (cable, ADSL or fibre) while others are still using spectrum in various wavelengths: DTT, satellite, mobile data networks or Wi-Fi. This diversity of access is reflected in the no less diverse variety of terminals on which to watch programmes: TV sets, tablets, computers and smartphones. Simultaneously, consumption of audiovisual content, which used to be entirely linear, now includes video-on-demand and interactive audiovisual services. Finally, digitisation of the signal has paved the way for general access to high-definition (HD) and the birth of ultra-high-definition (UHD) or 4K, capable of broadcasting cinema-quality pictures in a format suitable for the ever increasing dimensions of home TV screens.

These developments have contributed to modifying the space occupied by broadcast television, either via satellites (22.1% of households) or DTT (55.9% of households in the second quarter of 2016).

Two frequency bands in succession were released by the terrestrial platform, one in 2010 and 2011 (the 800 MHz band, transferred to mobile communications), and the other is expected for clearance between April 2016 and mid 2019 (the 700 MHz band, given over in part to mobile communications and the rest to security networks). This repurposing became possible because of the move to digital broadcasting which greatly improved the platform's spectrum efficiency so that, with fewer resources, the number of terrestrial channels could be increased thanks to DTT, and HD broadcasting could be rolled out widely. In keeping with the proposals contained in P. Lamy's report to the European Commission, regulatory authorities were keen to guarantee that the UHF band currently used by DTT (470-694 MHz) would continue to be allocated to the audiovisual sector until 2030. This decision was ratified by law.

In coming years, television transmission will no doubt be witness to the appearance of new standards enhancing spectrum efficiency, in the wake of the second-generation Digital Video Broadcasting-Terrestrial Transmission standard (DVB-T2) or the High Efficiency Video Coding Compression standard (HEVC). These standards are due for deployment by 2020 in some European countries, Germany among them. In France, CSA has begun working on the future of standards and usage on the DTT platform.

Since programmes for terrestrial broadcasting tend to vary in richness of content from one country to another, the 470-694 MHz band, which is entirely occupied by DTT in France, features some available capacity in other countries. Some countries, like Finland, are thinking of using this resource to extend the mobile network although they are committed to making sure that in doing so they do not interfere with audiovisual broadcasting in neighbouring countries. In the United States, because of the preponderance of cable and satellite broadcasting, the space reserved for terrestrial television is already smaller than in Europe. As a result, the 600 MHz band in the United States is currently being allocated to other services.

Turning to satellites, the vast areas covered by geostationary satellites qualify them as excellent broadcasting platforms. Thousands of television channels and radio stations use satellites to broadcast programme content in Europe and their numbers are constantly growing. In France, all of the DTT channels are broadcast in HD via two satellite platforms. Satellite technology pioneered improvements to TV broadcasting formats: digital broadcasting was introduced in the 1990s, then high definition arrived in 2005 (and it is expected that by 2020, HD channels will be generating 20% of the satellite broadcasting market) and finally, today, UHD has just arrived on the scene. As with the terrestrial platform, this new format will be facilitated by the HEVC video compression standard. One of the advantages of the satellite platform for UHD broadcasting is its immediate availability: satellites already in orbit are technically capable of broadcasting a large number of extra UHD channels without delay.

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As for the frequency bands in use for satellite broadcasting, almost all the satellites currently transmitting to Europe do so via the 13-14 GHz/10-11-12 GHz frequency range. This being the core range for satellite broadcasting in Europe, it seems clearly earmarked for hosting today's channels well into the future and providing room for expansion to house the new channels constantly being created.

**Air transport**

Radio-electrical equipment for air transport provides links between different aircraft (in-flight anti-collision systems), between aircraft and ground and also inside a single aircraft. It is conducive to greater in-flight safety and regularity. Since development costs are high for such equipment, a degree of regulatory stability is recommendable.

The aeronautical sector is of strategic importance for the French economy. French companies operating in this sector (designers of commercial and business aircraft, helicopter designers, avionics and radar manufacturers, satellite constructors and operators) are world leaders in their respective fields, in civilian and defence applications alike. Their contribution to aeronautical safety worldwide is significant.

The SESAR programme (Single European Sky ATM Research), the technological section of the “Single European Sky” (SES) initiative, aims to modernise systems and infrastructures used for Air Traffic Management (ATM) so as to facilitate the reorganisation of European airspace and meet essential requirements for the sustainable development of air transport as regards safety, the environment, capacity and economic efficiency.

For air transport, spectrum use includes air-to-ground, navigation and surveillance communications. There are a number of very different applications for use in radiodetermination (radars) as well as in voice and data transmission, by direct links or via satellites.

HF and VHF bands are used for voice and data communications over long and medium range and also for radio beacons and landing aids.

Bands just above 1 GHz are exploited extensively to determine aircraft distances (DME), for secondary radars (SSR), anti-collision systems (ACAS) and the aircraft tracking system (ADS-B). The future aeronautical communication system (LDACS) is also in the process of development in this band.

The 5 GHz band (5030-5150 MHz) was initially set aside for an improved mobile landing system (MLS). Now, however, it is mainly being considered for other developments, in particular direct or satellite communication systems, as well as communications for drone command and control, for aircraft on the ground and for the Airbus aeronautical telemetry system.

A large number of bands are widely used for ground and airborne radars. Each frequency is assigned to a different specific purpose. The 1.3 GHz band is used for long-range primary radars, while the 2.8

GHz band is preferred for medium-range radars.  Motion-sensing ground-based radars use the 9 GHz and 15 GHz bands. Onboard radars are on the 4.3 GHz band (altimeters) and the 5.3 GHz and 9 GHz bands (weather radars).

Forthcoming innovation in the air transport sector will require appropriate spectrum resources. Manufacturers of commercial aircraft (including Airbus) are developing wireless connections (WAIC/Wireless Avionic Intra Communication) to replace some of the wiring needed to pilot an aircraft. Equipment of this kind will probably be appearing on the market by 2019.  WRC-15 concluded that the portion of the spectrum reserved for altimeters could be shared with these new applications.

**Rail transport**

The wireless communications system developed for rail is GSM-R (Global System for Mobile Communications-Railway). Although GSM-R is still in the roll-out phase, in France in particular, thought is already being given to how best to respond to the need for higher throughput. Choosing this new system is one of the most important decisions that will have to be taken in the next few years by the rail transport community and authorities in charge of this sector. According to the European Union Agency for Railways (EURA), the GSM-R standard will cease to be maintained by the GSM-R Industry Group after 2030. The rail transport community aims to define the future system by 2019 for it to be referenced in European regulations as of 2022.

As the name implies, GSM-R is based on GSM, the 2G standard for mobile communications. It enables drivers (in their cabs) and maintenance workers to speak to each other (group calls) or to rail traffic regulators. GSM-R also implements the European Train Control System (ETCS) which unifies trains and railway signalling and makes them smarter and safer. This system is part of ERTMS (European Rail Traffic Management System) which should, eventually, replace the automatic warning signalling systems on board trains. For example, in the event of an emergency, the GSM-R system would broadcast the radio alert that brings all train traffic to a stop in a given area.

In accordance with current European regulations, all GSM-R networks in Europe use the 876-880 MHz frequency band for the train-to-ground link and 921-925 MHz for the ground-to-train link. Thanks to this guaranteed interoperability, trains can cross European borders without having to change their radiocommunication system.

Upgrading to higher data rates aims to increase safety, enhance performance and improve the efficiency of rail transport. Eco-driving and real-time monitoring of energy consumption will also be enabled. The new high-speed network, the Future Railway Mobile Communication System (FRMCS), will be used by railway operators to communicate between trains, or with mobiles and other trackside communication devices.

The next decision to be taken is related to the technology to be adopted for the next generation. The rail transport community's current preliminary thinking is based on the LTE standard, in use for 4G on mobile networks, which would have to be adapted to the needs of rail. Another option would be to choose 5G, which would appear to meet new rail transport requirements in view of the low latency and reliability of service features that it is expected to provide.

A second point for decision will be the spectrum to be used for the future system and the process for coexistence and migration. Among the possibilities, the most promising would be the introduction of new technology in bands currently exploited or, possibly, in other bands dedicated to private networks (PMR), such as the 400 MHz band or bands above 1 GHz, or perhaps the use of commercial networks (4G or 5G). Work will be needed on European harmonisation and also on coordination between member states on migration, before introducing the successor to GSM-R.

Communications-Based Train Control (CBTC) is an application in use for urban rail networks (metros and tramways) to locate and direct trains via a two-way high-speed communication system between trains and the ground infrastructure.

This application for metro trains contributes to ensuring fully automatic light rail systems for example in Paris and also in Lyon and Lille. It operates in the 5915-5935 MHz radio spectrum band.  This essential application for the development of tomorrow's urban transport systems is not, as yet, contained in any harmonised framework.  In a handful of countries, CBCT is occasionally implemented in the 2.4 GHz band although it is hardly suitable for a critical communication system to be running on a general authorisation framework.

In the long term, there is also the possibility that the technology could converge within the ERTCMS system.  The feasibility of this option and its impact on spectrum management should be explored.

**Maritime Transport**

By the end of the 19th century, one of the earliest uses for radiocommunication was communicating with ships. To this day and over a century later, frequencies are still irreplaceable for keeping in touch with seafarers and ensuring the safety of sailors and cargoes, although in the meantime, the volume of information needing to be transferred has increased. Digitizing communications is helping to increase the quantity of data that can be transmitted using the same amount of spectrum and plans are under consideration for responding to these new requirements by making new frequency bands available.

It should also be noted that maritime transport is a major component of national economies: 90% of the global movement of goods is seaborne. This represents some 8 billion tonnes of freight. In the case of France, 72% of imports and exports are transported by sea. In addition, French maritime transport companies carry 15 million passengers annually. In contrast with the economic crisis prevailing in recent years, maritime transport has increased by an annual average of 4%.

The growth in maritime radiocommunication requirements is the result of increasing maritime traffic and data transfer rates. In the last fifteen years or so, items have appeared on successive WRC agendas with the aim of facilitating the introduction of digital technology to the spectrum in use by the maritime community, following the earlier example of maritime HF bands.

Conventional communication systems (i.e. the telephone) have turned out to be ill-suited to transferring the information required to improve navigational safety, in particular when conditions are poor. To ensure the safety of ships and the efficient management of maritime traffic, the sector needs more real-time information, thus upgrading operational decision-making on land and at sea, including for example: weather forecasts, ice coverage maps, the position of aids to navigation, water levels and data on rapidly evolving port situations.

For security purposes, shore-based authorities also wish to gain access to more real-time shipping information, including for instance travel data, passenger lists and notifications in advance of a ship's arrival. Efficiency would certainly improve if such data could be digitized and transmitted before a ship docks. Several projects of this kind are under way internationally, such as Mona Lisa, Mona Lisa2 and EfficienSea.

