

# Spectrum access for live media production using Non-Public Networks (NPNs)

This report focuses on the spectrum access models and frequency bands suitable for the deployment of Non-Public Networks (NPN) for live media production scenarios, including those captured in the 5G-MAG Report ["Towards a comprehensive 5G-based toolbox for live media production"](#).

This report provides:

- a description of **spectrum access models** in different frequency bands that would enable deploying NPNs. Examples of different approaches to spectrum access by administrations are also given;
- information on the **bands defined in the 5G standards** where NPNs may potentially be deployed;
- discussion on **relevant spectrum access requirements** for the deployment of NPNs for media production applications.

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## Introduction

Spectrum access models come in a variety of forms but are in general agnostic both to the technology and to the specific band in which they are applied.

From a regulatory perspective, the suitability of 5G systems configured as NPNs is linked to the support of frequency bands enabled by standards. At the same time, support in standards would enable the building of ecosystems, including availability of network equipment and user devices. This is not static as new bands are allocated according to market and regulatory needs.

Some frequency bands are harmonized across large geographical areas (e.g., several countries or entire continents, ITU regions, or even globally). The level of harmonization may vary, i.e., it may include only an allocation (e.g., to the mobile service) or also some specific technical conditions of use. Harmonization is favoured as it allows economies of scale and cross-border use of the equipment (notwithstanding the need for a licence in each country).

Furthermore, a precondition for radio equipment to use the spectrum is compliance with the relevant technical standards. For example, in the European Union radio equipment can only be used if it is compliant with the Radio Equipment Directive, which is usually achieved via compliance with the relevant ETSI standards.

There are two main types of NPN:

- Deployments independent of a public network operator, i.e., [Stand-alone Non-Public Networks \(SNPN\)](#), where the network can be configured for private use.
- Deployments in [collaboration with third-party networks](#), including Public-Network-Integrated Non-Public Networks, that utilize parts of a public 5G network for private use.

The relevant network architectures are specified by 3GPP. These include interworking with non-3GPP access technologies, which is a requirement for the 5G system to support radio access technologies whose specification is out of the scope of 3GPP.

Specifications may provide support for certain parameters (e.g., network identifiers) to ease their implementation for private use. However, additional details may also be subject to regulation.

# Spectrum access models

## Licensed access

Licensed spectrum access requires the applicant to obtain a *licence* from a competent regulatory authority or in some cases a designated band manager or spectrum database manager.

Spectrum licences could be:

- **exclusive**, giving a licensee an exclusive right to use certain frequency bands within a geographical area, or
- **non-exclusive**, where multiple users could use the same spectrum under certain conditions.

There are also different mechanisms for spectrum licensing including **administrative procedures** (e.g., the user applies for a licence that is issued by the competent authority) and **auctions** (the spectrum licence is issued to the highest bidder). In some countries and in certain frequency bands the rules also allow **spectrum trading/leasing** where the licence holder may trade/lease the right to use the spectrum, or part thereof, to third parties.

A licence is usually not bound to a specific technology or application. Usually, the assignment is coordinated by the national authority and involves a fee. The fee often scales with bandwidth, geographical area, and duration. The licence is sometimes applied to a geographical area where the applicant is based. Thus, a network deployment is only allowed on the

premises of the applicant. Additional technical expertise and a description of the intended application may need to be provided to receive a licence.

The intended spectrum use normally includes a definition of the coverage area (usually described in geographical coordinates) and the location(s) of base station(s) and terminals, either fixed or mobile, or both, within the given area. The geographical confinement has implications on the maximum transmit power of the devices. Coordination with the geographical neighbours can be necessary and be part of the application.

## Examples of regionally/nationally licensed spectrum schemes

Examples include spectrum licensed to Communications Service Providers (CSPs) or subleasing/working with CSPs, among others. Subleasing is applied to the 3.4–3.8 GHz band in Italy and Finland, and local licensing is enabled in the UK in certain underutilized bands licensed to CSPs.

## Examples of locally licensed spectrum schemes

Examples include exclusive licensed access in a defined geographical area.

An example of non-exclusive licensed access is *secondary licensing* where, in addition to a primary user of the spectrum, a licence is issued to a secondary user, e.g., for a limited period of time and/or in a limited geographical area, under the condition of non-interference to the primary user.

### UK: Ofcom's approach to local licensing supporting mobile technology in 3.8–4.2 GHz

On 25 July 2019, Ofcom published a Statement, [Enabling wireless innovation through local licensing](#), which sets out two licence products introduced to make it easier for a wider range of users in the UK to access radio spectrum on a shared basis. In particular:

- the [Shared Access licence](#), which gives access to four spectrum bands that support mobile technology. These are 1800 MHz, 2300 MHz, 3.8–4.2 GHz and the lower 26 GHz band.
- the [Local Access licence](#), which provides a way for other users to access spectrum that has already been licensed to the UK's Mobile Network Operators (MNOs), in locations where an MNO is not using its spectrum. This is available for the 800, 900, 1400, 1800, 1900, 2100, 2300, 2600 and 3.4 GHz bands.

While Ofcom uses the term Shared Access licence, these are essentially local licences as defined in this report. The difference with Ofcom's Local Access licence is that the Shared Access licences are not issued in the spectrum already licensed to public mobile network operators.

### Europe: Harmonized conditions for local area networks in 3.8–4.2 GHz within CEPT administrations

CEPT is currently studying the possibilities to define harmonized conditions for local area networks (low/medium power) in 3.8–4.2 GHz. The work involves, among other things, developing a harmonized frequency arrangement as well as the least restrictive harmonized technical conditions

for the shared use of the 3.8–4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area connectivity (i.e. low/medium power). These harmonized technical conditions should avoid interference, protect relevant incumbents within the band and in adjacent bands, and facilitate cross-border coordination.

The corresponding work items started by CEPT are dealt within FM60 (regulatory framework – [FM60\\_01](#)) and ECC PT1 (sharing studies – [PT1\\_47](#)).

If adopted, the harmonized technical conditions would be incorporated in national and EU regulations, thus potentially opening up the band for NPNs across Europe.

### Germany: BNetzA's approach to local spectrum in 3.7–3.8 GHz

In connection with the 2019 mid-band auction for 5G, Germany set aside 100 MHz between 3700 and 3800 MHz for local use. Intended use cases include private standalone 5G networks primarily, but not exclusively, for factory automation. The band is assigned on a technology and application neutral basis. However, the spectrum can only be used at applicants' own premises.

The local regulatory body (BnetzA) is responsible for assigning the licence to operate a [campus network](#). The spectrum is assigned in multiples of 10 MHz and only TDD (time division duplex) mode is allowed. If necessary, the applicant needs to coordinate with their geographical neighbours on the planned deployment of base stations. Any guard bands are up to the licence applicant to consider, with regard to frequency usage below 3700 MHz and with regard to their local neighbour in the spectrum above 3700 MHz.

## Shared spectrum access

Spectrum sharing is a way to optimize the use of spectrum, or RF channels, by enabling multiple categories of users to operate in the same bands. Sharing can be applied in time, frequency, and area, depending on the deployment characteristics of the spectrum users and their requirements. A spectrum sharing model, which is usually under the responsibility of national regulatory bodies, can be separated into the following two approaches:

- **tiered access** with predictable, and in some cases guaranteed QoS (Quality of Service) with distinct hierarchies of spectrum users; and
- **coexistence in a licence-exempt environment** where all users have the same rights to use the spectrum without a guaranteed level of protection from interference.

Tiered access is always based on licensed access at least for the highest priority user, otherwise a required QoS cannot be guaranteed. Therefore, there is always an entity that prescribes the sharing conditions and monitors compliance with the sharing rules. For different tiers different protection levels and different QoS can be supported. In addition, different sharing rules can be prescribed for each tier, which must be followed by the respective users to get access to the spectrum.

The architecture of tiered shared access can vary. In practice there could be two tiers, where a primary user shares its frequency band(s) with secondary users that have fewer rights than the primary, three tiers, where three different user classes exist each with different licensing and sharing rules and different QoS.

## Examples of shared spectrum access schemes

### Coordination scheme in the frequency range of UHF (470–694 MHz)

An example of spectrum sharing without an automated spectrum access or coordination system is the sharing framework in the frequency range 470–694 MHz.

Sharing is made possible between terrestrial television broadcasting, which is the primary user and has to be protected against interference, and audio PMSE (Programme Making & Special Events) as the secondary user.

At locations where some television channels are not used by television broadcasters, audio PMSE can be deployed within these free channels as long as certain rules are followed, e.g., maximum output power, frequency distance to the present primary user, etc.