**Autonomous cars**

While not yet autonomous, the car of today is already connected. Many manufacturers now offer models featuring a SIM card slot to connect the car and its occupants to Internet. In addition, from 2018 onwards, all new cars will have to be equipped with eCall emergency call technology as standard. In the event of an accident, eCall informs the emergency services automatically, and can also be triggered manually. In addition to sensors and smart communication systems, the electric car of tomorrow will also use spectrum for wireless power transmission (WPT) applications to recharge batteries, an issue that will be discussed at the WRC-19.

Over the next decade, private cars will offer considerably more than this kind of assistance to drivers. Several key players are already looking ahead to milestones to the driverless car. Three phases are envisaged, for example:

- the first phase, already in progress, consists of vehicles that offer the driver “safety-net” features;
- a second phase, around 2020, will see the increasingly common use of vehicles fitted with cameras, sensors and radars, capable of operating autonomously but predicated on the constant presence of a driver able to intervene in complex situations;
- in a third phase, vehicles will dispense with all human intervention. They will not feature a driver cockpit and will manage the hazards of the road unassisted.

Leading motor manufacturers and suppliers of connectivity systems have spent several years gearing up for these developments, which will depend on increasing access to spectrum. In many ways, these developments bear similarities to the Internet of Things, but the often critical nature of their operation puts them in a specific category.

Driverless cars require spectrum resources for two categories of use: one to perceive their environment via sensors, and the other to communicate with their environment via cooperative intelligent transport systems (C-ITS). Sensors relying on radio spectrum are essentially radars operating in the 76-81 GHz bands. The band has been harmonised in Europe for the past 10 years, in consultation with French motor manufacturers, and is in the process of global harmonisation following a favourable decision at WRC-15. C-ITS will enable vehicles to communicate with one another (vehicle-to-vehicle communications, V2V), but also with the infrastructure provided by the operator of the road they are on, with road signs and even with pedestrians.

Traditional players in the transport sector (Renault, PSA or Volvo, for example) and new entrants (such as Google) are offering cooperative systems and driver assistance solutions, and are also developing autonomous vehicles, i.e. vehicles capable of travelling without a driver. The communications requirements of smart vehicles are dictated both by critical safety-related applications (communication between two vehicles to avoid collisions, for example, or platooning) and by others that are less critical (transmitting information to drivers on traffic conditions, for example, the state of the road surface, or road works ahead).

National, European and international authorities are supporting these developments. The European Commission, for example, has set up the C-ITS Platform, a cooperative framework including national authorities, relevant C-ITS stakeholders and the Commission, with a view to creating a shared vision (recommendations or operational roadmap) on the deployment of interoperable C-ITS. A number of C-ITS pilot projects are also under way at the European level.

Initially, according to C-ITS Platform recommendations, the aim will be to deploy driver information services, particularly as regards traffic or road conditions (traffic jams, road works, stationary vehicles, presence of emergency vehicles, or weather conditions), on road signs (speed limits) and possibly on other subjects such as parking availability, navigation around a city centre or over the last kilometre of the journey. Some of these functions are already available.

The issues facing ITS range from technical (access to spectrum or connectivity) to legal (liability in the event of an accident involving a connected, semi-autonomous or autonomous vehicle, protection of privacy), economic (economies of scale in the deployment of C-ITS), political (coordinating the actions of the various stakeholders, public and private, encouraging investment to accelerate the rate of deployment and improve road safety, establishing legal frameworks for truly autonomous vehicles and the use of personal data) and even geopolitical (the role of Europe and its industries in these developments).

Spectrum resources for ITS have been identified in the 5.9 GHz and 63 GHz bands. Which technology motor manufacturers will adopt for ITS, either G5 or LTE-V2X, is currently still a matter for debate.

Finally, 5G also seems well suited to the needs of the driverless car and connected car, given its ability to ensure, in certain environments, latency as low as 1 m/s, compatible with the rapid response times required for a vehicle moving at speed.

**Wi-Fi**

RLAN (radio local area networks) or WLAN (wireless local area networks) are often referred to as Wi-Fi networks, from the standard most commonly used for this type of short-range wireless communication. These networks provide the French population with everyday connectivity, in the workplace, at home and in many public places. They are a vital resource for cellular traffic offloading.

The term “local network” — such as Wi-Fi or Bluetooth — is generally understood to apply to networks operating in licence-exempt bands under a general authorisation (for a discussion of the general authorisation regime, particularly within a framework of dynamic spectrum sharing, see, for example, the report by Joëlle Toledano, *Une gestion dynamique du spectre pour l’innovation et la croissance*/Dynamic spectrum management for innovation and growth, published in March 2014), often in the home, over short distances and which require users to procure the requisite device (Internet box, for example) and configure their network. Local networks differ from “operated” networks – which are open to the public, generally managed by mobile operators and giving nationwide coverage – or from private networks such as TETRA, which rely on individual authorisations.

Wi-Fi mainly uses two frequency bands: 2.4 GHz and 5 GHz, which are shared with many other applications (radars, Earth observation systems or intelligent transport systems).

Cisco reported that traffic carried on cellular networks in 2015 was, for the first time ever, lower than the traffic offloaded from them via Wi-Fi access or femtocells. To meet this growing demand, the industry would like access to wider bands in the 5 GHz range in order to implement new generations of RLAN technologies: wider bandwidth channels would offer speeds comparable to those of optical fibre.

The question of widening the Wi-Fi bands in the 5 GHz range has been under consideration since 2013 and appears on the agenda for WRC-19. In another development, the first “WiGig” devices are starting to appear on the market in the 57-66 GHz band, operating at multi-gigabit per second speeds. WiGig’s short range, however, restricts its usefulness other than as a complement to other bands or with several relays.

3GPP has also developed a number of solutions for making use of the resources available in the Wi-Fi bands, and combining them with mobile operator network resources, with the aim of providing ever-higher speeds. This may involve the simple aggregation of data flows on the Wi-Fi and mobile networks. Another solution might be, subject to the technical conditions of the general authorisation, to introduce LTE technology into these bands, particularly LTE-LAA (LTE License Assisted Access) in the 5 GHz range. ANFR has worked closely with ETSI to ensure that LTE-LAA and Wi-Fi technologies are able to coexist without one pre-empting all the capacity at the expense of the other, in accordance with the principle of technological neutrality.

# Strategic plan

# Spectrum management issues

**5G**

4G is in the process of being deployed across the country, but the mobile communications sector, from the business players to the spectrum managers, is already looking to the next generation of mobile systems, 5G. Due to be rolled out in 2020, its strategic orientations, in terms of technology, spectrum, partnerships and international harmonisation, are being decided now.

5G should allow for improvements in mobile communications in three areas:

- Increased capacity: theoretical data rates should reach 10 Gbps, 100 times faster than 4G, while 5G networks should carry 1,000 times more data than 4G. Every user should be able to enjoy an effective data rate of 100 Mbps, anywhere in the country and even when travelling at speeds up to 500 km/h.
- Scope for linking large numbers of connected objects to the network: this calls for protocols tailored to how these objects communicate, and in particular lightweight data exchanges for low bandwidth objects consuming very little energy;
- Access to more reliable, low-latency connections: this would mean networks could be used for critical applications such as driverless cars, industrial applications (robots) or telemedicine (surgery).

The issues of 5G thus intersect in part with those relating to the Internet of Things (IoT).

Today's mobile networks use frequencies below 3 GHz. One of the new aspects of 5G will be its use of higher frequency ranges (known as "capacity bands"), particularly above 24 GHz. The 5$^{th}$ generation of mobile communications networks will still need lower frequency bands (known as "coverage bands"), however. As with previous generations of mobile networks, spectrum harmonisation will be important for 5G. The greater the harmonisation at European and even global level, the easier it will be for manufacturers to design products that can be used in many different countries, meaning greater economies of scale.

Industry experts do not expect 2G and 3G networks to be phased out before 2020 or even 2025. Many terminals will continue to find the possibilities offered by 2G adequate, and the technology may even attract renewed interest with a view to developing the Internet of Things using GPRS technology (for payment terminals in restaurants, for example). 3G networks, meanwhile, will continue to serve a purpose as long as the proportion of voice traffic remains high, given that few devices offer a voice service in 4G (VoLTE). Opinions differ, but it is possible that 2G networks will outlive 3G networks.

The authorisations issued by ARCEP to mobile operators for the three frequency bands used by the 2G and 3G networks expire in 2021. A number of players, mobile operators in particular, have mentioned the possibility, when the 2G and 3G networks start to be switched off, of ultimately creating a shared inter-operator 2G network, taking into account the lifetime of connected objects using GPRS technology.

**Proposal 1**

ANFR will prepare the transfer to mobile communications of the 5G band, which runs from 3.4 to 3.8 GHz, the C band, identified by the RSPG as the primary band in Europe for the introduction of 5G by 2020. The Agency will contribute to the drawing up, at European level, of satisfactory harmonised technical conditions and the introduction, at national level, of specific measures to protect incumbent users of this and adjacent bands, i.e. satellite receiving earth stations, which will continue to receive in the 3.6 GHz to 3.8 GHz band, and radars operated by the French Ministry of Defence below 3.4 GHz.

**Proposal 2**

ANFR will support harmonisation of the 26 GHz band as the pioneer band in Europe, identified by RSPG from the bands above 24 GHz under scrutiny for WRC-19. This harmonisation will also take into account the protection of incumbent users. The Agency will pay particular attention to the possibility of future installation of scientific services earth stations, which calls for reflection, at both national and European level, on the regulatory approach to be adopted.

**Proposal 3**

ANFR will contribute at the European level to drawing up harmonised technical conditions and will provide mobile operators with access to resources in the L band, which offers very favourable propagation characteristics. The L band is currently occupied primarily by radio relay systems managed by ARCEP and by government applications, which will first need to be migrated.

**Proposal 4**

ANFR will work with stakeholders concerned to find the best solution for shared use of the 2.3 GHz band. The Agency will seek a solution that protects current Ministry of Defence uses (aeronautical telemetry service, varying in its intensity in space and time) and provides satisfactory conditions for

ARCEP and mobile operators. The technical conditions of shared use have been studied at national level and specifications are available for the purposes of experimentation. Depending on the interest shown by mobile operators in shared access to this band, ANFR will consider other uses (PPDR, PMR or IoT) that might be developed.  In any event the Agency will work towards a European framework compatible with strategic decisions taken at national level.

**Organising cohabitation in the 5 GHz band**

The 5 GHz band is currently home to several services that need to continue to coexist even though, in some cases, their needs are growing: these include usages that have long been authorised (radars, satellites), as well as RLAN (Wi-Fi) applications and intelligent transport systems (ITS).

Local radio networks are often referred to in France by their English acronyms: RLAN (radio local area networks) or WLAN (wireless local area networks). They are more commonly known as Wi-Fi networks despite the fact that, strictly, the term refers more specifically to access technologies based on IEEE 802.11 standards, and that other technologies, in particular LTE-LAA developed by 3GPP, also have access to these bands.

European regulations provide for mechanisms for sharing the band between other existing users and RLANs. The 5 GHz band is used by military and meteorological radars, aeronautical radionavigation systems (onboard meteorological radars for the detection of cyclones and tornadoes), for earth exploration satellites and feeder links to the Globalstar satellite constellation. RLANs are permitted to use these frequencies, as long as they do not interfere with these devices.

To meet the growing demand for very high-speed broadband, the RLAN industry has been asking since 2013 for broader contiguous spectrum in the 5 GHz range in order to introduce new technologies using wider channel bandwidths (up to 160 MHz) that will offer wireless access at speeds comparable to those of optical fibre. Their request has been examined at both European and international level, particularly as part of WRC-15. The work, which focuses on the 5350-5470 MHz, 5725-5850 MHz and 5850-5925 MHz frequency bands, has not yet produced a satisfactory solution for safeguarding existing systems. The European Commission stressed in particular the need to protect applications covered by EU policies, such as Earth observation systems, including COPERNICUS (over €3.4 billion in EU and ESA investment, with €3.8 billion scheduled over the next six years), and the intelligent transport systems (ITS) that contribute to smooth traffic flows and road safety.

**Proposal 1**

ANFR will continue its work to find a technologically neutral solution to facilitate coexistence between the various RLAN technologies in the 5 GHz range.

**Proposal 2**

In response to the item on the agenda of WRC-19, ANFR will contribute to work undertaken on new techniques for sharing the band with other users, and will analyse the regulatory constraints applicable in the existing bands. The Agency proposes in particular to:

- assess the advisability in Europe of a relaxation of the regulations on the current frequency bands (5150-5250 MHz and 5250-5350 MHz) whilst protecting the other (incumbent) systems, particularly satellite systems;
- safeguard COPERNICUS' use of the 5370-5470 MHz band and consider making this frequency band a “safe haven” for radar systems, including weather radars;
- examine, in return, a reasonable solution for the extension of Wi-Fi in the 5725-5850 MHz band, which takes into account the need to protect existing uses (remote tolling or radars).

**Proposal 3**

Regarding ITS, to contribute to possible economies of scale and facilitate the inherent mobility of vehicles, ANFR will strive to preserve the 5855-5925 MHz band for ITS applications, seeking, as far as possible, conditions for cohabitation with other potential users (RLAN or CBTC, the communications-based train control system for urban light rail transport systems).

**57-66 GHz band**

As a supplement to the 5 GHz band, some manufacturers are developing Wi-Fi technologies, known as “WiGig”, in the 57-66 GHz band. They point to its usefulness in offloading traffic from mobile to fixed networks via Wi-Fi access points, but also for infrastructure connections between small cells, under a general authorisation regime.

The development of these new usages could be achieved by relaxing regulatory conditions, in particular by removing the restriction on indoor use and by authorising higher maximum power. Agreement on these points would open the way to European harmonisation. Nonetheless, many countries authorise fixed services (Fixed Local Area Network Extension systems) in this band, and any options that may be adopted will necessarily have to take such situations into account.

A further consideration lies in the fact that the 63 to 64 GHz band hosts ITS applications. The band provides a resource supplementing the 5.9 GHz band, particularly for traffic and mobility management applications that will be required for the development of driverless cars (transmission of data captured by sensors, particularly vehicle-mounted radars in the 76 to 81 GHz band, which extend visibility beyond adjacent vehicles). The coexistence of ITS with equipment operating under general authorisation will therefore require special provisions to be made.

**Proposal 1**

ANFR will study and support, at European and global level, the harmonisation of relaxed and convergent technical conditions between the different connectivity applications in the 57-66 GHz band under a general authorisation regime. The Agency will ensure that these conditions offer adequate protection for ITS applications in the 63-64 GHz band.

**470-694 MHz band**

The 470-694 MHz band is the part of the "UHF band" currently allocated to terrestrial television broadcasting. The band is also used by wireless microphones mainly in the programme making and special events (PMSE) sector.

To give the audiovisual sector sufficient long-term visibility to organise the modernisation of broadcasting, the French parliament decided that the 470-694 MHz band will continue to be allocated to the audiovisual sector until 2030. This decision was in line with the conclusions of the Lamy report of September 2014 and the RSPG opinion of February 2015. The Lamy report, commissioned by Neelie Kroes, European Commissioner for the Digital Agenda, put forward a three-stage roadmap:

- 2020 as the deadline for clearing the 700 MHz band for mobile services in Europe, with scope for early adoption by any countries wishing to do so;
- retention of the rest of the UHF band by the audiovisual sector until 2030;
- a stocktaking point in 2025 to re-examine UHF spectrum use, taking into account developments in the audiovisual and electronic communications sectors.

In France, Law n° 2015-1267 of 14 October 2015 on the second digital dividend and the continued modernisation of digital terrestrial television amended Law n° 86-1067 of 30 September 1986 on freedom of communication and provided that "*the 470-694 MHz frequency band shall continue to be allocated, at least until 31 December 2030, to the* Conseil supérieur de l'audiovisuel *[French broadcasting authority] for the terrestrial broadcasting of television services. At least five years prior to that date, the Government shall present a report to Parliament on the prospects for television services broadcasting and distribution in France*".

The 470-694 MHz band is currently allocated for audiovisual usage in Region 1, which consists mainly of Europe, Africa and part of the Middle East. In contrast, the band has already been singled out for international mobile telecommunications in a number of countries in Region 2, including the United States, and in Region 3 (Asia-Pacific). The United States even organised a so-called "incentive" auction procedure in the 600 MHz band, initiated in March 2016. The aim was to encourage licensees to voluntarily relinquish spectrum usage rights in return for compensation (reverse auction), prior to a conventional auction of licences to mobile operators.

The European Commission has also expressed the desire that countries wishing to do so should be able to introduce mobile links known as Supplemental Downlinks (SDL) in the 470-694 MHz band, particularly to carry multimedia traffic.

2023-2025 will be crucial years in determining the future of the 470-694 MHz band. At global level, allocation of the frequency band will be examined at WRC-23 on the basis of studies to be launched at the close of WRC-19. At European level, the proposal made in the Lamy report to re-examine UHF spectrum usage in 2025 was incorporated into the European Commission proposal for a decision by the European Parliament and the Council on the use of the 470-790 MHz frequency band.

**Proposal 1**

ANFR will support the modernisation of audiovisual broadcasting by defending, at European and international level, the allocation of the 470-694 MHz frequency band to the audiovisual sector until 2030. With this end in view, the Agency will contribute to studies on the future of the UHF band, in preparation for WRC-23 and the European Commission study in response to the stocktaking clause in the Lamy report.

**Proposal 2**

ANFR will be attentive to the changing needs of the audiovisual sector and experimentation under way in Europe on the use of mobile Supplemental Downlinks (SDL) to carry audiovisual content in the 470-694 MHz frequency band or in other bands.

**Proposal 3**

ANFR will also examine the consequences of any development in uses of the 470-694 MHz band on the spectrum available for wireless microphones (PMSE).

**900 MHz band**

Since 2015, together with ARCEP and the French Ministry of Defence, ANFR has been working on how to provide scope for the development of connected objects in the 900 MHz band under a general authorisation regime. This responds to a request from Axelle Lemaire, Secretary of State for Digital Development, who tasked the Agency with considering the technical and regulatory conditions that would promote the use of low-power devices in the 870-876 MHz, 915-921 MHz and 863-870 MHz bands, thus contributing to the development of connected objects. The request was made following Joëlle Toledano's 2014 report — *Une gestion dynamique du spectre pour l'innovation et la croissance*/Dynamic spectrum management for innovation and growth — which emphasised the need to support innovative applications of the Internet of Things (IoT).

These studies facilitate the development of IoT and provide support for French companies innovating in this sector who have begun to invest in the bands which are already open: 868-870 MHz and, with severe limitations, 863-868 MHz. Possibilities for sharing were identified in compatibility studies and described in the public consultation that ANFR published jointly with ARCEP on 3 June to 18 July 2016. IoT applications in these bands are numerous and varied: remote metering (Sigfox, LoRa), smart cities, RFID, social alarm systems, smart homes, audio headsets, etc.

The European Commission Mandate of 15 July 2014 tasked CEPT with analysing possibilities for EU harmonising in the 862-870 MHz, 870-876 MHz and 915-921 MHz bands. In November 2016, CEPT approved for public consultation a draft reply to the European Commission. The harmonised regulatory framework will be discussed by the Radio Spectrum Committee (RSCom) and will presumably be adopted in the first semester of 2017.

Spectrum occupancy for IoT was also the subject of an ECC workshop. Work on the 862-863 MHz band is not completed, mainly because CNES drew attention to an emerging need for remote metering via satellites which required the adoption of restrictions to spectrum occupancy.

A regulatory framework at national or European level must cater for the great variety of applications and technologies under consideration for IoT and ensure overall compatibility. Such a framework must safeguard military needs and provide protection for mobile operator networks in the 800 and 900 MHz bands and for the railway wireless communications system known as the Global System for Mobile Communications - Railways (GSM-R) and also the possible requirements of the future railway communications system that will be replacing GSM-R sometime between 2025 and 2035.

In the medium term, the contiguity of bands allocated respectively to GSM-R and public mobile services is such that, to safeguard rail safety requirements, some constraints must be applied to GSM-R network architecture and to ensure compatibility with onboard GSM-R terminals.

Since 2016, rail regulations require that GSM-R receivers marketed and in use have the capacity to withstand the conditions of coexistence brought about by proximity with mobile broadband networks, also called “rugged terminals”. While awaiting an upgrade, the European Commission recognised in July 2016 that conditions for coexistence between mobile systems and GSM-R would have to be found at a national level. In France, under the aegis of ANFR, temporary procedures applicable since 1 November 2016 have been implemented by all stakeholders, in particular railway and mobile network operators, so as to prevent and manage possible disruption of GSM-R networks exposed to the presence of public mobile networks in the 900 MHz band. These procedures include:

- a preventive coordination process based on an adaptation of the approval procedure for implanting a radio frequency installation, delivered by ANFR; this is to avoid, in particular, new instances of disturbances to GSM-R reception related to the implantation or modification of a public mobile station subject to the Agency’s approval;
- a corrective coordination process, subsequent to ANFR approval in the event of investigation of an interference incident.

**Proposal 1**

ANFR will defend, at European level, the outline that was adopted following the public consultation on IoT in the 900 MHz band conducted by ANFR and ARCEP jointly, from 3 June to 18 July 2016.

**Proposal 2**

ANFR will examine, in consultation with ARCEP and the French Ministries of Defence and of Sustainable Development, any possibility of facilitating, in terms of access to the 900 MHz band, GSM-R transition to a future rail communications system in this band, whilst respecting immediate needs for access to spectrum for IoT applications.

**L Band (1427-1518 MHz)**

The first commercial mobile networks operated in the low frequencies below 1 GHz and the high frequencies in the vicinity of 2 GHz. Later on, they started to use the 2.6 GHz part of the spectrum and now they are at 3.5 GHz. With the European harmonisation of the 1452-1492 MHz band and, shortly, of the 1427-1452 MHz and 1492-1518 MHz bands, an intermediate opportunity is emerging.