For large events, where a large number of PMSE devices will be in use, a dedicated person or entity may be in charge of spectrum planning and coordination. This spectrum coordinator will be on hand before and during the event to manage all of the PMSE frequency assignments and ensure that there is no interference between devices or with primary users in the band, such as television broadcasting. In the United States, the [Society of Broadcast Engineers \(SBE\)](#) maintains a national network of volunteer frequency coordinators that event coordinators work with. In some cases, owners of venues with permanently installed PMSE equipment such as theatres or large houses of worship will have a frequency coordinator on staff. Smaller venue owners often contract with an equipment rental house that has its own frequency coordinator.

## Licensed Shared Access in 2.3–2.4 GHz

The first practical use case for Licensed Shared Access (LSA) to additional spectrum was within the 2.3–2.4 GHz band, for mobile broadband services (Mobile/Fixed Communications Networks). It has not been commercially deployed, with the exception of the Netherlands, where a permanent LSA service is deployed in the 2.3–2.4 GHz band, in 2019. This [licensing scheme](#) does not allow the deployment of cellular services as secondary spectrum users but enables the use of audio/video PMSE.

[ETSI TS 103 154](#) defines system requirements for the operation of mobile broadband services in the 2300–2400 MHz band under LSA. [ETSI TS 103 235](#) defines the system architecture and high-level procedures for operation.

## Evolved Licensed Shared Access (eLSA) scheme

In Europe a two-tiered geolocation-database-based sharing framework, called eLSA (evolved Licensed Shared Access) has been developed; see [ETSI TS 103 652](#). It offers a two-tier method for local area licensing/leasing by relying on the existing regulatory framework for LSA. The objectives are to:

- deliver a generic framework for demand-driven spectrum access,
- extend LSA,
- be frequency-band and radio-interface-technology agnostic, and
- be tailorable and scalable to support different national spectrum-access regulations.

eLSA relies on an automatic tool to facilitate spectrum sharing and coordination between incumbents, National Regulatory Authorities (NRAs)

and eLSA Licensees (e.g., vertical sector operators) and targets operation of local high-quality wireless networks in licensed bands to guarantee predictable QoS levels. Its generic concept ensures a high degree of flexibility with regard to deployment area, time and frequency.

## Citizens Broadband Radio Service (CBRS) scheme

A three-tier approach is [CBRS \(Citizens Broadband Radio Service\)](#) in the USA, applied to 150 MHz of spectrum in the range 3550–3700 MHz.

The three CBRS tiers of users are:

- *tier 1*: Incumbent users, including the US Navy as well as commercial fixed satellite stations.
- *tier 2*: Priority access licence (PAL) users, for users that purchased spectrum licences, valid for a single geographical area, through competitive bidding. PAL channels are within the first 100 MHz of the CBRS band, purchased on a per-county basis (bidding limited to 40 MHz per county). PAL users are protected from interference coming from Tier 3 users but not allowed to interfere with Tier 1 users.
- *tier 3*: General authorized access (GAA) users. GAA users have the lowest priority and therefore no interference protection. They can access any portion of the CBRS band not assigned to a higher tier without having to purchase a licence. They may also operate opportunistically on unused PAL channels.

A Citizens Broadband Radio Service Device (CBSD) can be implemented using 4G (LTE band n48), 5G (NR band n48) or proprietary wireless technologies/systems.

## Automated Frequency Coordination system

Also in the USA, the [FCC](#) authorized two different types of unlicensed operation: standard-power and indoor low-power operations in the 6 GHz band.

Standard-power operations, which encompass standard-power access points and fixed client devices (collectively referred to as standard-power devices), are permitted in the 5.925–6.425 GHz and 6.525–6.875 GHz portions of the 6 GHz band. They must operate under the control of an [Automated Frequency Coordination \(AFC\)](#) system to prevent harmful interference to fixed microwave links that operate in the band.

The standard-power devices are required to have a geolocation capability and, at least once per day, must communicate their location to an AFC system, which will provide them with the frequencies and maximum power levels at which they may operate without causing harmful interference to any microwave links. The AFC system will also prevent operation of standard-power devices in the 6.6500–6.6752 GHz band near a limited number of radio astronomy observatories.

AFC systems are a centralized approach, coordinating the use of the 6 GHz spectrum according to regulatory rules/databases. AFC supports a two-tier model with incumbents and unlicensed users without additional sensing and inter-AFC coordination/synchronisation.

The FCC conditionally [approved](#) thirteen entities to operate AFC systems to manage access to 6 GHz band spectrum by standard-power unlicensed devices. This conditional approval begins the next phase of the process towards full commercial operations. As these thirteen entities continue to

develop their AFC systems, the next step in the approval process will entail testing to verify that they operate in accordance with the FCC's rules. Testing protocols are still under development and the FCC will approve for commercial operations those AFC systems that successfully complete testing.

# Deployment models and frequency bands for NPNs

## Potential deployment models for NPNs in the context of spectrum usage

The spectrum access models described above can in principle all be applied to the deployment of NPNs, including both SNPNs and PNI-NPNs.

These are the main deployment scenarios possible:

- **PNI-NPNs are supported by public networks.** Spectrum is therefore linked to the public mobile network. This option can support specific requirements from a professional user, such as the transport of audiovisual content in news-gathering scenarios.
- **SNPNs are run in isolation from other networks**, including entities other than public mobile networks. This option allows the setup of a local area network for media production at a remote location or at a venue alongside a public network.
- It may also be possible to **supplement spectrum** licensed to different entities. For example, by using supplementary uplink (SUL), a multi-band serving cell (with a default carrier for connectivity and additional carriers for payload) or dual connectivity (using two carriers in parallel) a carrier in one network (either SNPN or PNI-NPN) could be used to provide connectivity while data-intensive traffic could be carried over a carrier deployed at another band.

## Potential bands for NPN operation

Tables 1 and 2 contain an overview of 5G frequencies under consideration in different countries for potential NPN deployments as of July 2023, based on information from [Qualcomm](#) and [Ericsson](#). They include bands defined in the 3GPP for 5G-NR (see 3GPP [TS 38.101-1](#), [TS 38.101-2](#)), operation mode, bandwidth and spectrum access model considered by administrations.

**Table 1: Mid-band spectrum for NPN deployments**

Country	Spectrum (MHz)	NR band	Mode of operation	Bandwidth	Access model
Australia	3700–4200	n77	TDD	TBD	Local licensing
Belgium	3800–4200	n77	TDD	TBD	Considering allocation
Brazil	3700–3800	n78	TDD	100 MHz	Local licensing
Chile	3750–3800	n78	TDD	50 MHz	Local licensing
China	5925–6425	n96 n102	TDD	TBD	Licensing
Croatia	3400–3480	n78	TDD	80 MHz	Local licensing / leasing option



Czech Republic	3400–3480 3640–3700	n78 n78	TDD TDD	2*20 MHz	Allocated to two CSPs with a leasing option
Denmark	3740–3800	n78	TDD	60 MHz	Allocated to CSPs with a leasing option
Finland	2300–2320 3410–3800	n40 n78	TDD TDD	20 MHz TBD	Allocated to CSPs with a leasing option
France	2575–2615 3490–3800 3800–4200	n38 n78 n77	TDD TDD TDD	40 MHz 4x50 MHz 100 MHz	Allocated to four CSPs with a leasing option
Germany	3700–3800	n78	TDD	100 MHz	Local licensing
Greece	3410–3800	n78	TDD	TBD	Allocated to CSPs with a leasing possibility
Japan	2575–2595 4600–4900	n38 n79	TDD TDD	20 MHz 300 MHz	Local licensing

Netherlands	2300–2400 3410–3450 3750–3800	n40 n78 n78	TDD TDD TDD	100 MHz 40 MHz 50 MHz	Available with restrictions. New regulation by 2023.
New Zealand	2575–2620	n38	TDD	TBD	Local licensing
Norway	3400–3800 3800–4200	n78 n77	TDD	TBD	Allocated to CSPs with a leasing possibility
Poland	3410–3480	n78	TDD	70 MHz	Considering allocation
Republic of Korea	4720–4820	n79	TDD	100 MHz	Local licensing
Sweden	3720–3800	n78	TDD	80 MHz	Local licensing
Taiwan	4800–4900	n79	TDD	100 MHz	Considering allocation
UK	2390–2400 3800–4200	n40 n77	FDD + TDD	10 MHz 400 MHz	Local licensing/ shared spectrum
US	3550–3700	n48	TDD	< 150 MHz	Shared spectrum