It will be necessary to make these new resources available, in particular to meet the growing needs in data transmission capacity to mobile terminals known as Supplemental Downlinks (SDL), boosted by changes to audiovisual content (video, audio streaming) and software updates to smartphones and tablets. The 1452-1492 MHz band has been harmonised at European level since 2015; at national level, ARCEP, the assignee for this portion of the spectrum, can deliver authorisations. Germany and Italy have already given authorisations to mobile operators in this band. The 1427-1452 MHz and 1492-1518 MHz bands were identified by WRC-15 for mobile broadband networks and the CEPT has already started on the regional harmonisation process for these sub-bands. The Commission is seeking to achieve mandatory European-level harmonisation by 2018-2019.

In France, the 1427 MHz-1452 MHz and 1375-1400 MHz bands are currently connected to, and exploited by, over 1,600 fixed links for commercial and government applications. The 1492-1518 MHz band is used for various government applications.

**Proposal 1**

ANFR will support European harmonisation of these bands and will embark on the spectrum replanning process at national level with a view to arriving at an appropriate national framework by 2019.

**Proposal 2**

ANFR will initiate negotiations between ARCEP and the Ministry of Defence to arrive at an exchange of spectrum use rights between 1375-1400 MHz and 1492-1518 MHz bands.

**Proposal 3**

ANFR will ensure a reorganisation of rights enabling mobile networks to operate across the whole L band, from 1427 to 1518 MHz.

**Proposal 4**

ANFR will facilitate the migration of fixed links from the 1375-1400 MHz and 1427-1452 MHz bands to the 6 or 10 GHz bands, and that of other government usages to longer-term bands.

**Proposal 5**

ANFR will consider and propose changes in the spectrum regulatory framework with a view to providing opportunities for audio PMSE in the 1375-1400 MHz band to be shared with government usages, following on from the reconfiguration of the fixed links now using them.

**Licence-exempt spectrum**

Licence-exempt or unlicensed spectrum denotes frequencies used without the need for a licence by short-range devices (SRD) such as remote controls, telemetry equipment, alarm or motion detector devices, but also devices used to transmit sound or voice and, of course, Wi-Fi. Nowadays it also relates to a wide range of applications associated with the Internet of Things (IoT), in sectors such as industry, motorcars, smart homes, logistics or medicine. Although the term SRD is still employed, suggesting that these usages remain "short-range", these devices can have much wider uses. The Internet of Things has seen the emergence of what are known as Low Power Wide Area Networks (LPWAN) and their associated usages: smart cities, connected homes or health, for example. These networks rely on access to licence-exempt spectrum.

On the regulatory front, SRDs use spectrum under a general authorisation regime formalised by ARCEP decisions: they may transmit freely as long as they comply with predetermined technical parameters such as transmission power, for example, or timing of use. SRDs enjoy no protection from other authorised usages. These parameters, inferred from deployment scenarios, determine the radio environment for these devices: they must share spectrum with other devices subject to the same constraints and, in certain frequency bands, with primary usages (government requirements or based on an individual authorisation) that then take priority.

Such devices are extremely varied in nature and are developing swiftly as a result of the rapidly expanding IoT. Devices coming to market also enjoy free movement throughout the European Union. If the sector is to develop, therefore, a harmonised regulatory framework is essential.

The most commonly known licence-exempt bands are found in the following ranges: 6.7 MHz, 13.56 MHz, 27 MHz, 40.7 MHz, 169.4 MHz, 433 MHz, 868 MHz, 2.4 GHz, 5.8 GHz, 24-24.25 GHz, 60 GHz, 122 GHz and 244 GHz. They are widely recognised and their regulatory framework is geared to SRD applications.

It is possible for SRDs to use other frequency bands, but this is limited to specific applications and under stricter conditions for sharing with incumbent services. The 5GHz range, for example, is available to Wi-Fi networks but must be shared with earth exploration-satellite systems (EESS) or with radar systems, which means that advanced interference reduction techniques are required. Specific regulations also exist for medical implants authorised in the 401-406 MHz band, or for hearing aids and for intelligent transport systems (5.9 GHz and 63 GHz).

Ultra Wide Band (UWB) applications follow the same logic. These devices, which are used for communication, location or radar imaging, require very wide bandwidths that are necessarily already in use by radiocommunication systems with very varied characteristics.

**Proposal 1**

ANFR will support the development of shared use of licence-exempt bands, which offer considerable opportunities for innovation for both IoT and for Wi-Fi. The Agency will pay particular attention to defining the technical conditions governing the coexistence between SRD applications (IoT in particular) and with other users of the bands concerned.

**Proposal 2**

In order to meet the growing needs of IoT, ANFR will support at European level the adaptation of the EU framework to needs expressed at national level, particularly during the summer 2016 consultation on new opportunities for use of the 862-870 MHz, 870-876 MHz and 915-921 MHz bands.

**Proposal 3**

ANFR will examine the possibilities for relaxing the constraints applicable to Wi-Fi in the 5 GHz and 57-66 GHz bands.

**Geolocation and spectrum control**

The spectrum used by geolocation systems is becoming increasingly critical for the many sectors of the economy that rely on it. It is important to protect the spectrum against potential risk, by adopting a response commensurate with the level of that risk.

One new risk that has emerged in recent years is the use of GPS jammers. The more widely GPS tracking is deployed, the greater will be the risk that citizens will seek to escape it by locally disabling their GPS. GPS jammers are cheap but very crude devices that, far from confining their effects to their owner's vehicle, block all GPS tracking over an extended area of some hundreds of metres. The spread of these devices could jeopardise the entire economy of geolocation in high-density areas, or create dangers for critical applications such as air navigation.

At present, the risk remains under control, as the total number of jammers is small overall. On the heavily used A1 motorway between Paris and Lille, for example, an average of just one GPS jammer a day is detected. The loss of GPS tracking as a result of jamming is currently only very temporary, and may be offset by certain more sophisticated but expensive systems. The risk of creating harmful disruption of geolocation systems will only become real once a certain density of jammers is reached. In the worst-case scenario, the presence of several jammers per kilometre would completely block all geolocation. The threshold above which this disruption would have a major economic impact is as yet unknown. It is important, however, to be in a position to assess the risk as of now in order to be prepared for such a situation and, if necessary, to take appropriate action to limit or contain it.

**Proposal 1**

ANFR will monitor developments in interference with the spectrum used by GNSS in order to forestall risks, including economic risks, and to define a policy and the appropriate resources to remedy the situation.

## Higher data rates and spectrum control

Higher data rates in mobile telephony are driving not only the search for new spectrum but also attempts to make more intensive use of the spectrum already available. Very high-speed mobile communications require, amongst other things, emitting more Mb/Hz using appropriate modulation schemes; these are, however, much more sensitive to electromagnetic interference. While 2G networks can cope with a relatively high level of interference, the introduction of 4G at the same point on the same frequencies requires much lower noise levels to ensure that data rates live up to the technology's promises. Very high speeds are also prompting greater concern for spectrum quality, as a result of which mobile operators are filing numerous interference resolution requests.

The number of interference incidents reported by the mobile operators is already an order of magnitude higher than for other spectrum users, a particularly sensitive issue when reallocating spectrum: in the 800 MHz band, for example, audiovisual users encountered no more than a handful of interference incidents a year. Since 2012, however, interference resolution requests from mobile operators in the same band have been running at several hundred a year. In 2015, mobile operators in the 800 MHz band filed close on 600 interference resolution requests.

The number of interference resolution requests is increasing annually, at an average of +21% per year between 2013 and 2015, largely due to the reallocation of the 800 MHz band for mobile operators.

As a result, the increase in the spectrum managed by mobile operators and the need to ensure ever-higher speeds will increase the number of interference incidents that ANFR will be called upon to deal with. The ability to resolve these incidents rapidly is essential if the spectrum made available to the mobile operators by the state is capable of ensuring the services expected by the regulator. It is also directly linked to the future exploitation of spectrum, an intangible national asset, since the performance — and hence the value — of services that may be affected depends on the quality of that spectrum.

### Proposal 1

ANFR will respond to the growing demand for interference resolution for high-speed mobile networks, and will ensure the optimum exploitation of national assets.

**LPWAN and spectrum control**

Low Power Wide Area Networks (LPWAN) for the Internet of Things use general authorisation spectrum (also known as the ISM band) in the 870-876 MHz, 915-921 MHz, 863-870 MHz bands, with no guaranteed interference protection. They are based on conditions of use that allow for spectrum sharing, but these conditions only operate within certain limits. They are predicated upon not exceeding a density level (number of devices per unit of volume, communication time of each device) considered plausible when the spectrum was opened up. These limits could be exceeded if the success of these applications exceeds the initial forecasts, as seems set to happen in the near future.

Business investment in these low-power networks is set to soar, and regulation must be put in place to protect their operation. Two phenomena related to the use of spectrum under general authorisation may entail risks for these networks. The first of these is non-compliance with the rules of spectrum use or interference created by other users. To protect the networks, ANFR should be required to ensure compliance with the rules of use and to deal with interference incidents. Its action could be envisaged as either preventive or corrective. Leverage for preventive action lies in market supervision, to ensure the compliance of devices offered for sale. Laboratory testing would be carried out to test compliance under normal operating conditions. Further development of test protocols would probably be required to make this possible. Corrective action would involve inspecting devices *in situ* in the event of interference.

The second risk for these networks is that, if the devices are deployed in great number, the density limits used to draw up the operating rules laid down as standards could be exceeded. Spectrum sharing only works well if the shared frequency remains operable without coordination between the various users, which supposes a limited call on resources by each of them for positive statistical effects. As with any other system (Internet, LAN, IT or road networks), if the utilisation rate exceeds forecasts, access to the resource is degraded. Above a certain threshold, the overall effective utilisation rate for each device will shrink rapidly or even collapse, because the collision rate will rise faster than the required utilisation rate. This outcome seems unavoidable if these low-power networks enjoy the success they envisage, and will probably occur by geographical area, starting with the most sensitive; at this stage of network deployment, this would be fraught with major economic consequences.

To avoid this risk, ANRF is proposing to contribute, in conjunction with ARCEP, to observation of general authorisation spectrum usage, putting the Agency in a position to intervene before the threshold of saturation is reached. This would then make it possible to define the actions required for the overall proper functioning of general authorisation spectrum, either by improving the spectrum utilisation rules to allow for a higher spectrum usage rate, or by increasing the frequency bands available whilst ensuring the proper distribution of usage by the various users.

**Proposal 1**

ANFR will monitor usage of general authorisation spectrum to ensure the economic development of low-power networks used for the Internet of Things, in order to improve resources and the rules of spectrum sharing (optimisation of spectrum usage).

**GMDSS**

The Global Maritime Distress and Safety System (GMDSS) was adopted in 1988 as part of the process amending the 1974 Safety of Life at Sea Convention (SOLAS). It was fully implemented in 1999. Since its inception, it has served the interests of the maritime community efficiently but some of the technologies on which it relies need modernising. In its current configuration, GMDSS guarantees that, wherever a ship in distress might be, its call will be heard and a response given. The system is supported by an exclusive combination of international technical and operational standards and recommendations. It is based on the coordinated and global use of certain frequencies, operating at sea and on shore.

Since the system became operational, Inmarsat has been the sole provider of satellite communications within GMDSS, with coverage limited to between latitudes 70° North and 70° South. The modernisation plan now under consideration includes the introduction of satellite constellations with polar coverage, Iridium for example. The new satellite cover will have the capacity to replace the now obsolete HF radiotelex (NBDP). Maritime HF frequency bands will remain in GMDSS to serve as backup or a complement (redundancy) to satellites. Ships not using an approved satellite mobile communications service will still be able to fall back on the HF option. The decametric waves (HF) will also be available in the A3 sea area as a secondary alert system for ships using an approved mobile satellite communications service.

NAVDAT is a French maritime digital data broadcasting system that the International Maritime Organization (IMO) has decided to integrate into GMDSS. NAVDAT operates in FM and HF. It will eventually replace NAVTEX, the equivalent analogue system that has been on the scene for over 30 years, which is reliable but has limited capacity. For a modern GMDSS, there has to be an upgraded capacity for receiving maritime safety information (MSI) via HF which is easier to process on board ship and thereby provides shore-based entities with a more flexible array of MSI distribution options. As a result, future receivers will have to combine NAVTEX/NAVDAT capabilities enabling the reception of messages in the 490, 500 and 518 kHz bands as well as in all the decametric wave ranges designated for MSI. The possibility should also be examined of using the VHF Data Exchange System (VDES) to carry the future MSI distribution systems now under consideration.

VDES was developed by the International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA) when the Automatic Identification System (AIS) VHF digital link (VDL) first showed signs of overloading. VDES will no doubt facilitate a great many applications related to, in particular, navigational safety and security, or to the protection of the marine environment and the efficiency of maritime transport. In future, VDES should be able to contribute significantly to maritime information services, including navigational aids. It could possibly supply local MSI. WRC-15 has validated the terrestrial component of the VDES system and WRC-19 will be taking decisions on the satellite component. From then onwards, VDES will become a fully comprehensive data exchange system compatible with the VHF channel already aboard ships. VHF satellite service would be a less costly alternative to the options provided by bands already assigned to satellite mobile services in the L band. The French space industry (Airbus and Thalès for instance) and CNES have expressed interest in this satellite-based alternative. One of the challenges facing the maritime transport community by 2025 is the use of e-navigation, a concept developed by IMO whose Mona Lisa and Efficiensea projects were precursors in this field. The purpose of e-navigation is to merge all the shipborne radiocommunication systems into a single smooth and reliable navigation entity. VDES is a prime candidate for integration into e-navigation. Lastly, AIS technology, initially conceived as simply a means of ship identification, has branched out into many other applications: monitoring pollution slicks and the drift of sea ice, tagging drifting fishing nets, tracking floating objects, seismic studies, research on ocean currents and climatology, search and rescue of crews overboard.

**Proposal 1**

ANFR will support the entry of new satellite systems supplying GMDSS services at WRC-19 and will seek to achieve final approval of HF MSI broadcasting for NAVDAT.

**Proposal 2**

ANFR will support French industrialists developing HF applications with a view to helping them in their efforts to achieve harmonised global deployment whilst complying with IMO and ITU rulings.

**Proposal 3**

ANFR will continue to support the introduction of VDES in international negotiations and, in particular, in consultation with IALA, will carry on with the technical studies for recognition at WRC-19 of the VDES satellite component.

**Proposal 4**

As regards AIS technology and its new maritime applications to be discussed at WRC-19, ANFR will remain attentive to the concerns of French industry.

**Fixed links infrastructure**

Radio relay (RR) or fixed links infrastructure designates point-to-point microwave links between two radio stations exploited by commercial or government networks, in particular commercial mobile communications networks of base stations (2G, 3G, 4G), security infrastructure networks (Defence, Interior and Transport Ministries), large-scale private network infrastructure (energy suppliers and motorway operating companies) and base stations feeding programme content to radio and television transmitters.

These links form the infrastructure backbones (long-distance transport) or the mesh networks (access, connection and distribution). They are present throughout national territory and distinctive in that hop-length (distance between two relays) and transmission capacity vary depending on which frequency is in use, ranging from 1 GHz to 83 GHz. RR infrastructure uses harmonised blueprints and spectrum, in accordance with EU recommendations. The directional antennas are designed to focus the radio signal for transmission in a single direction, to facilitate good reception.

This flexible method of transmission is the obvious choice if wired infrastructure is unavailable. It also provides some redundancy for protected communications. It can, for example, act as a backup for a copper wire connection at much lower cost. Furthermore, the cost of installing RR infrastructure is ten times less than the cost of fibre optics since there is no need for structural engineering work. With this kind of equipment, very high-speed Internet access can be extended to hilly or mountainous areas. RRs are therefore included in France’s national broadband plan and will be receiving some of the €20 billion the state has decided to invest in this project.

RR technology is in use worldwide. It is a reliable, mature and cost-effective technology and is still the only option for certain geographical configurations and therefore certain to be part of the telecommunications landscape for a long time to come. In France, RR infrastructure is widely used: 150,000 installations are currently operating on national territory, but some major changes are in the offing:

- the increasing prevalence of fibre optics over various segments of the communication networks (transport, access and distribution) may encourage operators to move away from RR infrastructure on these pathways;
- but for remaining RRs, the increased throughput that is a corollary of fixed and mobile usage diversification, of growing needs and the emergence of big data, requires new modulations or new frequency ranges to carry the data flow;
- the densification of mobile networks entails a proliferation of base stations (2G, 3G, 4G today and 5G tomorrow), often resulting in the rapid construction of new segments in these networks using RRs;

- the emergence of more efficient equipment increases transmission capacity while using the same amount of spectrum;
- frequently deployed in shared bands, RR infrastructure raises coexistence issues in certain areas, for example with satellite reception stations;
- mobile networks are moving into the frequency bands that RR was using up to now, for instance for 4G mobile (1427-1452 MHz) or for 5G mobile (26 GHz); using the same frequency bands for access and connection of a base station is not unheard of, but it does raise issues;
- growing requirements for servicing connections to commercial mobile network base stations are saturating some frequency bands.

**Proposal 1**

In EU debates, ANFR will assist in frequency harmonisation for RRs and will identify major spectrum planning challenges.

**Proposal 2**

ANFR will, together with the assignees concerned, conduct the process of migrating the 1375-1400 MHz and 1427-1452 MHz bands in which RR is currently operating, so as to meet European harmonisation objectives for commercial mobile usage in the 1427-1452 MHz band. The Agency will identify the target harmonised band that could host the links concerned.

**Proposal 3**

ANFR will support efforts to implement sharing schemes between RRs and satellite reception stations in the 17.7-19.7 GHz band.

**Proposal 4**

ANFR will cooperate with assignees concerned to find the best option for facilitating the introduction of 5G in the 26 GHz band in which many commercial and government RR installations currently operate.

**Proposal 5**

ANFR will support the harmonisation of new bands for RRs in the high-frequency bands through channels compatible with increasing throughput on fixed and mobile networks.

**Proposal 6**

ANFR will encourage the emergence of short-range technology in the high-frequency general authorisation bands.

## Enhancing database reliability

ANFR databases keep detailed records of statistics concerning all transmitters, antennas and frequencies in use in France. *Ex ante* analysis of this data (known as “station coordination”) increases the efficiency of spectrum management by preventing interference, lightens the burden of spectrum control by forestalling the need for costly intervention in the field and also supplies pointers for improving the organisation of local spectrum sharing, thus enabling increased density of spectrum usage. Another use of the data is to simulate exposure levels which is helpful in the detection of atypical points that ANFR will be required to map by law. To reap all these benefits, however, data must be reliable. Enhancing database reliability is a major frequency management challenge at a time of rapidly expanding spectrum usage.

When network operators send ANFR the data, the transmitters are generally still in the design stage. Once operators receive the Agency’s approval for transmitter installation, their characteristics may have been slightly modified and the final parameters are not always communicated to ANFR. Additionally, some low-power transmitters are exempt from notification and are therefore not recorded in ANFR’s databases although they contribute locally to the public’s exposure.

Once the transmitter is in service, data accuracy can be verified in a number of ways:

- when ANFR teams examine the records for consistency checks or compatibility calculations;
- when spectrum control agents carry out on site inspections;
- in a recent development, via reports from members of the public to collaborative communications platforms where ANFR open data is available; this approach has been in preparation for several years through enrichment of the cartoradio.fr site, which provides information on all transmission installations for public or corporate networks;
- in future, through data feedback obtained via crowdsourcing applications, whereby volunteer smartphone users collect and submit field emission level readings.

### Proposal 1

ANFR will broaden its open data policy and will encourage the user community to make use of the data on a partnership footing.

**Proposal 2**

ANFR will promote the use of crowdsourcing applications so as to enhance the reliability of its databases by cross-referencing the information they contain with the field emission levels recorded by smartphone sensors.

**GADSS (including GFT)**

The safety of air transport is a continuing concern of the aeronautical community and spectrum management is a key component. For decades, thanks to radio frequencies, aircraft have kept track of their flight paths with or without visibility, avoided collisions, communicated with air traffic control and achieved three-dimensional aircraft location.

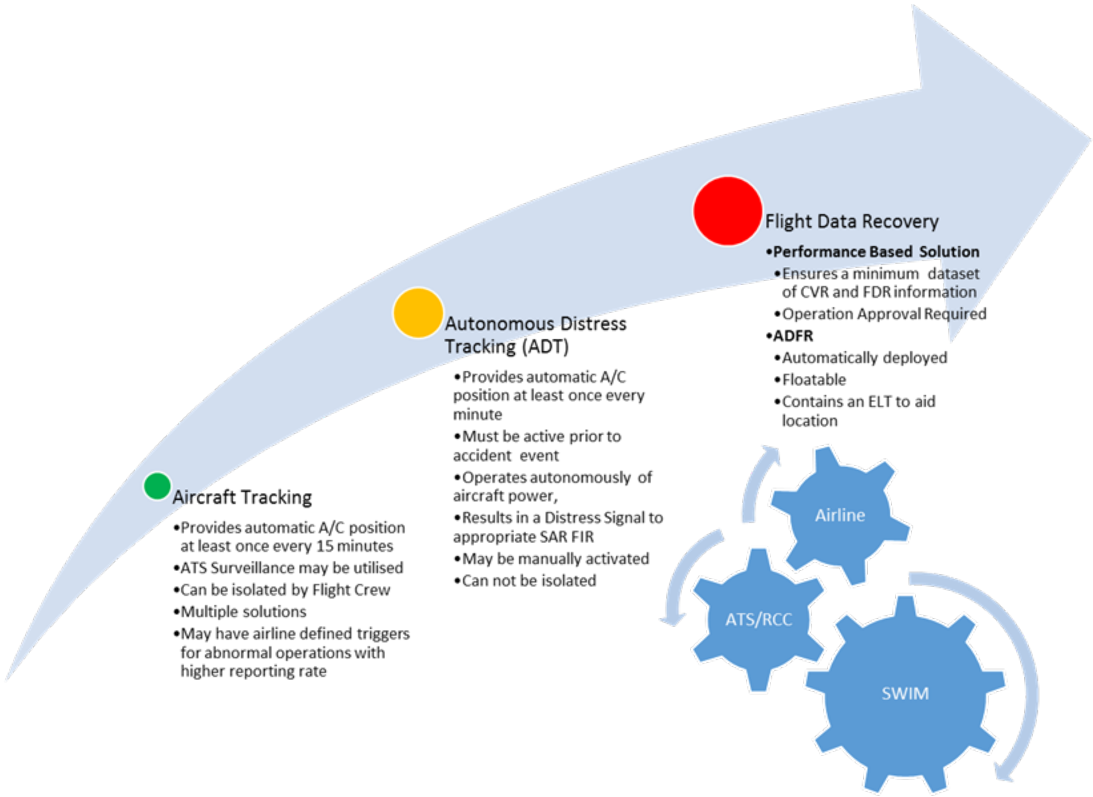
The needs of the airline industry are still considerable and after the disappearance of the Malaysia Airlines flight MH370, WRC-15 decided to assign a frequency band as a matter of urgency to satellite reception of broadcasts (ADS-B) from commercial aircraft so as to ensure around the clock global aircraft tracking. The Iridium Next satellites, programmed to launch between July 2016 and 2019, will carry dedicated receivers with this assigned frequency. The system will be able to locate a disabled aircraft anywhere in the world and will furthermore have the capacity to process aircraft location data to facilitate air traffic control.