**Table 2: High-band spectrum for NPN deployments**

Country	Spectrum (MHz)	NR band	Mode of operation	Bandwidth	Access model
Australia	24.25–27.5 27.5–29.5	n258 n257	TDD TDD	50 MHz	Local licensing
Brazil	27.5–27.9	n257	TDD	TBD	Local licensing
Denmark	24.25–24.65	n258	TDD	400 MHz	Local licensing
Finland	24.25–25.1	n258	TDD	850 MHz	Local licensing
France	24.5–27.5	n258	TDD	800 MHz	Considering allocation
Germany	24.5–27.5	n258	TDD	800 MHz	Local licensing
Greece	26.5–27.5	n258	TDD		Allocated to CSPs with a leasing possibility
Hong Kong	27.95–28.35	n257/n261	TDD	400 MHz	Local licensing
Japan	28.2–28.3 28.3–29.1	n257 n261	TDD TDD	100MHz 800 MHz	Local licensing
Israel	24.25–27.5	n258	TDD	TBD	Considering allocation

Norway	24.25–25.1	n258	TDD	850 MHz	Considering allocation
Republic of Korea	28.9–29.5	n257	TDD	600 MHz	Local licensing
Spain	24.25 – 24.70	n258	TDD	TBD	Considering allocation
Sweden	24.25–25.1	n258	TDD	850 MHz	Local licensing
UK	24.25–26.5	n258	TDD	<2.25 GHz	Local licensing

In actual deployments, each frequency band comes with a specific set of regulatory and technical conditions including a channelling arrangement, transmission power, spectrum mask(s) (including out-of-band transmission limits), paired uplink/downlink (e.g., FDD/TDD) or unpaired (e.g., downlink only) bands, or specific framing configurations (e.g., with a defined uplink/downlink ratio in TDD bands).

# Spectrum access requirements for media production in NPNs

This section details requirements related to spectrum access for media production scenarios deployed using NPNs.

**Table 3: Characteristics for content production in SNPNs**

	Live content production / special events		News gathering
Deployment	Nomadic	Fixed	Nomadic, mobile
QoS levels	Very high reliability Audio: ultra-low latency Video: high UL bitrate	Very high reliability Audio: ultra-low latency Video: high UL bitrate	High/very high reliability Audio: low latency Video: high UL bitrate
Coverage	Local	Local	Local
Duration	Hours to several weeks	Days to several months	Few hours to a few days
Access	Planned, ad hoc	Planned	Planned, ad hoc

Technical requirements in content production use cases can be found in [“Towards a comprehensive 5G-based toolbox for live media production”](#).

## Access: planned and ad hoc

Two cases should be considered for media production deployments:

- **Planned access:** the spectrum availability at a location is known in advance and all spectrum requirements (e.g., spectrum occupancy, device density, ...) of the production equipment in use can be assessed, calculated and planned before the event.

- **Ad hoc access:** circumstances mean that no a priori planning of the production is possible regarding, in particular, spectrum usage. Hence, spectrum access needs to be enabled on the fly.

## Deployment: fixed, nomadic and mobile

Licences are generally linked to a geographical location. Recent approaches to local licensing mainly target industrial premises with well-defined and static service areas. Media production deployments may involve:

- **Fixed installations** (e.g., stadiums, music halls, campus networks), in which the service area is static and infrastructure pre-installed,
- **Nomadic installations** (e.g., concerts, news gathering, etc.), where infrastructure may be set up for a specific event and location and dismantled afterwards. The service area is static during operation.
- **Mobile installations** (e.g., road bicycle races), where the infrastructure and the service area can move during operation.

## Duration: long-term and short-term access

In terms of duration, professional media production requires both **long-term** spectrum access (e.g., several years or permanent – at a known location such as a stadium, theatre, music hall, ...) and **short-term** spectrum access at specific locations (e.g., from several hours – news gathering – to a few months – a seasonal music stage) depending on the nature of the scenario.

## Duplex modes: uplink-intensive traffic

For media production applications, downlink/uplink throughput requirements may call for specific configurations that differ from those normally used in public networks. In particular, **high uplink throughput** can be required for video applications and stringent low-latency requirements need to be fulfilled for audio.

## During operation: certainty and reliability

The nature of media production applications, in particular live media production, implies a series of considerations regarding spectrum usage during operations. For example:

- the spectrum should not be shared with other networks in the geographical vicinity in order to avoid the risk of interference;
- the imposition during operations of a change of frequencies allocated to the NPN should be avoided; spectrum resources, once assigned, need to be guaranteed for the user for the duration of the event production to avoid operational disruptions;
- obliging TDD alignment between co-located SNPNs should be avoided due to the isochronous and data-intensive nature of the streams that may require specific TDD frame structures. Instead, interference should be minimized by insertion of guard bands.