This decision is part of a much more exhaustive project aiming to improve inflight aircraft tracking and safety. The International Civil Aviation Organization (ICAO) is currently working on the definition of a Global Aeronautical Distress and Safety System (GADSS). The objective is to secure precise and updated location of an aircraft as soon as possible once abnormal aircraft behaviour is detected. According to ICAO, GADSS will consist of a set of systems for locating and alerting before the accident happens. Various technologies are under scrutiny, each of which responds in part to requirements.

With this in view, Airbus is working on the concept of black boxes for ejection before the crash while Boeing is in favour of using existing non-specific commercial satellite links for real-time data flows. COSPAS SARSAT, the CNES-supported global alert system for the detection and location of emergency radio beacons, could also contribute to GADSS when an aircraft sends out a distress call.

On another point, all-weather landing facilities are still central to ensuring flight regularity and safety. Existing systems require costly ground infrastructure only available in major airports, but in future onboard systems (Enhanced Flight Vision System/EFVS) could be of assistance for landing on smaller airfields. One solution under consideration would involve assigning millimetre wave radars in the 32 GHz band to the aeronautical radionavigation service.

Bearing in mind aircraft ranges, global spectrum harmonisation is essential to satisfy this kind of requirement.




**Proposal 1**

ANFR will keep abreast of ICAO deliberations on GADSS operational concepts and will work in consultation with the French Directorate General for Civil Aviation (DGAC) to determine which of the various applications on offer could meet GADSS requirements. If necessary, the Agency will arrange to make new spectrum resources available.

**Proposal 2**

After having recommended EFVS recognition to ITU, the Agency will contribute to research on compatibility with 5G in the 32 GHz band to ensure the possibility of global EFVS implementation.

**Developments in HAPS regulations**

High altitude platform stations (HAPS) are a recent development in digital connectivity. These objects, which may be balloons or self-piloted drones, will be flying at altitudes between 20 and 50 km, which is twice the cruising altitude of commercial flights and situated above meteorological disturbances such as storms. With their payload of telecommunications equipment, HAPS could in the near future provide Internet access in areas with no terrestrial service, either because of their remoteness or in the aftermath of a natural disaster. Their advantage over a satellite constellation is that they are less expensive and yet provide good coverage and acceptable bandwidth.

The most newsworthy of the HAPS-based projects for connecting populations with poor Internet access is probably the Google initiative. This is Project Loon, for which Google has entered into a partnership with CNES. It will be a network of helium-filled stratospheric balloons, the first of which were launched in June 2013 in New Zealand.

France is also contributing to research on these platforms through a French government investment plan, (*Programme d'investissement d'avenir* (*PIA*)/Investing in the Future) developed by the *Commissariat général à l'investissement.* €17 million have been earmarked for the Thales Alenia Space Stratobus project.

The HAPS concept is not new, but the progress made on drones now makes the project feasible at a reasonable cost. Following these recent developments, the international community of spectrum management agencies must review their respective positions within ITU on the spectrum required to implement these new services.

**Proposal 1**

Concerning the HAPS concept itself, ANFR will consult French stakeholders developing such projects on whether the current international legal definition ("a station on an object at an altitude of 20 to 50 km and at a specified, nominal, fixed point relative to the Earth") still matches the technological and operational developments envisaged for these systems.

**Proposal 2**

ANFR will consult French stakeholders regarding spectrum required for payloads onboard HAPS so as to determine whether the frequency bands that have already been identified — as well as the related technical and regulatory conditions — will be sufficient and adequate. If not, the Agency will consider the possibility of identifying the 38-39.5 GHz band for use by HAPS.

**Proposal 3**

Regarding the frequencies needed for HAPS control and their movements in the airspace, ANFR will consider, in cooperation with the French General Directorate for Civil Aviation (DGAC), whether conclusions arrived at for drones are also applicable or if there is a need to draft specific measures for HAPS.

**Intelligent transport systems (ITS)**

Intelligent transport systems (ITS) will enable driverless cars to communicate with one another, with road infrastructure and even with pedestrians. ITS solutions in Europe will be deployed in the 5.9 GHz (5855-5925 MHz) and 63-64 GHz bands, and the 5875-5905 MHz band is also subject to EU harmonisation.

Industry standard-setting bodies are currently debating the technologies to be adopted for communication between a vehicle and a road infrastructure unit (vehicle-to-infrastructure, V2I) or between two or more vehicles (vehicle-to-vehicle, V2V). Motor manufacturers are contemplating two approaches:

- G5 technology based on IEEE 802.11p: this involves adapting an existing Wi-Fi standard to the needs of ITS;
- 3GPP technology, often referred to as V2X (vehicle-to-everything), based on LTE (4G); LTE-V2X specifications have recently been finalised.

Today’s regulation is technologically neutral, but could change in the future, given the demands of interoperability and the need for the two technologies to coexist. Furthermore, ANFR is currently working at the European level on integrating the CBTC (Communications-Based Train Control) system into ITS. CBTC is key to automating the running of metro trains, in particular fully automatic systems. It has already been deployed on the Paris Metro and in Lyon and Lille, for example, in the 5915-5935 MHz band. This application, essential for the development of tomorrow’s urban transport systems, could benefit from harmonisation measures for ITS in the 5855-5925 MHz bands.

The proliferation of technologies and usages in the 5.9 GHz band raises uncertainty over the prospects for its use by wider bandwidth Wi-Fi, examined as part of the preparation for WRC-19.

The 63-64 GHz band, meanwhile, offers a resource supplementing the 5.9 GHz band, particularly for traffic and mobility management applications that will be required for the development of driverless cars. It can be used to transmit data from sensors, particularly vehicle-mounted radars in the 76 to 81 GHz band, used to sense the vehicle’s wider environment beyond adjacent traffic. The 64-66 GHz band falls within the 57-66 GHz band, which is destined for increasing use by Wi-Fi type equipment (WiGig) or radio relay infrastructure under a general authorisation regime. Compatibility between these two usages will need to be ensured.

**Proposal 1**

To contribute to possible economies of scale and facilitate the inherent mobility of vehicles, ANFR will strive to preserve the 5855-5925 MHz band for ITS applications while pursuing, as far as possible, the conditions for cohabitation with other potential users (Wi-Fi or CBTC). Its work will be carried out on a European and global scale, including concerning the “Wi-Fi” agenda item for WRC-19.

**Proposal 2**

ANFR will ensure the coexistence between all the technologies (G5, V2X and CBTC) that may be brought into these frequency bands and that support critical functions. The Agency is only indirectly concerned by the technological debate over G5 versus 3GPP V2X technology.

**Proposal 3**

ANFR will contribute to promoting EU harmonisation of the 63-64 GHz band, essential for platooning applications, and will ensure protection for ITS applications in this band with respect to Wi-Fi type (WiGig) applications in the 57-66 GHz band.

**Proposal 4**

If the stakeholders consider it worthwhile, ANFR will examine, at national and European level, possibilities for using the 76-81 GHz band for ITS communications, as a complement to the 63-64 GHz band.

**Proposal 5**

Some stakeholders have called for the authorities concerned by the development of connected road vehicles (Ministry of Transport and Ministry of the Economy, ANFR or ARCEP) to set up a coordinating body to better to establish milestones for these developments (roadmap) and optimise investments, given that ITS should lead to improved road safety and traffic fluidity but that there are still many challenges to overcome. ANFR will examine this possibility with all the stakeholders concerned.

**Measurement of public exposure**

Measuring public exposure to electromagnetic fields (EMF) is one of ANFR's missions. The need for a reliable protocol by which to measure EMF became pressing following the publication on 12 July 1999 of the European Council recommendation on the limitation of exposure of the general public to electromagnetic fields. ANFR published the first version of the protocol for *in situ* measurement of electromagnetic fields in 2001, having first submitted it to public consultation.

Exposure measurements are now the tool of choice for monitoring exposure levels, and as the basis for dialogue and consultation at public meetings and for detecting atypical points. They also provide data for exposure research.

Since 1 January 2014, ANFR has managed the national EMF exposure monitoring system, under which members of the public may request *in situ* exposure measurements, free of charge, in homes and public places. Results of the measurements, taken according to the ANFR protocol, are published on the ANFR website cartoradio.fr, in keeping with the government's objective of transparency of information on public exposure. Some 3,550 measurements were carried out in 2015. ANFR regional services are also equipped to measure exposure as part of their monitoring activities, and have access to a COFRAC-accredited measurement laboratory at the international monitoring centre (CCI) in Rambouillet.

ANFR is also the national agency tasked with supervising the market in radio and telecommunications terminal equipment (R&TTE). This means primarily checking mobile telephone compliance with exposure limits in terms of specific absorption rate (SAR). As part of its market supervision, ANFR checks the SAR values for dozens of mobile phones. Targeted measurements are carried out according to all or part of the harmonised European standards in force. Of all the European supervisory agencies, ANFR is the most active in terms of SAR inspections of mobile phones.

**Proposal 1**

ANFR will continue measuring levels of exposure from relay antennas and terminal equipment, for monitoring and research purposes. The Agency will be able to use its measurement resources to produce studies characterising exposure to EMF in specific configurations, such as in transport, for example, or in the vicinity of smart meters.

**Proposal 2**

ANFR will develop the measurement protocol. The Agency updates the protocol at regular intervals. For its next scheduled development, there are plans to extend the protocol to frequencies below 100 kHz, specifically to take into account the exposure created by Linky smart electricity meters, for which there is considerable public demand. This will be a first step towards addressing the specific nature of connected objects on the basis of the experience gained by the Agency in the field of smart meters.

**Proposal 3**

ANFR will address the relay antenna/terminal pairing. Conventional methods of assessing exposure do not pay sufficient attention to the link between exposure created by mobile terminals and that created by network relay antennas.

**Proposal 4**

ANFR will develop measurement resources. Measurements can be taken using conventional methods or by more original means, including trace mobiles or scanners aboard moving vehicles on the ground. In the longer term, drones could be used to measure emissions from outside buildings, or smartphone applications to measure levels within a building.

**Future evolution of orbit/spectrum regulation**

Satellite systems serve vast geographic areas extending well beyond national borders. The spectrum resources they use are managed, in the main, under international rules: once certain frequency bands are identified for satellite use, ITU Member States agree on mechanisms for access to spectrum/orbit resources. Together, these procedures make up an important component of the international treaty known as the ITU Radio Regulations.

In addition to preparing and coordinating proposals for developments to these international procedures, ANFR is responsible for implementing the agreed access mechanisms in France: dealing with requests for frequency assignments to satellite systems, followed by international coordination of these assignments and processing, on behalf of the Ministry responsible for electronic communications, of applications for authorisation to operate the frequency assignments.

In matters relating to orbit/spectrum resources, ANFR makes every effort to promote clear, transparent regulatory frameworks, applied identically by each ITU Member State and hence more conducive to investment at the global, European and national level.

**Proposal 1**

In the wake of the measures on geostationary satellites decided by WRC-12 and WRC-15, ANFR will henceforth focus its efforts on clarifying the regulatory conditions governing non-geostationary constellations (bringing into use, possibility of varying their orbital parameters during the coordination process).

**Proposal 2**

ANFR will ensure that current procedures are appropriate to the growing use of small satellites (pico or nano satellites).

**Proposal 3**

In the longer term, ANFR will work towards greater transparency in the effective use of orbit/spectrum resources by cross-referencing databases related to satellites as spatial objects with others related to them as radio stations.

**Proposal 4**

ANFR will consult French stakeholders on the actions and resources necessary to guarantee that frequency assignments to satellite systems filed by the French authorities on their behalf are properly coordinated with the satellite systems of the other ITU Member States.

**Proposal 5**

ANFR will promote the use of the ITU international monitoring system to counter interference affecting satellite communications or measurements.

**Proposal 6**

To ensure that French space requirements continue to be taken into consideration over the long term, ANFR will maintain fora for dialogue with the industry and with space operators in France, in both the public and private sectors, as a means of identifying the developments necessary to the sector's growth.

**Opening access to databases**

The French state is aware of the importance of the data produced and collected by government departments and of the need to make it available to users, free of charge, in order to reinforce democracy, develop the economy and modernise public governance. Open data creates a new dynamic across the board, in everything from data processing to data distribution. It has beneficial effects on the private sector's capacity to innovate, on the creation of new data-related markets and services and on the quality of public information.

Law n° 2016-1321 for a Digital Republic, enacted on 7 October 2016, consolidates the "open data" strategy, introducing in particular the release by default of public data, to be implemented by the creation of a public data service, as well as launching the "data of general interest" concept. Spectrum management can contribute to the opportunities provided by open data. The Agency, which maintains several reference databases that organise spectrum and transmitter management in France, has adopted a policy of disclosing the contents of its databases, as far as is permitted by laws relating to the protection of classified defence material, personal privacy and trade secrets. ANFR data on radio frequency sites over 5W is posted to the "Cartoradio", "Cartoradio mobile", "data.anfr.fr" and "data.gouv.fr" websites. The Agency also publishes information on electromagnetic field readings on "data.anfr.fr" and "data.gouv.fr" allowing for public exposure at a given location to be calculated. Also released is the data on radio-maritime equipment associated with a Maritime Mobile Service Identity (MMSI) and with ship registration numbers, and data on radio-electrical easements for the protection of certain radio stations from interference or obstacles. The Agency is also associated in radio frequency assignment across national territory. In pursuit of a proactive, usage-centred approach, as a complement to its open data policy, the Agency is promoting the creation of services based on data available to the public. Its first hackathon dedicated to the subject of spectrum was held on 28 and 29 May 2016. ANFR is now supporting development of the winning project (Connected Urban Transport) in preparation for the Dataconnexions 7 competition organised by Etalab.

**Proposal 1**

ANFR will organise hackathons to continue encouraging more creative use of its data sets by innovative start-ups.

**Proposal 2**

ANFR will expand its open data approach by working on visual representation, using data visualisation (DataViz). The Agency will explore collaborative working models (content crowdsourcing, aggregation of external data, affiliate marketing or a joint offer with a private partner). As a first step, users will have the opportunity of proposing improvements to the data or of pointing out anomalies.

**Proposal 3**

ANFR will look into the merits of creating a data lab, i.e. a multi-disciplinary unit tasked with analysing information produced by the Agency or by the data ecosystem, with the object of responding to its “business” needs: reinforcing spectrum control, protection of RF systems, prevention of interference and improvement of spectrum management.

**Spectrum sharing**

Certain services are able to coexist within the same frequency band without mutual interference. The sharing may be geographic (one service is deployed in a given location, and a different service in the same band but some distance away), but closer proximity is also acceptable as long as the two usages are intermittent or protected by selective antennas. This is true particularly of the frequent sharing of spectrum between highly directional radio relays in the horizontal plane and satellite links towards the sky.

Spectrum sharing techniques have progressed over the past ten years or so and offer more advanced solutions for improving the efficiency of spectrum usage. Techniques such as the detection of users requiring protection and dynamic selection of unused spectrum can now be deployed in a number of “licence-exempt bands”. This has made it possible, for example, to open up spectrum in the 5 GHz band for Wi-Fi to share with radars. This particular example has also demonstrated, however, that the technique has its limits: meteorological radars have suffered from chronic interference because they use waveforms that Wi-Fi equipment was unable to detect. Furthermore, when sharing depends on the compliance of consumer electronic equipment that is easy for expert users to modify, certain forms of protection may be deactivated, which then hampers the sharing of spectrum with other users.

Another approach relies on the use of databases and geolocation techniques. In this case, a “secondary” (non-priority) spectrum user obtains information from a database on the “primary” users requiring protection in the immediate vicinity and adjusts its technical transmission characteristics accordingly. The best-known example of this technique is the UK and US regulation authorising the use of TV “white spaces” by low-power communication devices (SRD). The regulation has not resulted in the expected development of such devices, because of the very strict rules required for the protection of television transmissions (Yagi antennas’ reception is highly sensitive) and the numerous evolutions of television spectrum with the introduction of DTT and then the widespread adoption of HD TV.

This approach has nonetheless attracted a degree of interest and many studies are now under way in other frequency bands. ANFR contributes to this research and has learned lessons on the need to enhance database reliability and to harness the specific characteristics of each frequency band: the rules of sharing depend very much on the nature of the primary and secondary users envisaged within a particular band. The Agency has also helped develop the concept of Licensed Shared Access (LSA), which aims to promote spectrum sharing under an individual authorisation regime but which may, in the event of dynamic sharing, rely on the same geolocation and database techniques as described above. The initial results from these studies have made it possible to:

- open up the 2.7-2.9 GHz band to video news gathering, sharing with radars and radio astronomy;
- facilitate protection of earth stations receiving in the 17.7-19.7 GHz band from FSS stations, by making data about these stations available;
- envisage introducing mobile communications into the 2.3-2.4 GHz band as part of an LSA approach alongside national defence usages.

**Proposal 1**

ANFR will contribute to the development of spectrum sharing solutions based on geolocation and databases, in particular by continuing work on enhancing database reliability, in readiness for their possible use in spectrum sharing.

**Proposal 2**

ANFR will facilitate the protection of earth stations in the 17.7-19.7 GHz band by making available data on FSS stations.

**Proposal 3**

ANFR will continue experimenting with spectrum sharing in the 2.3-2.4 GHz band between mobile networks and defence usages, based on LSA.

**Small cells**

Small cells are low-powered radio access nodes (under 6W, as defined by ETSI) integrated into mobile telecommunications networks. Their range is much shorter than that of conventional antennas, ranging from tens to hundreds of metres.

Small cells are deployed as an adjunct to 2G, 3G and 4G macro networks, which remain essential to providing coverage and capacity across an entire territory. Small cell deployment in urban areas will be one of the major issues of 5G. The use – new to mobile networks – of high bands with consequently shorter ranges could bring about a revolution in mobile network architecture. Homogeneous networks made up of conventional relays could thus be supplemented by a potentially large number of small cells, typically to increase local capacity or to cover a limited area.

Incorporating small cells in urban environments will be crucial to the deployment of 5$^{th}$ generation mobile networks. The idea is that they will be deployed on street furniture or building facades. Because of the higher frequencies used by 5G and the trend towards low-energy buildings whose walls attenuate radio signals, there will be a greater need for more low-power relays inside buildings. Small cell deployment in the future could be undertaken by significantly more economic stakeholders than at present: from stadium or building managers to communities, school administrations or shopping centre managers. There will be several challenges to be met, whether in terms of spectrum management, public exposure to electromagnetic fields, competition, access or coordination between the interested parties.

The first challenge will arise from the volume of small cells deployed, which could, in some locations, be up to ten times higher than for conventional relays. This development could lead to a review of the conditions for registering and authorising these deployments, in view of the economic implications for the mobile operators submitting the requests and the administration's capacity to process them. At European level, in its proposal for a European Electronic Communications Code, the European Commission called for a simplified regime for these small cells, a formal definition of which will be established by a Commission implementing decision.

A second challenge will be the exposure generated by these devices and their acceptability to the general public. The deployment of small cells will change the radio landscape: less radiated power, but more emission points and the use of new spectrum. This could have implications for the exposure measurement and information procedures managed by ANFR. Changes might also be necessary to health and safety provisions, which are outside the Agency's remit. Further studies and an effective communication policy to inform the public will be essential.

A third challenge will be access (to sites, inside buildings, even to an existing antenna) for stakeholders wishing to deploy or use small cells. Access could be subject to commercial agreements, including small cells as a service (on the same basis as Software as a Service/SaaS), between the mobile network operator and the owner of the small cells, or between the owner of the street furniture or the building in which they are located. This is primarily a regulation issue, but it might have an impact on the databases maintained by ANFR.

**Proposal 1**

ANFR will promote the organisation of small cell deployment trials, monitor progress and publish the resulting reports.

**Proposal 2**

ANFR proposes that a working group meet to examine, for example:

- new stakeholders with a potential interest in installing small cells;
- the conditions governing their installation, including authorisation procedures allowing for the processing of significantly higher volumes, for both mobile operators and ANFR;
- the implications in terms of public exposure to EMF and hence for ANFR, which is responsible for exposure measurement and information procedures;
- where appropriate, the health implications, which do not fall within the Agency's remit;
- possible conditions for sharing between mobile operators and other stakeholders, given that the potential locations for small cells in densely populated urban areas are necessarily limited.

**PMSE**

Services ancillary to broadcasting are frequently known collectively as PMSE (programme making and special events) systems, referring to the wireless microphones (audio PMSE) and video cameras (video PMSE) used by professionals, mainly for the production of video content, TV shows and major events. Harmonisation already exists, defining tuning ranges so that frequencies can be used in each country according to national regulations. Professionals are nonetheless concerned over recent reallocations to commercial mobile networks of spectrum hitherto used for PMSE.