# General considerations on suitable spectrum access models

Spectrum access models should take into consideration the following general characteristics:

- use of local unused spectrum,
- a static frequency allocation for the NPN during the operation,
- a predictable level of QoS, and
- a geographically constrained deployment.

The existence of “local unused spectrum” is a condition for shared spectrum, since SNPNs cannot be deployed in spectrum bands already occupied.

Suitable frequency ranges should be identified, together with appropriate spectrum sharing models. The latter should be found and/or developed, with desirable features and characteristics potentially including, among others:

- protection of the primary user;
- automatic coordination between secondary users, including dynamic interference prediction;
- automatic frequency/channel negotiation;
- support of highly dynamic access;
- low complexity (preferably a two-tier approach);
- support of local deployment;

- coordination via a centralized entity including predefined sharing rules; and
- support of all possible 5G technologies.

The spectrum access model should also allow ad hoc access usage for SNPNs.

Automated coordination between secondary users should consider, among others, the following features:

- interference monitoring;
- interference/propagation calculation;
- protection criteria;
- exchange of information about the RF environment; and
- adaptivity of the physical layer and/or MAC layer.

A compromise should be found between the level of complexity of the spectrum access model (linked to the specific frequency bands and incumbents) and the efficiency of spectrum sharing.

**Currently, there is no spectrum sharing model available that supports all above-mentioned features. With some limitations, CBRS, eLSA and AFC could be suitable candidates. However, adjustments (e.g., adding, removing, and/or modifying features) are needed in order to meet all requirements and support all necessary features.**

## Related documentation

- [1] Ofcom: "[Enabling wireless innovation through local licensing – Shared access to spectrum supporting mobile technology](#)", July 2019
- [2] Ofcom: "[Shared Access Licence – Guidance document](#)", September 2022
- [3] Ofcom: "[Local Access Licence – Guidance document](#)"
- [4] ECC Work Item [FM60\\_01](#) "Terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity in 3.8–4.2 GHz (Task 2 of the EC mandate)"
- [5] ECC Work Item [PT1\\_47](#) "Feasibility and sharing studies on the shared use of the 3.8–4.2 GHz frequency band by terrestrial wireless broadband systems providing local-area (i.e. low/medium power) network connectivity (Task 1 of the EC Mandate)"
- [6] Bundesnetzagentur "[Nummern für Campusnetze](#)"
- [7] The Society of Broadcast Engineers "[Frequency Coordination](#)"
- [8] Rijksinspectie Digitale Infrastructuur "[Frequentieruimte boeken via LSA-boekingssysteem](#)"
- [9] [ETSI TS 103 154](#): "Reconfigurable Radio Systems (RRS); System requirements for operation of Mobile Broadband Systems in the 2 300 MHz – 2 400 MHz band under Licensed Shared Access (LSA)"
- [10] [ETSI TS 103 235](#): Reconfigurable Radio Systems (RRS); System architecture and high level procedures for operation of Licensed Shared Access (LSA) in the 2 300 MHz – 2 400 MHz band
- [11] [ETSI TS 103 652-2](#): Reconfigurable Radio Systems (RRS); evolved Licensed Shared Access (eLSA); Part 2: System architecture and high-level procedures
- [12] FCC "[3.5 GHz Band Overview](#)"
- [13] FCC "[FCC Requests 6 GHz Automated Frequency Coordination Proposals](#)", October 2021
- [14] Intel "[Spectrum Sharing Using Automated Frequency Coordination](#)", December 2022
- [15] FCC "[OET Announces Conditional Approval for 6 GHz Band AFC Systems](#)"
- [16] Qualcomm "[Global update on spectrum for 4G & 5G](#)", December 2020
- [17] Ericsson White Paper "[5G spectrum for local industrial networks](#)", April 2023
- [18] [3GPP TS 38.101-1](#): "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 1 Standalone"
- [19] [3GPP TS 38.101-2](#): "NR; User Equipment (UE) radio transmission and reception; Part 1: Range 2 Standalone"

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5G Media Action Group (5G-MAG) Association  
17A L'Ancienne-Route  
1218 Grand-Saconnex (Switzerland)

[info@5g-mag.com](mailto:info@5g-mag.com) • [www.5g-mag.com](http://www.5g-mag.com)