In the case of audio PMSE, as part of the plans to reorganise the L band with a view to exchanging the 1375-1400 MHz and 1492-1518 MHz bands, France is considering authorising wireless microphone applications in the 1375-1400 MHz band, part of a tuning range (1350-1400 MHz) for this usage currently in the process of European harmonisation. Despite its limited capacity, the 1518-1525 MHz band is attracting interest from the PMSE industry, and harmonised conditions for its use are being considered at European level. Lastly, CEPT is examining the possibility of shared used of the 960-1164 MHz band, in the light of Ofcom's opening of the band in the UK.

Finally, ANFR proposes making its contribution, in coordination with ARCEP, to national reflection on coexistence between the various audio PMSE applications. Operational coexistence between the different PMSE users could be improved by identifying preferential blocks for certain applications (microphones, on the one hand, and onstage monitor systems on the other, for example, or separating fixed and mobile microphones). In addition, new conditions of usage and sharing with other users are beginning to emerge, and the concept of a standard filing platform could be explored to provide better monitoring of usages in certain bands. In the case of video PMSE, two additional bands have recently been made available:

- 2010-2025 MHz: this band is covered by recent EU harmonisation transposed into the national framework. In practice, however, it limits video PMSE use to a single 10 MHz channel. ANFR proposes exploring the possibility of an extension of 5 MHz above 2025 MHz so as to provide a second 10 MHz channel.
- 2700-2900 MHz: since 2015, the national framework has allowed the use of certain types of video PMSE, after coordination with assignees holding rights over the spectrum concerned, so as to ensure protection of radar systems (2700-2900 MHz) and radio astronomy observations at the Nançay observatory (2690-2700 MHz and 2700-2735 MHz). To facilitate development of the PMSE ecosystem in this band, France will support EU harmonisation of the spectrum sharing solution developed nationally, whilst leaving the flexibility necessary for member states to manage coexistence with the different types of radar.

In addition, video cameras can already operate over 3G networks. The advent of 5G, given its characteristics — in particular its low latency and guaranteed quality of service — will present new opportunities for video PMSE. At times of major events, intensive use of temporary spectrum and frequency channel saturation can create problems of allocation and coordination. In France, the spectrum for audio PMSE is subject to ARCEP general authorisation, which can create local implementation problems when a large number of users are concentrated in the same area. Some countries, including the UK, have opted for an individual authorisation regime: the regulator thus plays the role of coordinator of spectrum usage. In France, organisers of major events frequently seek to avoid problems by asking ANFR to take charge of coordination when a large number of users is expected. The Agency then intervenes, on a preventive basis by coordinating spectrum allocations and, if corrective action is required, by resolving interference issues or non-coordinated usage with the help of its measuring devices. Growing PMSE usage and the increasing scarcity of spectrum resources will intensify the need for coordination. Determining the response best suited to evolving usage will require some thought.

**Proposal 1**

ANFR will examine frequency bands that could be made available for audio PMSE, in particular the 1375-1400 MHz and 1518-1525 MHz bands. At European level, the Agency will contribute to technical studies concerning audio PMSE and the services currently authorised in the 960-1164 MHz band, to determine a forward-looking perspective on the band's long-term importance.

**Proposal 2**

In coordination with ARCEP, ANFR will contribute to national deliberations on coexistence between the different audio PMSE applications, in particular the possibility of identifying preferential blocks for certain applications and possible changes to the conditions of authorisation.

**Proposal 3**

In the case of video PMSE, ANFR will explore at national level a 5 MHz extension of the 2010-2025 MHz above 2025 MHz, so as to provide a second 10 MHz channel. The Agency will support EU harmonisation of the 2700-2900 MHz band and will examine the prospects for using 5G to meet certain needs.

**Proposal 4**

ANFR will explore ways in which the Agency can intervene in the coordination of audio PMSE spectrum and the consequences of growing demand in a context of limited Agency resources.

**Space policy**

Satellite technology is used in a number of contexts: television broadcasting, civil or governmental telecommunications, scientific data acquisition and technological experiments. A point all these applications have in common is the need for radio spectrum.

As regards spectrum management, French space policy has two mandatory requirements: firstly, secure current spectrum resources essential for satellite applications and secondly, provide conditions favourable to the development of new satellite applications, if necessary by allocating new resources to the sector. Another important point is that operating all these applications is in essence an international undertaking and there is therefore a compelling need for harmonisation in order to maintain existing capacity and seek out new capacity. French space policy concerning spectrum management also fosters France's industrial policy in that the international harmonisation of satellite frequencies is crucial for the export potential of the products of its space industry.

**Proposal 1**

ANFR will seek to ensure that the whole 30/20 GHz range can accommodate applications providing mobile connectivity to means of transport.

**Proposal 2**

ANFR will support a regulatory environment favourable to satellite systems in the 50/40 GHz range, in particular in preparation for WRC-19 (spectrum availability, coexistence between satellite and terrestrial services, coexistence between geostationary and non-geostationary systems).

**Proposal 3**

ANFR will seek recognition within international bodies of the satellite component of the maritime data exchange system in the VHF band (VDES).

**Proposal 4**

ANFR will opt in favour of long-term stabilisation, at national, European and international levels, of the 10.7-12.75 GHz and 21.4-22 GHz frequency bands, as well as the associated feeder-link frequency bands, for satellite broadcasting, of the 8/7 GHz and 31/21 GHz ranges for military telecommunications and of the frequency ranges used by Earth-observation and weather satellites and by French and European space research satellites, in particular those used for the European COPERNICUS programme.

**Proposal 5**

ANFR will seek protection for earth stations receiving observed data and for the operation of the European Data Relay System (EDRS), in particular when work on 5G in Europe begins and at WRC-19.

**Proposal 6**

ANFR will seek to improve operating conditions on data-collection platforms in the 400 MHz and 460 MHz ranges, in particular at WRC-19.

**Proposal 7**

To ensure that the long-term needs of French space policy are given due consideration, ANFR will maintain the various fora allowing discussions with French industry and space operators, both public and private, with a view to identifying evolutions required for the sector's growth.

**Private networks of the future**

Public service networks dedicated to the needs of the security and emergency services are generally referred to as Public Protection and Disaster Relief (PPDR) systems.

The Ministry of Internal Affairs and several users of professional mobile radio (PMR) networks have expressed a need for additional spectrum resources to cope with the shift in usage towards broadband. The plan is to work from the LTE technology used by commercial 4G mobile networks and carry out the additional developments needed to support specific PPDR features. The spectrum needed for implementation of the future sovereign PPDR system has been evaluated at a minimum of 2x10 MHz at European level. This does not cover the needs of direct mode communications, or of air-ground-air or voice communications.

Another option lies in the use of 5G: with its capacity for tailoring throughput, latency and quality of service to each user within the same spectrum block, it offers a possible solution to the specific operational constraints of PPDR.  As regards the future PMR network, systems that will provide broadband communications are eagerly awaited by existing PMR operators such as *Aéroports de Paris*, *EDF* or *Société du Grand Paris* . Their low-speed networks are currently regional or national in scope, in the 400 MHz band. They have joined forces to set up an organisation of major PMR network users (AGURRE).

Certain usages could in future be hosted by mobile networks open to the public, but most PMR users prefer to retain control over their facilities, in view of security considerations and the need to fine-tune coverage according to their needs, for example in areas out of bounds to the public (power stations, airports, railway stations) or with no other coverage (power lines in mountainous areas).

The Prime Ministerial decree of 23 October 2015 amending the French National Table of Frequency Allocations (*Tableau national de répartition des bandes de fréquences/TNRBF*) provided an initial response to broadband PPDR and PMR needs with an exclusive allocation to the Ministry of Internal Affairs of 2x5 MHz and 2x3 MHz respectively in the 698-703 MHz, 733-736 MHz, 753-758 MHz and 788-791 MHz bands, with effect from 1 July 2019 in Region 1 (Europe-Africa-Middle East), and with effect from the date of the decree’s adoption in Region 2 (the Americas), for the implementation of a sovereign broadband PPDR network. Notwithstanding the Ministry’s exclusive allocation, ARCEP is empowered to issue authorisations to third parties in these bands, on conditions that will be subject to agreement between the two assignees, thus offering an initial solution to certain broadband PMR needs.

ANFR is actively working on the possibilities of identifying additional spectrum for the broadband PPDR and PMR networks in other bands. Technical studies are under way at the European level to assess the possibilities of introducing LTE in the 410-470 MHz band, and the 450-470 MHz band is already subject to European harmonisation for the purposes of broadband PPDR. In France, a plan to make two 2x3 MHz sub-bands available to meet broadband PPDR and PMR needs in the 400 MHz band was confirmed by a working group chaired by ANFR and made up of representatives from ARCEP, the Ministry of Defence and the Ministry of Internal Affairs. The group concluded that the initial aim of the proposed replanning should be to introduce a broadband PMR network in the frequency bands allocated to ARCEP, followed by the introduction of a broadband PPDR network in the 450-470 MHz band. A number of different options, mainly relating to the migration programme, have been identified and will be examined over the next few years before decisions are made.

The bands above 1 GHz are among the new territories to be explored, with a particular eye to opportunities in the 1900-1920 MHz and 2570-2620 MHz bands. The PPDR sector has expressed an interest in the 1900-1920 MHz band, particularly for “tactical bubbles”. In the 2570-2620 MHz band, encouraging results have emerged from the many broadband PMR experiments already carried out in France.

**Proposal 1**

ANFR will produce a detailed plan for migration to broadband PPDR and PMR in the 400 MHz band, taking into account the necessary trade-offs between the options proposed.

**Proposal 2**

ANFR will support development of the LTE ecosystem and work on LTE standardisation in the 400 MHz and 700 MHz bands, in accordance with the associated rules of coexistence, with particular emphasis on Ministry of Internal Affairs needs.

**Proposal 3**

ANFR will study the identification and harmonisation of high frequency bands (above 1GHz) for broadband PPDR or PMR at the European level (CEPT).

**Ensuring improvements to air transport safety**

The International Civil Aviation Organization (ICAO) is currently defining a Global Aeronautical Distress and Safety System (GADSS). Its object is to secure precise and updated location of an aircraft as soon as possible once abnormal aircraft behaviour is detected.

All-weather landing capacity is also central to ensuring flight regularity in safety. Existing systems require ground infrastructure only available in some large airports, but in future onboard systems (Enhanced Flight Vision System/EFVS) could be of assistance for landing on smaller airfields. One solution would involve millimetre wave radar in the 31.8-33.4 GHz band operating in the radionavigation service.

For all of these requirements, global spectrum harmonisation is vitally important.

**Proposal 1**

ANFR will follow ICAO's work on the GADSS concept of operations and will cooperate with the French Directorate General for Civil Aviation (DGAC) to determine how best to respond to spectrum requirements for GADSS development.

**Proposal 2**

After supporting EFVS recognition in ITU-R, the Agency will make a contribution to 5G compatibility studies in the 31.4-33.8 GHz to ensure EFVS protection at global level.